UNIVERSITEIT GENT

FACULTEIT DIERGENEESKUNDE
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# Calving problems and calving ability in the phenotypically double muscled Belgian Blue breed

Proefschrift voorgedragen tot het behalen van de graad van
Doctor in de Diergeneeskundige Wetenschappen (PhD) aan de Faculteit Diergeneeskunde,
Universiteit Gent

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Merelbeke, 2010

KAHO SINT-LIEVEN HOGESCHOOL
Associatie K.U.Leuven

Foto cover: Geert Verhoeven

Foto's achterkant: Stefaan Ribbens

Printing: Ryhove Plot-it, Merelbeke

Printing of this thesis was financially supported by Intervet Schering-Plough

# Calving problems and calving ability in the phenotypically double muscled Belgian Blue breed

## Afkalfproblemen en afkalfmogelijkheden bij het fenotypisch dikbil Belgisch Witblauw ras

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14 januari, 2010

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# TABLE OF CONTENTS

# List of Abbreviations

| | |
|---|---|
| ANOVA | analysis of variance |
| BB | Belgian Blue |
| BL | body length |
| BoW | body weight of the cow |
| BW | birth weight of the calf |
| CAR | congenital articular rigidity |
| CC | carcass classification |
| CI | confidence interval |
| CFF | circumference of the fetlock of the front leg |
| CFH | circumference of the fetlock of the hind leg |
| CMD | congenital muscular dystony |
| CTS | crooked tail syndrome |
| CS | caesarean section |
| CW | carcass weight |
| DM | double muscled |
| DM-BB | double muscled Belgian Blue |
| E (SEUROP) | excellent muscularity |
| EBV | estimated breeding value |
| EF | East Flemish |
| EPD | expected progeny difference |
| FVM | Faculty of Veterinary Medicine |
| HF | Holstein Friesian |
| HG | heart girth |
| HPA | hypothalamic-pituitary-adrenal |
| HW | hip width |
| IA | intra-abdominal |
| IM | intramuscularly |
| IU | international unit |
| IV | intravenous |
| LH | length of the head |
| M1 | one month before parturition |
| M2 | within 24 hours of parturition |

| | |
|---|---|
| M3 | one month after parturition |
| MD | mild difficulty |
| ME | metabolisable energy |
| mh | myostatin |
| O (SEUROP) | moderate muscularity |
| ODL | left oblique diameter |
| ODR | right oblique diameter |
| OR | odds ratio |
| P (SEUROP) | poor muscularity |
| PA | pelvic area |
| PH | pelvic height |
| PUFA | poly unsaturated fatty acid |
| PV | per vaginam |
| PW | pelvic width |
| R (SEUROP) | good muscularity |
| S (SEUROP) | extreme muscularity |
| SC | subcutaneously |
| SD | severe difficulty |
| StD | standard deviation |
| SW | shoulder width |
| TcTc | distance between both *tubera coxae* |
| TDN | total digestible nutrients |
| TiTi | distance between both *tubera ischiadica* |
| TSE | Transmissible Spongiform Encephalopathy |
| U (SEUROP) | very good muscularity |
| USP | United States Pharmacopeia |
| WH | withers height |

# Chapter 1

# General Introduction

# INTRODUCTION

Meat production is an important part of the steeply accelerating demand for food. During the last decade, this demand has grown with the increase of the world's human population. Besides the increase of the world's population, some nations also became wealthier and the public purchasing power increased. The modern consumer insists to have access to daily food including high quality meat at a reasonable price. To provide beef meat for this immense market, attempts were made to improve the individual productivity of cattle and huge animal feeding operations were developed to minimize the investment cost (de Kruif, 1998). An increasing competition between food producing countries intensified this process. Apart from a rising number of humans consuming meat, the individual consumption of meat also continues to grow. Currently nearly 42 kilograms of meat is produced per person worldwide, although the individual meat consumption varies greatly by region and socio-economic status (Halweil, 2008).

There are innumerable health benefits of eating (beef) meat as it serves a fabulous source of high quality proteins, which not a single vegetarian food is able to provide. It contains all the essential amino acids that the body requires coupled with very high quantities of iron. However, in certain areas meat is something people are discouraged to eat as consumers become aware of the industrialization of meat production. Modern industrial meat production consumes energy, pollutes water supplies, and generates significant amounts of greenhouse gasses (Siegford et al., 2008; Ilea, 2009). Improving waste management and farming practices would certainly reduce the "carbon footprint" of beef production. Individual consumers can reduce the potential negative effects of meat production on the planetary climate. Eating locally produced food, for instance, can reduce the need for transport. Regardless the above mentioned criticism on meat production, still more than half of the world's surface that is suitable for agriculture can only be used as pastures (Lips et al., 2001). To produce high quality meat for the world's population, cattle can use land that is too rough, too high, too dry, too wet and largely inaccessible for humans, to graze. Ruminants also eat forages that humans and even chickens and pigs cannot consume and convert them into a high quality food. To produce meat in a more efficient and less pollutant way, we have to look for breeds that are able to convert low quality forages into high quality meat with a maximum efficiency.

Also in Belgium, the demand for food had increased during the last decades. After World War II, women participated more on the labour market, leading to an increase of the purchasing power of individual families. Being wealthier, these families started to demand a higher quality of beef meat. Furthermore, as women worked out of the house, there was a gradual transition towards ready-made meals which require only minor preparation before consumption (Dagevos, 1998), resulting in the urge for more tender meat with a shorter preparation time. Both the demand for a higher quality and the urge for more tender meat, has contributed to the development of an extremely muscled beef breed, the double muscled Belgian Blue (DM-BB). Nowadays, the meat production still is an important part of the Belgian agriculture. Beef meat is the third most important agricultural product besides pork meat and dairy products (Van Ommeslaeghe et al., 2009). The DM-BB breed is responsible for 65% of this beef meat production and 75% of the red meat production (Hanset, 2004). But, as Belgium is a relatively small country with a limited area of land suitable for agriculture, there was and still is an urge for intensive animal husbandry systems, creating a unique situation for beef production. In this perspective, also this specific situation has contributed to the development of the typical DM-BB breed.

## ORIGIN OF THE BELGIAN BLUE BREED AND ITS DOUBLE MUSCULARITY

As mentioned before, the development of the DM-BB breed was driven by the specific Belgian situation. During the second half of the 19th century, Shorthorn bulls were imported from the UK to improve the local cattle population. Between 1920 and 1950 an active selection for a dual purpose type of animal was noticed, which shifted towards a heavier muscled phenotype since 1950 - 1960. The real breakthrough came in the 1960’s with the development of the extreme muscling characteristics. Encouraged by the better price, the Belgian wholesaler was willing to pay for extremely meaty and low-fat animals. The double purpose breed of Middle and Upper Belgium at that time was gradually transformed to a more beefy breed, the BB breed. Furthermore, the liberated European economy with consumers demanding for leaner and more tender meat resulted in an increased quality and quantity demand of meat. This economic need accelerated the development of BB cattle towards an even more heavily muscled phenotype. The breed was officially established by the introduction of the Belgian Blue Herd Book in 1973. Finally, in 1974, the breed was divided into two branches, one for continued use as a dual purpose animal and the other exclusively for meat production (the double muscled [DM] branch).

Later on, around the 1990's it was discovered that the extreme muscularity characterizing the BB breed had its origin in a mutation of the myostatin (*mh*) gene. Myostatin is a member of the TGFβ super family of growth and differentiation factors (McPherron and Lee, 1997). In cattle this gene has been mapped 3.1cM from microsatellite TGLA44 on the centromeric end of chromosome 2 (Grobet et al., 1997). In conventional animals, skeletal muscle growth is repressed by myostatin. A specific mutation in the *mh*-gene causes inactivation and gives rise to "muscular hypertrophy" resulting in an increase in muscle mass of about 20% (Grobet et al., 1997). This increased muscle mass is created by an increase in the number of muscle fibers (hyperplasia; Grobet et al., 1997; Bellinge et al., 2005) rather than an increase in their individual diameter. The hypermuscularity in the DM-BB breed is due to a deletion of 11 nucleotides (Grobet et al., 1997), which has been mapped to the centromeric tip of chromosome 2 under a recessive model, suggesting an autosomal recessive inheritance (Charlier et al., 1995). A similar mutation in the *mh*-gene has been shown to be the cause for double muscling in the Asturiana breed (Grobet et al., 1998), the Blonde d'Aquitaine, the Limousin, the Parthenaise, the Rubea Gallega (Karim et al., 2000) and the South Devon (Smith et al., 2000). Other mutations also causing double muscling were discovered around that time in the Piedmontese, the Gasconne (Kambadur et al., 1997), the Maine-Anjou, the Charolais, the Limousine (Karim et al., 2000) and the Marchigiana breed (Cappucio et al., 1998; Marchitelli et al., 2003).

## CHARACTERISTICS OF THE DOUBLE MUSCLED BELGIAN BLUE BREED

There are many benefits in raising the DM-BB breed, most of which being production related. Selection towards the development of these economically beneficial advantages was mainly market driven. Firstly, because of the DM phenotype, the carcasses have a significantly increased muscle mass leading to the production of leaner meat. The high butcher's value is mainly due to a high dressing percentage due to a large reduction in the '5$^{th}$ quarter' (organs, blood, the head, the claws and lower part of the legs) and also to a larger proportion of muscles in the carcass compared to bone and adipose tissue (Ménissier, 1982a). The slaughter percentage is nearly 70%, which is unique. DM-BB animals have a lower total fatty acid content compared to conventional animals coupled with a higher proportion of poly unsaturated fatty acids (PUFAs), resulting in a higher PUFA/saturated fatty acid ratio (Raes et al., 2001). This is believed to be beneficial regarding human health, as fat consumption, especially of saturated and mono-unsaturated fatty acids, has been associated with major risks for coronary heart disease and cancer development. It has also been reported that meat from DM-BB cattle has a higher percentage of white muscle fibers as well as a lower collagen content of muscles (Uytterhaegen et al., 1994). This contributes to its increased tenderness (Bellinge et al., 2005). All these above mentioned characteristics are of benefit to both the producer, who makes a larger profit in sales, and to the consumer who buys leaner, and hence healthier meat. Besides the exceptional carcass and meat qualities, another major advantage is that the breed has a docile temperament, which makes it easy to handle and treat. Furthermore, DM-BB animals have a relatively short gestation period (282 days), a quick growth (1.2 - 1.6 kg/day) and a good feed conversion ratio (within the 5 kg range from 7 to 13 months). All these characteristics have led to the fact that the DM-BB breed is popular and newborn animals are extremely valuable. This causes Belgian farmers to prefer the breed above other beef breeds such as Blonde d'Aquitaine or Limousin. Apart from this, the real increase of the success of the DM-BB breed in Flanders took place after the introduction of the milk quota system in 1984. To raise their income, many dairy farmers included beef production in their business. Specifically in our country, the DM-BB breed is a good option as it fits in small intensively managed farms. The DM-BB breed is not only important for Belgium. This is illustrated by the fact that the breed has been world-widely used as a terminal cross to improve beef livestock. The DM-BB bull has been the terminal sire of choice for a lot of beef and dairy herds to ‘beef-up’ the profits as it improves the weight and the quality of the carcass of its crossbreds (Liboriussen, 1982; Bölcskey et al., 1999). It furthermore increases the retail product with 10% when compared to the maternal breed, and it results in a high killing-out percentage of tasty, tender and lean meat (Ménissier, 1982a).

## Consequences of selection towards the double muscled Belgian Blue breed

Apart from the multiple benefits of the race, every medal has two sides and the extreme selection for DM in the BB breed also brought along some important disadvantages. The DM gene is known as a monogenic trait characterized by general hyperplasia of skeletal muscle, particularly of the hindquarters, the back and the shoulders, accompanied by a relative decrease in the size of the viscera and length of the limb bones (Arthur et al., 1988; Arthur, 1995), due to the pleiotropic effect of the *mh*-gene. Many disorders, but not all, are related to this DM gene.

Inherited disorders are not always clearly recognisable and can be the result of selection for higher productions as they have negative correlations with traits like fitness, fertility and disease resistance. The level of inbreeding in the DM-BB breed is also considered to be involved in the high rate of genetic disorders like congenital muscular dystony (CMD 1 = spinal muscular atrophy; and CMD 2), crooked tail syndrome (QTS; Charlier et al., 2008), dwarfism, hamartoma, arthrogryposis and prolonged gestation (Cornillie et al., 2007).

The sexual behaviour, especially in young animals, is affected by the DM gene and the fertility of DM females is lower than that of normal females (Ménissier, 1982b). The fertility of bulls is also impaired, as was shown in a study of Hoflack (2006). Furthermore, the viability of DM calves is lower than that of normal ones and the milk production of DM cows is reduced (Ménissier, 1982b). Examples of the disadvantages due to this highly-muscular physique are macroglossia and rigidity of the joints known as congenital articular rigidity (CAR; Lips et al., 2001). Muscular hypotonia of the limbs, brachygnathia inferior and superior, dermatosparaxy, lethal spasticity, and spastic paresis are other disorders described in the breed (Hanset et al., 1993; Coopman et al., 2000a, b; Rollin, 2000).

As a cause of the relatively decreased size of the organs due to the pleiotropic effect of the *mh*-gene, animals of the DM-BB breed have a very short digestive tract – causing the need for a high energy and protein diet (De Campeneere et al., 2001) – and a lower ventilating and cardiac reserve capacity. The latter is leading to a higher susceptibility for respiratory diseases and a higher percentage of mortality compared to other breeds (Gustin et al., 1988; Amory et al., 1993; Bureau et al., 2001).

The relative reduction in size of the limb bones is associated with a smaller pelvic area (PA) in comparison with other beef breeds (Johnson et al., 1988; Deutscher, 1989; Murray et al., 1999, 2002; Coopman et al., 2003). This smaller pelvic dimension in offspring of DM-BB cattle in combination with a higher average fetal weight at birth, results in a discrepancy between the dam and her calf, and thus dystocia with high mortality rates if births are unassisted. Dystocia is defined as a difficult or delayed birth at any stage of labour (Oxender and Adams, 1979; Anderson and Bullock, 2000; Mee, 2004), and although factors affecting dystocia are similar in DM cattle to those in non-DM cattle, the occurrence of dystocia is tremendously higher in DM cows due to the high birth weight caused by the extreme muscularity. In the DM-BB breed, this discrepancy is mainly treated by performing a Caesarean Section (CS). Based on the high value of the calf due to the extreme muscularity and the relatively low cost of a CS in Belgium, Belgian farmers are not willing to take any risk and oblige their veterinarian to perform a CS in case of any doubt during parturition. Consequently, DM-BB calves are almost routinely born by CS: only 5 to 10% are born *per vaginam*, a relatively oversized calf being the most important indication to perform a CS. In many cases practicing veterinarians carry out a very basic gynaecological examination when they are confronted with a DM-BB cow in labour and start to perform a CS immediately. This differs substantially from other breeds. In addition, optimal conditions to perform a CS are present in Belgium: short distances to the farm, mild winters not hampering the accessibility of the herds, the ability of the farmers to detect the onset of parturition accurately and to provide adequate assistance during the operation, and well trained and skilled bovine veterinarians. Currently, almost 50% of all Belgian cattle farmers own at least one BB cow and a Belgian bovine veterinarian performs on average 500 to 1000

CS per year. So, in Belgium nowadays, the CS is performed on an elective base and a considerable number is carried out for economical, practical and safety issues rather than for biological reasons.

## ETHICAL ASPECTS OF THE CAESAREAN SECTION IN THE BELGIAN BLUE BREED

The general public is not familiar with most of the consequences of the breed characteristics, except for the CSs. The necessity to repeatedly undergo surgery is a topic open for ethical criticism. Animals of the DM-BB breed have been bred for specific characteristics as many other breeds and species, but selection and economic motives have driven this breed towards the inability to safely give birth to healthy offspring in a natural way. Consequently, an ‘unnatural’ breed has been created for the commercial benefit of its producers, without considering the probable discomfort and pain related to the CS. It is assumed that a CS may cause suffering for the individual patient, but also that the high incidence of CS is an indication of the excessive instrumentalisation of the animals belonging to this breed (Lips et al., 2001). These two assumptions need a totally different approach and provoke diverse discussions.

First of all, will the selection of this breed calving by CS impair the welfare of the individual cow and/or her calf? In this discussion, welfare includes the effects of the elective CS both on the cow as well as on the calf. We do not know whether an elective CS, when performed repeatedly, is imposing significantly more pain and distress than a delivery *per vaginam* (= natural calving without or with mild traction). In Belgium, only few ethical objections exist against the CS in the DM-BB breed. Farmers and veterinarians often observe cows ruminating during or shortly after the CS, and detect little in the behaviour of the animals that indicate stress or severe pain during or just after surgery. In addition, the operation is generally performed by well educated and trained veterinarians and farmers in our country are skilled in detecting parturition at an early stage. The animals of the BB breed have a very docile character and thus are very suitable for the standard procedure of this operation. Most farms are very well equipped for this kind of surgery (CS-box in a specially designed calving area). Furthermore, there are hardly any practical and climatological objections and veterinarians perform the CS for a rather low price. For this reason, in Belgium the CS is done on a routine base without major constraints. Additionally, the study of Vandenheede et al. (2001) showed no signs of impaired welfare during CS in DM-BB animals. According to these authors the CS is a relatively short surgical procedure and there is only a rare occurrence of aggressive behaviour towards the surgeon. The mother-young relationships in their study were similar to those reported after natural calving. However, it was not possible to find a control group of naturally calving DM-BB due to the high incidence of CSs and the results were compared with animals of the HF breed. Furthermore, we currently have no knowledge about the incidence of chronic discomfort and pain as a consequence of post-operative complications such as intra-abdominal adhesions following this surgical intervention.

Besides the debate concerning possible acute and chronic pain caused by the CS, a second ethical discussion concerning the DM-BB breed refers to the high incidence of CS being an indication of the excessive instrumentalisation of these animals (Lips et al., 2001). This assumption considers the fact that farmers created a cattle breed with such a high degree of instrumentalisation that it is no longer able to survive without human help. Ethics claim that any animal that has been changed in a way that it is incapable to safely reproduce can no longer be regarded as a natural animal. Animals should be bred, raised, and treated so that they do not experience any discomfort. The extreme selection of the BB breed towards the DM unnaturally looking phenotype with a high incidence of CSs causes some consumers to have an aversion towards the DM-BB breed. They claim the DM-BB phenotype is a genetic defect rather than a beneficial trait. Because most DM-BB calves are delivered by CS this is incompatible with the Protocol of Amendment to the European Convention for the Protection of Animals kept for Farming Purposes. That is why Scandinavian authorities urged to prohibit the use of BB bulls and their sperm. Also in the Netherlands, the government is concerned about the existence of the BB breed and started a project called 'Natuurlijk Luxe' to breed towards natural calvings. In the UK, the name 'Belgian Blue' was changed into 'British Blue' as for the negative correlation between the 'Belgian' term and the CS.

Selection of the DM-BB breed in a way that diminishes the CS rate would be an answer on the ethical concerns about the CS and will make the breed less controversial. Nevertheless, for the purebred DM-BB breed this selection should be without the loss of conformation and carcass quality. As in Belgium the parturition in the DM-BB breed is managed by CS routinely, a calving difficulty score cannot be obtained and the use of a calving ease index (Brinks et al., 1973; Burfening et al., 1978a,b; Burfening et al., 1981) is not the best option in the selection against CS in the DM-BB breed. Hence, the focus should be on other factors affecting parturition to allow the best possible genetic improvement for ease of calving. A solution to decrease the number of CSs in this breed is the simultaneous selection on a bigger PA in the dam and a smaller body size at birth of the calf. Both selection purposes should be synchronized as on the one hand focusing only on the dam and her PA would lead to an increase of the PA but might also lead to calves with a broader PA at birth experiencing severe problems to be born themselves. The use of a bull that gives smaller calves would probably increase the chance of a natural birth but these calves should develop into large animals to avoid dystocia when they have to calve. To start a selection program towards a decrease in the number of CSs there has to be knowledge about the existing variation within the pelvic dimension of the DM-BB dam and the body sizes of the DM-BB calf. Selection is only feasible if there is a substantial variation for this trait within the breed in combination with a moderate to high heritability for this specific trait. Additionally, when selection towards a higher incidence of naturally calving is suggested, information is needed about other factors – besides the PA of the dam and the body sizes of the calf – that may influence parturition and/or dystocia for the BB breed specifically.

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# CHAPTER 2

# STATE-OF-THE-ART/LITERATURE REVIEW

# The Caesarean Section (Chapter 2.1)

# History of the Caesarean Section (Chapter 2.1.1)

## Human medicine

The name Caesarean Section (CS) was suggested to originate from the birth of Julius Caesar, who was told to be born by this surgical procedure. However, later on this was questioned as at that time the procedure was only performed when the mother was dying or already dead and Aurelia, the mother of Julius Caesar, lived until her son's invasion of Britain. Some other researchers said that the word "caesarean" originates from the Latin verb "caedare" which means to cut or "caesones" that was applied to infants born by post-mortem operations (Sewell, 1993). Others believe that it came from the decree "Lex Regia" during the government of king Numa Pompilius (715-673 B.C.), which stated that all women who were dying during child birth had to be cut open as it was forbidden to bury a dead pregnant woman. During the 16$^{th}$ century the procedure was known as "caesarean operation". It was only until the publication of Jacques Guillimeau in 1598 that the term "operation" was replaced by "section" (Sewell, 1993). During the following years the indications to perform a CS in humans drastically changed. First the procedure was performed in an attempt to save the fetus when the mother was dying while an effort to try to save the mother was only made occasionally. In the 19$^{th}$ century the focus was more on the mother and whenever her health was in danger a CS was carried out. It took till the 20$^{th}$ century for the fetus to become a possible patient.

There are some stories reported in literature about the first CSs in human. An early report from southern Germany in 1480 described the first explicit instructions that midwives got whenever a woman's health at birth was at risk. Wine was used for anaesthesia as well as for analgesia and an incision was made around the pubic bone. After the fetus was taken out, the uterus was left open and the abdominal wound was closed with 3 - 4 silk ligatures. Another story reported on Jacob Nufer, a sow gelder around 1500 who got permission to operate his wife after she had been in labour for days. It was said that both the baby and the wife survived and afterwards she gave birth to five other children. On his trip through Africa in 1879, the missionary Felkin witnessed a technique used by the local Ugandans where banana-wine was used for anaesthesia and antisepsis (Figure 1). The incision was made in the midline and the baby was taken out. Afterwards the uterus was squeezed until it contracted and a red hot iron was used to control haemorrhages. The cervix was dilated from the inside to allow the lochia to escape (Sewell, 1993). The wound was closed with sharp spikes and a root paste (a kind of healing ointment) was used for wound care. The uterus was always left open as removal of the internal sutures was not possible and the people were afraid of infection of the sutures.

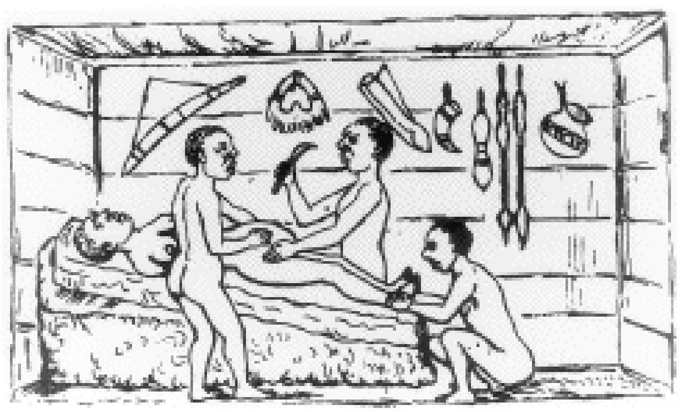

**Figure 1** Caesarean Section performed by healers in Uganda as observed by Felkin in 1879 (Sewell, 1993)

A lot of the earliest successful CSs took place in remote rural areas lacking in medical staff and facilities with the great advantage of operation in an earlier stage in failing labour. A CS performed in a hospital before the 19$^{th}$ century was bedevilled by infections passed between patients by hands of medical attendants (Sewell, 1993). By the increased urbanization, the growth of hospitals and the increased knowledge on the anatomy, the CS began to be performed routinely. During the years the techniques to perform a CS evolved as new products for anaesthesia (diethyl ether/chloroform) and antiseptics were developed. Anaesthetics permitted surgeons to take the time to operate with precision and spared the patient from agony and shock. Once anaesthesia, antisepsis and asepsis were firmly established, obstetricians were able to concentrate on improving the technique and hysterectomy was advocated to control haemorrhages and prevent systemic infection. This was quickly followed by the first employment of uterine sutures of silver wire in 1882. The discovery (1928) and introduction (1940) of penicillin dramatically reduced maternal mortality.

## BOVINE MEDICINE

The first CS on cattle was reported in 1813 by Morange to save a cow. In the following decades various veterinarians tried the technique in different species (Saint-Cyr, 1874; De Bruin, 1897; Berthelon, 1942). In Belgium the first CS was performed with success in the Faculty of Veterinary Medicine (FVM) in Ghent in 1949 on a standing animal. Two French beef heifers were brought to the clinic, the operation was performed in a chute for hoof trimming and both animals survived the operation probably due to the use of antibiotics. Before that, the technique had already been tried but never with success (Sierens, 2008). Shortly after this success story the standing procedure was changed towards a technique on a recumbent animal because of problems with straining and prolaps of the intestines during the standing operation (Vandeplassche et al., 1950). This technique performed on the animal lying down had already been described by Götze in 1926 (applied via the left flank approach; Sierens, 2008), was modified first after the Second World War by Wright (Sierens, 2008) and later on by Vandeplassche and Paredis (1953; ventrolateral incision). Luckily, antibiotics became easier accessible and cheaper, and the war resulted in an enormous stock of suture material available in military stores. The mortality after 150 CSs performed at the FVM in that period was 7% for the cows and 50% for the calves (Sierens, 2008). Because of the high success the amount of CSs performed in the FVM increased rapidly and a lot of people came to see the spectacle, among which a lot of veterinarians to learn the technique. After a while the CS was not only performed in the FVM of Ghent but was also carried out in the field with relatively good success. The CS gradually replaced the fetotomy for most indications of dystocia except in cases of dead calves where the latter was still used. The operation method on the lying animal was used for over 10 years, after which it was replaced again by the standing procedure around the 1960's (Sierens, 2008). In the beginning the results following the procedure on the lying animal were still superior as retained placenta occurred in 31% of the cases operated while standing compared to only 18% in the recumbent ones. Besides, fever occurred more often after the standing procedure as well (Laurier et al., 1982). The authors suggested that this was due to the inexperience with the standing procedure as it was more difficult to manipulate the uterus resulting in more trauma to the tissues.

# PROTOCOL OF THE CAESAREAN SECTION (CHAPTER 2.1.2)*

## INTRODUCTION

In this chapter the surgical procedure currently used by the veterinary practitioners of the Ambulatory Clinic of the Department of Reproduction, Obstetrics, and Herd Health of the Faculty of Veterinary Medicine (FVM) in Ghent (Belgium) and the way it is taught to the students is described. On a yearly basis, approximately 850 CSs are performed in the Ambulatory practice and approximately 400 in the clinic. The protocol described here, summarizes the procedure which has - based on the considerable practical experience - proven to give the most successful results in practice and is also discussed with the literature available on this subject. In other breeds, the CS is almost only performed as an emergency procedure when all other methods to deliver the calf naturally have failed. In the BB breed, where the CS is performed on an elective base, the most suitable time for surgical intervention has been said to be just after the allantoic sac has ruptured as at this stage the cervix is normally fully dilated and the uterine muscle is still relaxed allowing good uterine manipulation and decreasing the contamination of the uterus (Clark, 1987; Mijten, 1994; Uystepruyst et al., 2002).

## INDICATIONS FOR CAESAREAN SECTION

There are different indications to perform a CS. Through the development of the DM-BB, the most important indication nowadays is oversize of the (living) calf (Frazer and Perkins, 1995).

*Modified from: Kolkman I, De Vliegher S, Hoflack G, Van Aert M, Laureyns J, Lips D, de Kruif A and Opsomer G 2007. Protocol of the Caesarean Section as performed in daily bovine practice in Belgium. Reproduction of Domestic Animals 42, 583-589.

The latter can be caused by muscular hypertrophy (especially in breeds in which muscular hypertrophy is present, as in the case of the DM-BB breed), prolonged gestation, inappropriate crossbreeding or premature breeding of (dairy) heifers (Frazer and Perkins, 1995). Dystocia may be caused by the size of the calf (absolutely oversized calf) or may be due to the cow, in case of a narrow birth canal (relatively oversized calf). Other indications for CS in cows are the presence of an irreducible uterine torsion and an incomplete cervical dilatation (Mijten, 1994; Newman and Anderson, 2005).

Indications that occur less frequently are: serious anomalies in presentation, fetal malformation, uterine rupture, fracture of the pelvis, and tumours of the vagina, cervix or uterus (Frazer and Perkins, 1995; Newman and Anderson, 2005). A previous CS is a significant risk factor for a CS in dairy cows (Barkema et al., 1992).

## CHOICE OF SURGICAL APPROACH

The choice of the surgical approach mainly depends on the experience of the veterinarian. However, sometimes other factors such as the physical condition of the patient and her calf and the facilities available may be even more determining in deciding which surgical approach to use. The very first CSs were emergency operations and took place on the standing cow (Mijten, 1994). However, after the Second World War, veterinarians preferred the recumbent position which can be explained by the fact that most CS took place in clinics (Mijten, 1994). Since 30 years, the standing flank procedure is favoured, in case, no overwhelming uterine contamination is present, and in case the cow is not lying down. The advantages of the flank procedure are the fact that sedation is only seldom necessary and that the cow is tractable (Andrews et al., 2004). The flank procedure can be performed at the left or the right side. In general, the left flank procedure is preferred, because right side surgery implies a greater risk of eventration of the intestines during the operation and is contrary for right handed people. In case of an extremely large fetus located in the right uterine horn or an irreducible clockwise uterine torsion some recommend the right side (Frazer and Perkins, 1995; Schultz et al., 2008). To minimize the risk for prolaps of the intestines through a right-sided incision, a trained assistant should be present to manipulate the uterus and abdominal contents and the incision should be made high in the paralumbar fossa (Frazer and Perkins, 1995). To have a better exteriorization of the uterus on a standing cow a left oblique incision was described by Parish et al. (1995) which holds advantage for surgeons with either smaller stature or less physical strength (Schultz et al., 2008).

In case of an emphysematous calf, heavily contaminated uterine fluids, or a recumbent cow, preference should be given to perform the operation on an animal in lateral decubitus. In this position there are different options to open the abdominal cavity: the flank incision, incision along the *linea alba* (median incision), incision between *linea alba* and mammary vein (paramedian incision), incision parallel with the groin pleat (incision of Merkt) and the ventro-lateral incision (Frazer and Perkins, 1995). At our Department, we prefer the latter because compared with the *linea alba* technique there is less risk of postoperative hernia and in comparison with other techniques exteriorisation of a contaminated uterus is easier. According to Frazer and Perkins (1995), a high flank approach in a recumbent animal, is most suitable in case of a live fetus and a cow that is not able to stand for the CS. The ventral midline incision is preferable for exteriorizing the uterus and has the advantage in beef breeds that the incision is somewhat hidden and will not cause retail cuts afterwards (Schultz et al., 2008). The ventral oblique and the paramedian incision are both suitable whenever facing an emphysematous and mummified fetus as both also provide excellent uterine exposure. The ventral oblique incision however results in more tissue trauma compared to the paramedian incision and the incision is more difficult to close (Frazer and Perkins, 1995).

## OBSTETRICAL EXAMINATION

Being confronted with an obstetrical case, the veterinarian always starts with the anamnesis, followed by an inspection of the cow and a thorough obstetrical examination by vaginally probing. The latter consists of a vaginal examination during which the vagina, vulva and uterus are checked for possible injuries. He/she also verifies the dilatation of the cervix and the vagina. Besides that, the viability, the position and the size of the calf (relative to the size of the birth canal) is carefully checked. To ascertain whether the cow can be delivered *per vaginam* the veterinarian can try to extract the calf. If a normal delivery is impossible or too risky a CS is indicated.

## LEFT FLANK SURGICAL PROCEDURE ON THE STANDING COW

### Preparation

When the veterinarian decides to perform a CS, the cow is moved to a clean and brightly lit place in the stable. The cow's head is tied to the left to prevent her from falling on the operation wound in case she falls down during the operation. An assistant or the farmer is positioned by the head of the cow to distract/restrain her and to help in case of an emergency situation (e.g. to keep the head on the left side when the cow falls down). Standing with her right side against a wall or barrier will avoid the cow from swinging back and forth. The most ideal way is to place the cow in a CS box. This is a specially designed box made of a few metal bars with one bar protecting the veterinarian from getting kicked (Figure 1).

Initially, a tocolyticum (clenbuterol-hydrochloride, 0.15 mg) is injected in the tail vein to relax the uterus. The relaxing effect of clenbuterol (Dawson and Murray, 1992; Mijten, 1994; Frazer and Perkins, 1995) and isoxsuprine (Mijten, 1994) is due to their effect on the $\beta_2$-receptors on the myometrium of the uterus. On the other hand, when the uterus is already contracted, the effect of these drugs is low. Epinephrine may also have inherent tocolytic pharmacological properties as an empirical dose of 10 ml of 1:1000 diluted epinephrine preoperatively seemed to relax the uterus (Menard, 1984). Ritodrine, a $\beta_2$-adrenergic agonist has also shown to provide effective relaxation of the myometrium. One has to be cautious as the uterine wall tends too thin, secondary to the relaxed myometrium and hence special attention should be paid when closing the uterus (Boileau et al., 2001).

The tail is tied up to the right hind limb to prevent the cow from contaminating the surgical area. At no time should the tail be tied to anything but the animal itself as the tail could be torn off if attached to, e.g. the CS box when the animal flees. If necessary, the left hind limb can be fastened with a rope to prevent the cow from kicking the surgeon. The latter is however not always possible and mainly depends on the situation and the character of the cow. The use of a CS box should always be aimed for, as this significantly improves the circumstances in which the operation has to be performed and hence contribute to the success of the operation to a large extent.

**Figure 2** An example of a Caesarean Section box

Sedation by means of $\alpha_2$ agonists is used in case of an agitated cow. The authors however realize that the activity of these products is low when they are injected at the time of agitation. Known side effects of α-2 agonists are rumen atony and uterine contractions as well as certain effects on the calf (Andrews et al., 2004). The oxygen supply of the fetus can be effected through bradycardia, hypotension and uterine contractions caused by the α-2 agonists (Mijten, 1994). We use xylazine in a dose of 6 - 10 mg (0.01 - 0.016 mg/kg) (Frazer and Perkins, 1995). The use of sedative in form of phenothiazine, xylazine, detomidine, acepromazine and butorphanol tartrate is described (Mijten, 1994). Detomidine is expensive but has the advantage that it does not increase uterotonicity (Mijten, 1994) whereas phenothiazine induces vasodilatation which may lead to fetal hypoxemia and an increased risk of bleedings in the mother (Mijten, 1994). Acepromazine and butorphanol provide adequate sedation, without ataxia and without increasing the uterine tone (Newman, 2008).

Epidural anaesthesia is applied when the cow is pressing heavily. However, epidural anaesthesia must be administered with care since a slight overdose might cause unsteadiness and even recumbency, which is unwanted. For that reason, we never administer more than 2 ml (80 mg) of a procaine solution containing 4% adrenaline. When the cow has been in labour for a longer time, it is better to avoid epidural anaesthesia or to give it in a very low dose. Caudal epidural anaesthesia can also be performed with 1.5 - 2 ml of lidocaine 2% or xylazine (0.05 - 0.07 mg/kg). Lidocaine has the advantage that it blocks the sensory nerves without influencing the motor nerves (lower risk of recumbency) and it has a good and long analgesia. Xylazine however causes uterotonicity and ataxia, even when given epidural (Mijten, 1994; Newman, 2008). It can also have systemic effects causing a decreased heart, respiratory and ruminal contraction rate, and an increase of base excess and $PaCO_2$ (St-Jean et al., 1990).

Next, the operation site on the left flank is washed, an ample surgical area is shaved (from 10 cm cranially of the last rib till after the *tuber coxae*; Figure 3) and the area above the transversal vertebrae is thoroughly dried to prevent moisture from running down and contaminating this area. Subsequently, the region is disinfected with alcohol to prevent the needle from infecting the muscles and the subcutaneous tissue. Local anaesthesia is achieved by a line block about 5 cm caudal from the most caudal part of the last rib or 5 cm caudal from the incision of a previous CS with 80 - 120 ml of a local anaesthetic (procaine hydrochloride containing 4 % adrenaline, 3200 - 4800 mg procaine) over a distance of 40 to 50 cm, partly subcutaneously (SC), partly intramuscularly (IM). The authors prefer procaine hydrochloride with adrenaline to minimize bleeding during the incision. After injection of the local anaesthetic, the operation site is rewashed with a disinfecting (iodine) soap, the hair around is dried again and the area is disinfected with alcohol and a povidone-iodine solution. If possible, a plastic folio is put over the crossbeam of the CS box to prevent against contamination of the uterus and the suture material. The veterinarian washes and scrubs his arms and hands thoroughly and puts on surgical gloves.

Besides the use of procaine 4% for local anaesthesia, lidocaïne 2% is also described (Nuyten, 1996; Newman and Anderson, 2005). Other techniques beside line block as described here are the L-block (Mijten, 1994; Newman and Anderson, 2005) and the Paravertebral block of the T13, L1 L2, and L3 spinal nerves (Frazer and Perkins, 1995; Andrews et al., 2004; Newman and Anderson, 2005). Paravertebral anaesthesia is rather difficult to achieve in DM-BB animals and can cause hyperaemia of the muscle leading to bleeding (Mijten, 1994).

## Surgical tools

The standard surgical material consists of a scalpel and a disposable scalpel blade, a pair of tissue scissors for blunt dissection of the soft tissues, a pair of suture scissors, a pair of disserting forceps, a number of blood vessel clamps, calving chains and handles, a number of cutting and round needles, a needle holder and a uterine forceps.

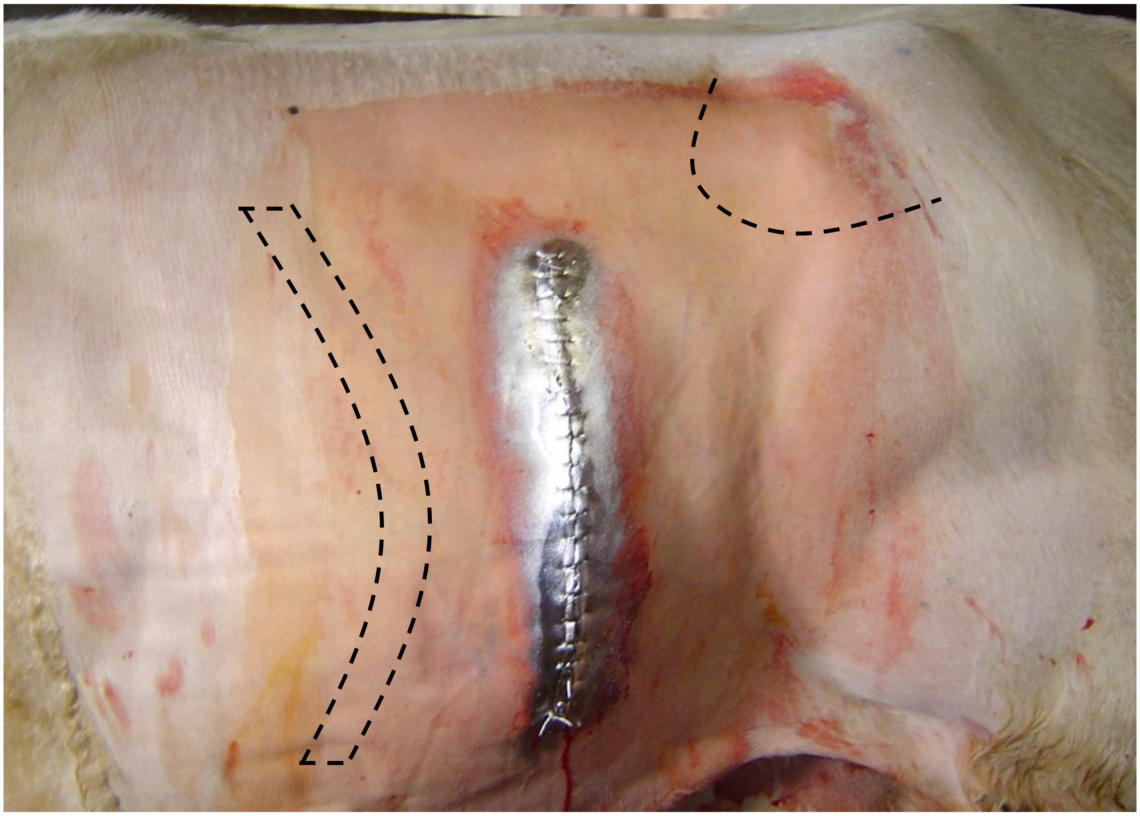

**Figure 3** Shaved surgical area with the position of the incision

## Surgical technique

The incision of the skin and dermis runs from approximately 10 cm below the lumbar transverse processes in the mid-paralumbar fossa until 30 - 45 cm lower and is situated a 5 cm caudally from the most caudal part of the last rib (Figure 3), or 5 cm caudally from the scar of the previous CS. The subcutaneous tissue, the *M. obliquus abdominis externus* and *M. obliquus abdominis internus* are vertically incised one by one with the scalpel. Squirting blood vessels are clamped or sutured. The *M. transversus abdominis* is cut with tissue scissors or cleaved in the direction of the muscle fibres. Then, the peritoneum is lifted with a dissecting forceps to avoid cutting in the underlying rumen and is cut with blunt tissue scissors. When the abdominal cavity is open, the veterinarian enters and locates the pregnant uterine horn.

When the calf is in anterior presentation, the calf may be located with its back or with its hind limbs towards the operational wound. In case of the latter, the hock of the nearest hind limb is used to locate the calf and to manoeuvre the pregnant horn in the abdominal wound. To do so, the right hand is placed around the claws and the left hand is placed under the tarsus of the nearest hind limb so that the foot can be "locked" into the dorsal end of the skin incision. Straight grasping of the calf's extremities through the uterine wall should be avoided because of the risk of perforating the uterus with the fingers.

The procedure is totally different when the calf is in posterior presentation. Then, the veterinarian is confronted with the head and the forelimbs of the calf in the uterine horn and should carefully grasp one forelimb through the uterine wall and guide it towards the incision site. Through a little incision in the uterine wall the veterinarian grasps one of the metacarpi. After extending the incision, the first forelimb is exteriorized from the uterus followed by the head and finally the other forelimb. It is important to get first one forelimb out before the head and only the other forelimb, to prevent the head from turning backwards, potentially causing a tear in the uterine wall.

When the calf is presented with its back towards the surgeon (Figure 4), in anterior as well as posterior presentation, the uterus and calf should be turned around its longitudinal axis. To do so, the surgeon puts his left hand and arm under the pregnant uterine horn, and pulls the metatarsus/carpus towards him. Meanwhile he/she pushes the back of the calf away with his right hand, finally rotating the uterus around its longitudinal axis. Twisting the calf should be done calmly to prevent the cow from falling down.

In case of an anterior presentation of the calf, and after rotating the calf, if necessary, the uterus is cut along its *curvatura major* with tissue scissors carefully avoiding cutting the placentomes. The incision should be long enough to avoid uterine tears when pulling out the calf. A too large incision reaching till the cervix should, however, be avoided since this complicates suturing severely. If prolongation of the uterine incision is necessary it should be done in ventral direction away from the *corpus uteri*.

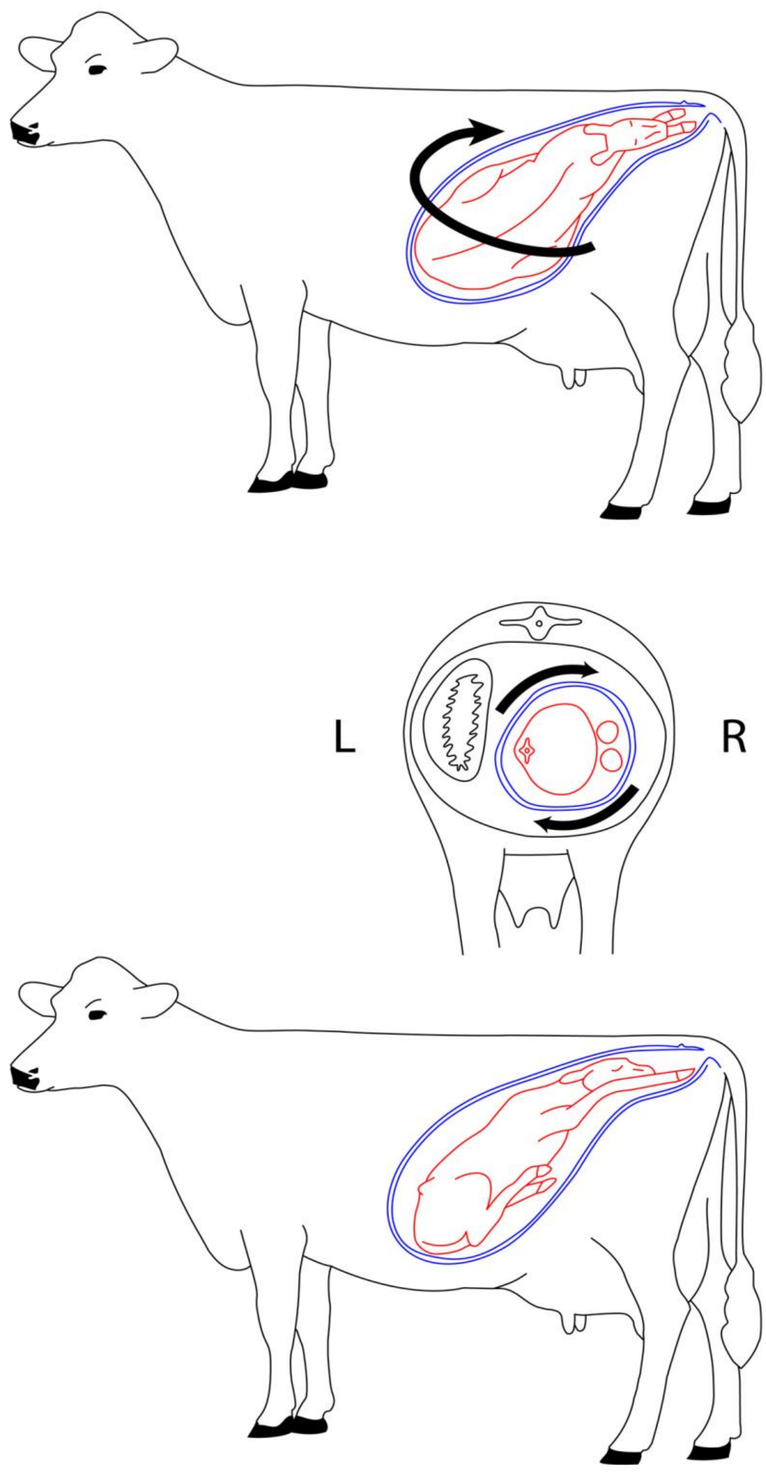


**Figure 4** Position of the calf in the uterus and the method of turning it (Made by Kolkman and Verhoeven, 2006)

The hind limbs are freed from fetal membranes and the loops of the calving chains are placed around either hind (anterior positioning of the calf) or fore- (posterior positioning of the calf) limbs, respectively, and at that time the calf can be pulled out of the uterus. When dragging the calf out of the uterus, the obstetrician carefully massages the uterus over the hind or forelimbs of the calf in an attempt to prevent the uterus from tearing. Attention is paid to prevent placentomes from being torn off. The surgeon should at all times be ready to extend the abdominal wall incision because excessive stretching of the surrounding tissues may cause postoperative seroma formation (Frazer and Perkins, 1995). When lifting the calf out of the uterus the veterinarian orders to stop pulling at the moment both hind limbs and the backside of the calf are delivered. At the same time he/she grips the umbilicus at 10 cm from its basis by his left hand. While this hand strongly holds the umbilicus, the amnion sheet is torn towards the calf. Thereafter the calf can be completely delivered.

When the calf was alive at the start of the operation, and when the operation was performed at an early stage of parturition, the amniotic fluid is generally minimally contaminated and a leakage of uterine fluids into the abdomen during the operation is of no risk. If the operation is performed in a later stage of parturition, mostly in the case of dairy cows, uterine fluids may be (heavily) infected and in this case an attempt should be made to avoid uterine fluids from entering the abdominal cavity in order to avoid peritonitis. In case the uterus is excessively infected, preference should be given to perform the operation in a recumbent position. Performing the operation in this position significantly reduces the risk of contamination of the abdomen and hence of peritonitis. Once the calf is born its vitality is checked and it is brought to a box on clean straw bedding. The umbilical cord is disinfected with tincture of iodine.

## Suturing

After ensuring the absence of a second calf, the veterinarian exteriorizes the complete uterine horn and immobilizes it with a uterine forceps, which is held by the assistant. To facilitate suturing, it is often helpful to cut the fetal membranes which are hanging out of the uterus. Before closing the uterine incision the surgeon thoroughly examines the uterine wall for bleeding (caused by squirting blood vessels, scattered bleeding in the wall or bleeding placentomes). Bleeding vessels are tied off individually and in case of diffuse bleeding of the uterine wall, it should be sutured continuously. Then the uterus is closed with a synthetic absorbable monofilament using a round needle starting well above the incision and using an inverting pattern without penetration of the wall. At our department today, we use a single modified Cushing suture pattern (Figure 5 and 6), paying special attention not to expose any suture material, in particular the knots.

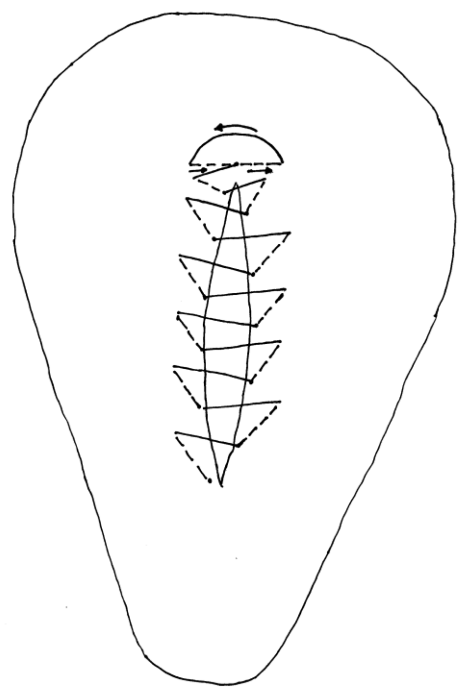

**Figure 5** Suturing technique of the uterus – the modified Cushing

Both the use of the synthetic absorbable monofilament and the single modified Cushing suture pattern are nowadays recommended in order to optimally avoid peri-uterine adhesions. Care is taken not to incorporate the fetal membranes into the suture. When uterine fluids were excessively contaminated or in case there is a risk of leakage, a two-layer closure is indicated. To ensure an adequate inverting closure, the modified Cushing suture is in that case followed by a normal Cushing pattern. If a 'Y' or 'T' tear has occurred and there is no clear overview of the uterine incision, an initial closure can be performed by a continuous suture with interlocking pattern, subsequently followed by a Cushing pattern.

A more regular tear can also be sutured with the modified or simple Cushing pattern alone. Before closing the uterus, 1 g of oxytetracycline is inserted into the lumen. After suturing, the uterine incision is carefully checked for leakage. If no leakage is present, the uterus is put back into the abdominal cavity. If leakage is present a second layer is applied and the incision is once more checked.

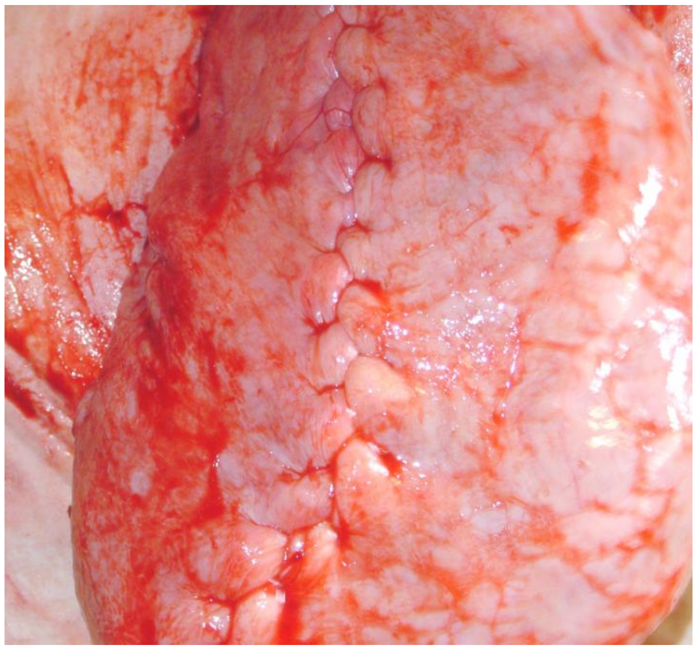

**Figure 6** Close-up picture of a modified Cushing

In literature the use of catgut for suturing the uterus is often mentioned (Cattell and Dobson, 1990; Frazer and Perkins, 1995; Andrews et al., 2004; Newman and Anderson, 2005) next to polyglecaprone, polyglyconate (Cattell and Dobson, 1990), polyglycolic acid, polydioxanone, polyglactin 910 (Frazer and Perkins, 1995) and nylon monofilament (Cattell and Dobson, 1990). Catgut is derived from sheep or bovine intestines and is braided and easy to handle, but it is characterized by a poor knot security. Plain catgut loses its tensile strength very rapidly, whereas chromic catgut loses 50% of its tensile strength after 7 days. The breakdown of this kind of catgut however is accelerated in the presence of infection. Polyglecaprone has the highest initial tensile strength but is also known to lose its tensile strength very rapidly so it is only recommended to be used to close the uterus (Newman, 2008). Polyglactin 910 is less damaged by surgical instruments compared to the other materials, has superior handling qualities, but demonstrates an increased capillary effect

(Newman, 2008). In general it is agreed that the suture material to close the uterus should be resorbable as the non-resorbable material can function as a corpus alienum. Theoretically, synthetic suture material should give less tissue reactions as it dissolves through hydrolysis whereas natural suture materials dissolve through phagocytosis (Mijten, 1994). However, there was no difference in the number and severity of adhesions following uterine closure using catgut versus polyglactin 910 (De Wit et al., 1993; Mijten et al 1997a). A disadvantage of polyglycolic acid and polyglactin is that these materials are woven, giving them a cutting effect on the tissues (Mijten, 1994), which limits their use for uterine closure. In Belgium the use of catgut in veterinary medicine is still allowed in contrast to human medicine. It will, however, most likely be forbidden in the near future due to the potential risk associated with Transmissible Spongiform Encephalopathy (TSE). The latter being another important reason to currently prefer synthetic suture material above the previously used catgut.

The technique of the modified Cushing suture pattern to close the uterus has been described by other authors as well (Frazer and Perkins, 1995; Andrews et al., 2004), but other techniques could also give satisfaction such as the Lembert suture (Cattell and Dobson, 1990; Dawson and Murray, 1992) or a simple continuous pattern. Some authors advise to use double layer of the uterus at all times (Dawson and Murray, 1992; Busch, 1993) while others believe this is only necessary in case of a contaminated uterus and/or a dead calf (Wolfe and Baird, 1993; Mijten, 1994), as we do. As for the muscle layers, Dawson and Murray (1992), Frazer and Perkins (1995) and Newman and Anderson (2005) close the peritoneum and the *M. transversus abdominis* together and the two oblique muscle layers were closed together using one single, continuous layer. Another method can be the use interrupted sutures (Cattell and Dobson, 1990). To prevent the incidence of seroma some postulate that it is better to include the underlying layer in every second or third stitch of the suture (Hoeben et al., 1997).

Superfluous blood and fluids are further removed from the abdominal cavity after which the abdominal cavity is closed. In heifers the peritoneum and *M. transversus abdominis* are sutured together with the *M. obliquus abdominis internus* using a simple continuous everting suture pattern to strictly appose the peritoneum at both sides of the wound. In older cows with thicker muscle layers the *M. obliquus abdominis internus* needs to be sutured separately. The *M. obliquus abdominis externus* is always sutured separately with a simple continuous pattern. Concerning these muscular layers, Dawson and Murray (1992), Frazer and Perkins (1995), Newman and Anderson (2005) and Newman (2008) advise to close the peritoneum and the *M. transversus abdominis* together while also the two oblique muscular layers were closed simultaneously using one single, continuous layer. Others suggest the use of interrupted sutures (Cattell and Dobson, 1990). Before the deepest layer is almost closed Newman and Anderson (2005) recommend pushing out the extra air inside the abdominal cavity, by gently pushing in the right flank. To prevent the incidence of seromas, some recommend including the underlying layer in every second or third stitch of the suture (Hoeben et al., 1997; Newman, 2008).

Before closing the abdominal cavity, penicillin (12 000 IU/ kg) is sprayed intra abdominally. In case of excessive contamination of the abdominal cavity, a broad spectrum antibiotic is used (usually a combination of penicillin and neomycin). Penicillin is also sprayed between each separate muscle layer before closure. Next, the subcutaneous tissues are sutured using a continuous mattress pattern. Finally, the skin is closed with a continuous interlocking suture. The skin can be sutured with simple interrupted sutures (Newman, 2008), single interrupted horizontal mattress sutures (Dawson and Murray, 1992) or simple interrupted cruciate sutures (Newman, 2008).

For all the latter layers – muscles, subcutaneous tissues and the skin – a synthetically absorbable polyfilament (United States Pharmacopeia [USP] 2) and a cutting needle are currently used. After closure of the skin, aluminium or plastic spray is applied on the wound to protect it against insects and dust. Penicillin (6 - 12 million IU) and oxytocin (50 - 100 IU), to provoke uterine contractions, are injected intramuscularly. After the operation, the cow is taken to a clean maternity pen and has to fast for one day. The farmer meticulously observes the cow and in case of disease (retained placenta, fever, recumbency, …) immediately contacts his veterinarian who will thoroughly examine and properly treat the animal.

Oxytetracycline (6.6 - 11 mg/kg per 24 hours intravenously [IV], IM or subcutaneously [SC] for 3 - 5 days) or ceftiofur hydrochloride/sodium (1.1 - 2.2 mg/kg per

24 hours IV, IM or SC for 3 - 5 days) are also described for postoperative antibiotic treatment. Florfenicol (20 mg/kg IM per 48 hours or 40 mg/kg SC per 96 hours) can also be used (Newman, 2008). In case of marginal preoperative and operative complications, the use of penicillin G procaine (IM) is used in dairy cows and oxytetracycline (SC) in beef cows (Newman, 2008). When complications are severe and risk for peritonitis is substantial, oxytetracycline (20mg/kg IV per 24 hours) should be administered for a longer period (5 - 7 days; Newman, 2008). A non-steroidal anti-inflammatory medication (flunixin meglumine or ketoprofen) can be used to provide postoperative analgesia (Newman, 2008).

# Complications of the Caesarean Section (Chapter 2.1.3)

## Introduction

Although in Belgium, the CS is most often carried out on an elective basis and bovine practitioners perform between 500 - 1500 operations a year, it should not be forgotten that every CS remains a major abdominal operation performed in a contaminated and sometimes unsuitable environment. Clearly, this surgical procedure cannot be considered to be without any risks and/or complications before, during and after the operation (Figure 7).

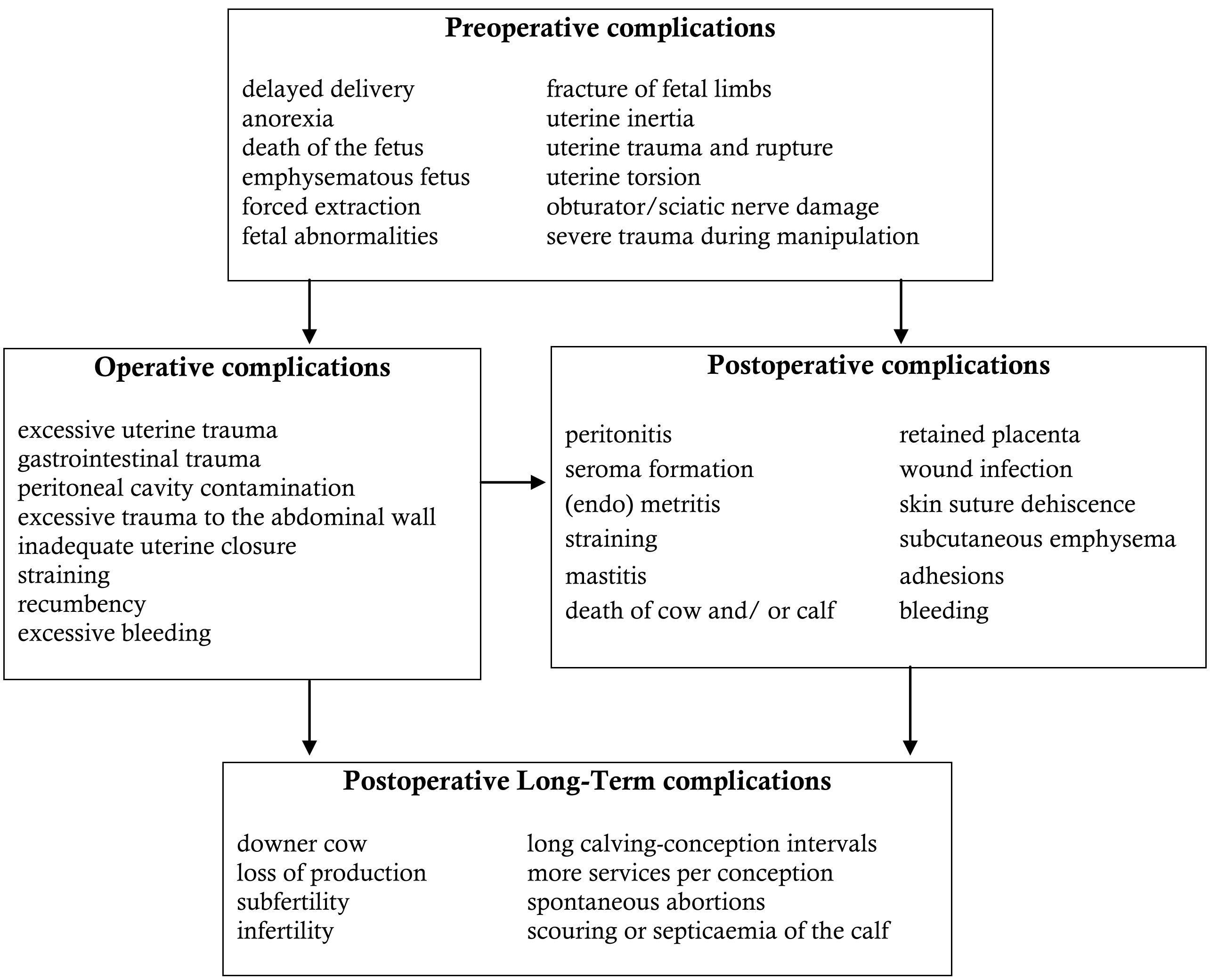


**Figure 7** Complications during and after the Caesarean Section (Modified from Dehghani and Ferguson, 1982; Newman, 2008)

## OPERATIVE COMPLICATIONS

Recumbency during the operation was reported at a rate of 14.8% in the Belgian study of Hoeben et al. (1997). In the same study it was furthermore demonstrated that this complication occurred significantly more often in dairy than in beef cows. Studies in other countries with other breeds recorded a recumbency rate during CS between 2.9 - 15 % (Sloss and Dufty, 1977; Busch, 1993; Newman, 2008). Factors affecting this recumbency rate are the use of tranquillizers, epidural anaesthesia and the general condition of the cow (Mijten, 1994). According to Newman (2008), cattle are more likely to become recumbent if difficulties were encountered when trying to exteriorize the uterus, probably due to the pain caused by the traction on the broad ligaments. Going down during the procedure does not systematically implicate major problems, and the occurrence of complications depends on the side on which the cow came down and the fact whether the calf is already exteriorized or not. Straining without or with prolaps of the rumen or intestines can hamper the CS to a great extent and can be prevented by an epidural anaesthesia (Mijten, 1994). Placing the uterus in the abdominal incision as quick as possible can also help to prevent a prolapse of the intestines.

One of the most difficult manoeuvres during the CS is the exteriorization of the uterus and the calf and even the most skilled veterinarians can experience problems with this once in a while. Problems with exteriorization of the uterus were illustrated to occur in 26.4% of the cases in a study of Hoeben et al. (1997), and in 5.8% of all operations the uterus had to be opened in the abdomen. Their study also revealed that the surgeon, parity, increased uterine contractility, the position of the calf and the presence of adhesions were all significantly associated with the occurrence of difficulties to exteriorize the pregnant horn. Based on a retrospective study of the Ohio State University, the uterus was not exteriorized in 24% of the cases and lack of surgeon experience accounted for the bulk of this percentage (Newman, 2008). The Odds Ratio (OR) to survive following a CS was 8 times higher when the uterus was exteriorized, in comparison with situations where exteriorization was not possible (Newman, 2008). Ahlers and Andresen (1967) also saw an effect of isoxsuprine, as exteriorization was possible in 90% of the cases with and only in 60% of the cases without application of this tocolytic, whereas Mijten (1994) demonstrated more difficulties when sedation with xylazine was used due to the induced contractility. Also the position of the calf has an influence on the exteriorization. In cases it is lying in the left horn with its back presented towards the surgeon, exteriorization is often experienced to be more challenging. In this case it is better to turn the calf and the uterus around its longitudinal axis first. Whenever it is not possible to turn the calf – in cases of a dead and/or very heavy calf or when adhesions are present – an incision can be made in the corpus uteri on the head and the back of the calf (or on the hindquarters in case of a posterior presentation) and extended away from the cervix. The latter procedure is known as the 'Schuurmanssnit' (Kuiper, 2007). Main disadvantage of this incision is that it is a blind procedure implicating a great risk of tearing of the incision towards the cervix during exteriorization of the calf causing difficulties with suturing afterwards. With this 'Schuurmanssnitt' the incision is made in the wall of the uterine corpus which is better perfused and contains bigger blood vessels increasing the risk of serious haemorrhages. In case where it is not possible to exteriorize the uterus and the calf in the abdominal wound, the incision has to be made intra-abdominally. The surgeon is not always able to make the incision on the recommended place (in the greater curvature) and the risk of excessive bleeding, incision in the intestines and problems with closing the uterus afterwards are main disadvantages in these cases (Mijten, 1994). Most of the problems with exteriorization were caused by periuterine adhesions in cows that had previously been delivered by a CS. In a study of Mijten (1994) these periuterine adhesions were present in 36% of the animals and in 6% of them the uterus could not be exteriorized and had to be opened inside the abdomen.

## POSTOPERATIVE COMPLICATIONS

Most studies published so far have investigated difficulties and complications following CS in breeds other than the DM-BB breed (Seger et al., 1994; Frazer and Perkins, 1995; Vaughan and Mulville, 1995; Newman and Anderson, 2005). In these breeds, the CS is seen as the last resort when all other means to give birth to the calf in a natural way have failed, while DM-BB cows are generally operated in an early stage of parturition often without any preceding attempts to extract the calf.

## Mortality rate of calf and cow

The incidence of perinatal calf death following CS decreased as the operation technique evolved. Vandeplassche and Paredis (1953) illustrated that 53% of the calves were already dead before the CS, 14% during the operation and 14% dead within 10 days after the surgical procedure. A few years later, Merkt (1957) demonstrated 20% perinatal death and Debackere et al. (1959) 26% all under clinical circumstances. In practice where the CS could be performed in a much earlier stage of parturition, the results were better. Top and Verdonck (1971) showed 4.3% perinatal death. Baier et al. (1973), Rasschaert (1980) and Michaux and Hanset (1986) demonstrated the perinatal death rate to be lower following CS versus natural calving. Probably, a large proportion of the success in calf survival rate after CS is due to the early intervention and thus the relatively short duration of parturition. Bailey et al. (1984) showed that calf survival rate is decreasing whenever parturition takes longer than 6 hours. In addition, Mijten (1994) saw that the perinatal mortality rate increased in cases the allantoic sac had been ruptured for more than 2 hours at the time of the obstetric intervention compared to an intact allantoic sac.

The average mortality rate in dairy cows within a week following CS is reported to vary between 1.5% (Barkema et al., 1992), 4.5% (Cattell and Dobson, 1990) and 14% (Bouchard et al., 1994). Other studies performed in non-BB animals also revealed a lower cow survival rate compared to natural calving (Vandeplassche et al., 1950; Debackere et al., 1959; Top and Verdonck, 1971; Sloss and Dufty, 1977; Roberts, 1986; Arthur et al., 1989; Cattell and Dobson, 1990). In animals that have been in labour for more than 18 hours or had a decomposing fetus and atonic uterus the mortality rate can increase up to 40% (Roberts, 1986). Factors affecting the mortality rate were recumbency during the CS and the duration of the surgery. Cattle that remained standing during the procedure had a significantly higher chance to survive (Cattell and Dobson, 1990), while an increased surgical duration is a key negative factor in surgical mortality. The most common complications that cause maternal death are peritonitis, toxaemia, metritis, and uterine rupture (Dehghani and Ferguson, 1982; Newman, 2008).

## Haemorrhages

Haemorrhages can occur, either originating from the muscles or the uterus. They can be diffuse or coming from a single blood vessel or caruncle in case of uterine bleeding. Normally a diffuse uterine bleeding will stop due to muscular contraction and if not an injection with oxytocin is usually sufficient to prevent further harm (Arbeiter, 1993). Ripping off or cutting in a caruncle usually causes a more severe haemorrhage and requires ligating (Ahlers et al., 1971). Often bleeding is not noticed immediately due to the fact that the blood is seeping from the frequently atonic uterus or abdomen and the animal is only showing symptoms after severe blood loss. In that case the surgical incision has to be reopened to search and ligate the bleeding vessels in combination with a blood transfusion to increase the animal's chance to survive (Arbeiter, 1993). Haemorrhages originating from other places – for example from an adhesion that has been ruptured or from a tear in the broad ligament – occur very seldom but are life-threatening in a lot of cases (Mijten, 1994).

## Retained fetal membranes

After CS, fetal membranes were retained in 35% of the cases in studies of Laurier et al. (1982) and Cattell and Dobson (1990), 24% in a study of Merkt (1957), 27.4% according to Top and Verdonck (1971) and 33% after 304 CSs by Debackere et al. (1959), whereas Ahlers et al. (1971) reported a percentage of 19% and Mijten (1994) of 16%. In most studies there was an increase in occurrence of retained fetal membranes after CS when compared to natural birth, except in the study of Barkema et al. (1992). Factors significantly associated with the incidence of retained placenta after CS were unsuccessful attempts to extract the calf, a CS on a recumbent cow and the delivery of a dead calf (Mijten, 1994) which are all three obvious indicators of the dystocia that preceded the CS. In addition, it was noticed that the incidence of retained placenta was increased in cows whose allantoic sac was ruptured for more than 2 hours at the moment of the obstetric examination and in cows whose calves were immediately weaned after birth (Mijten, 1994). Therapies that have been tried to decrease the percentage of retained placenta are oxytocin, diaethylstilboestrol, progesterone and $PGF_{2\alpha}$ (Mijten, 1994). A low dose of oxytocin (20 - 40 IU) may be administered IM postoperatively, to stimulate the expulsion of the placenta, provided that the cervix is open (Frazer and Perkins, 1995). Administering oxytocin when the cervix is closed increases the traction on the suture line and is contraindicated as it likely increases the risk of uterine wound dehiscence (Frazer and Perkins, 1995). Lower doses of oxytocin administered more frequently are advised rather than high doses less frequently as the first induces productive uterine contractions in a tubule-cervical direction whereas a high dose seems to cause titanic spasms (Frazer, 2001). A study of Stocker and Waelchli (1993) in dairy cows demonstrated that treatment with prostaglandin $F_{2\alpha}$, administered IM after removal of the calf and reposition of the closed uterus into the abdomen significantly reduced the incidence of retained fetal membranes in cows subjected to a CS.

## Peritonitis

Most of the complications following CS in cattle are the result of infections. Bacteria responsible for these infections can be exogenous or endogenous. The latter are bacteria originating from contamination of the uterine content with endogenous vaginal flora, and it was seen that as soon as the amniotic sac was broken before the obstetrical examination the total number of bacteria in the uterine fluid was higher compared to when the amniotic sac was still closed (Mijten et al., 1997b). As a result the abdomen, the wound and/or the uterus are at a higher risk to be infected. Spillage of uterine contents into the abdomen does not necessary lead to peritonitis. The latter only occurs when the clearance capacity of the abdomen is exceeded or when the uterine fluid is too contaminated. Normal clearance consists of the uptake of bacteria by the lymphatic system, by phagocytosis of the bacteria by leucocytes or by the isolation of the infection by adhesion formation (Mijten, 1994). Exceeding the capacity of this system leads to clinical symptoms due to the immune system of the animal. Peritonitis can occur by contamination before, during and after the operation. In case of a uterine tear, contaminated uterine fluids can be present in the abdomen before the surgical procedure has started and already cause peritonitis (Vandeplassche, 1963;

Dehghani and Ferguson, 1982). The extent of the endogenous infection depends on the amount of uterine fluids spilling in the abdomen on the one hand and on the sum of bacteria present in this uterine fluid on the other hand (Mijten, 1994). The odds to develop peritonitis were estimated to be twice higher when the uterus was not exteriorized before incision (Newman, 2008). Impairment of uterine involution due to e.g. a uterine torsion or retained placenta together with a break of the suture material can lead to excessive leakage in the abdomen (Sol et al., 1993). The peritonitis incidence rate was 5% in study of Mijten (1994), 10.5% in study of Hoeben et al. (1997) and 7.8% in a study of Newman (2008).

## Metritis/endometritis

The occurrence of puerperal metritis is increased after CS, on the one hand due to the higher prevalence of retained fetal membranes and on the other hand caused by the fact that a lot of the CSs are performed in animals with dystocia. Dystocia itself is known to augment the risk of puerperal problems. The probability to suffer from endometritis following a CS was twice as high after delivery of a dead calf versus a live calf (Gschwind et al., 2003). Research from Baier et al. (1973) demonstrated that the involution of the uterus took 9 days longer following a CS compared with a calving with heavy traction.

## Wound complications

Wound infection following CS has been reported by several authors. Cattell and Dobson (1990) reported a prevalence of 8.2% with better results when topical antibiotics had been applied. In a study of Mijten (1998) wound infection occurred in 21% of the cows with a higher frequency in dairy cows versus DM-BB cows. The DM-BB breed has two outstanding features that contribute to rapid healing of the wound namely the absence of fat and the thickness of the muscles involved (Clark, 1987). Researchers studying the factors associated with the healing process of the wound showed that the duration of parturition, the contamination of the allantoic and/or amniotic fluid and the degree of uterine exposure outside the laparotomy wound all had a significant negative effect (Seger et al., 1994). The duration of parturition being significant, once again reflects the importance of the uterine contamination on the incidence of wound infection. The longer the parturition has been going on, the higher the amount of bacteria present in the uterus, and the higher the risk of endogenous contamination of the wound (Mijten, 1994). Infection of the wound can also be of exogenous nature, through dust (Lensch, 1964), the use of infected suture material (Gunnink, 1971) or by the veterinarian (de Kruif et al., 1992; Mijten, 1994). A specific case of wound infection spread by a veterinarian was described by de Kruif et al. (1992) were an infection with *Actinobacillus ligniresii* was described to cause problems following CS carried out on different farms. These wounds typically became hard and were covered with granulomas. De Kruif et al. (1987) demonstrated a wound infection rate of 15% and flushing the wound for 1 minute with a 10% iodine solution before closure had no significant effect on the wound infection rate. Studies researching the effect of the application of antibiotics on the development of wound infection revealed that the parenteral administration of antibiotics just prior to surgery did not reduce the rate of wound infections while the topical application of an aqueous solution of ampicillin significantly reduced the wound infection rate from 45 to 19% (Mijten, 1994).

Other complications located at the wound can be emphysema, haematoma, seroma or hernia. Emphysema can develop strictly locally around the wound or extend over the whole left flank. It has been reported to take place following CS in 0 to 41% of the following operations (Sloss and Dufty, 1977; Cattell and Dobson, 1990; Dawson and Murray, 1992). Suggested causes of this rather innocent complication are a too far dorsally extension of the peritoneal incision or the skin incision that is too small. According to Newman (2008), attempt to avoid emphysema can be undertaken by closing the peritoneum along with the *M. transverses abdominis* and thus by stringently sealing the abdomen. A haematoma is a postoperative swelling filled with blood, normally not causing big problems. Treatment is seldom necessary except for large haematomas and the focus should be on prevention by guaranteeing strict haemostasis during the operation (Mijten, 1994). An accumulation of sterile fluids or serum is called a seroma and can be present in between the different muscular layers or between the muscles and the peritoneum. The difference between a seroma and an abscess is that an abscess involves the presence of white blood cells, bacteria, and the breakdown products of both. Normally small seromas are of no clinical importance, except when they become infected (Mijten, 1994). Bigger seromas can extend over the whole left flank and cause problems due to the pressure on the rumen (Debrosse and Debrosse, 1973). Sometimes it may be necessary to intervene, but also here prevention is of uttermost importance. The latter consist of the use of an atraumatic technique, meticulous attention to haemostasis, careful tissue apposition with complete obliteration of dead space (Löwenstein and Löwenstein, 1985), placement of active or passive drains and use of pressure dressings. When a seroma becomes of clinical concern it should be drained.

## Long-term postoperative complications

### Adhesions

One of the main long term complications following CS is the lowered fertility probably caused by the formation of periuterine adhesions (Bouters and Vandeplassche, 1986). Adhesion formation is thought to be the result of an imbalance between fibrin formation and fibrinolysis (Newman, 2008), and can develop in as little as three hours after surgery (Stangel et al., 1984). Most adhesions however are transient and lyse spontaneously within 72 hours after surgery (Stangel et al., 1984). The percentage of adhesions (uterine as well as other adhesions) varies between different papers. Debackere et al. (1959) reported the presence of adhesions to be 74% and 37% without and with intra-abdominal antibiotic treatment respectively, and Baier et al. (1968) showed 22% while Vandeplassche et al. (1968) found 33% adhesions. Uterine adhesions were seen in 9.4% of cattle at the time of surgery and in 31% the animals had had a previous CS (Hoeben et al., 1997). Adhesions usually occur after an inflammatory response secondary to surgical trauma. An unsuccessful attempt to extract the calf per vaginam increases the adhesion rate while administration of a uterine relaxant decreases their occurrence (Mijten, 1994). Other factors with influence on the formation of adhesions are named to be foreign bodies, haemorrhages and infections (Stangel et al., 1984). Strictly following the basic principles of surgery has been mentioned as the mainstay of adhesion prevention: minimal and atraumatic tissue handling, safeguarding an adequate blood supply, meticulous haemostasis, strict asepsis, careful approximation of tissues, avoiding excessive tension on the sutured tissues and obliteration of dead space (Southwood and Baxter, 1997). Surgeons should also minimize the use of talc- or starch-containing gloves (Holmdahl et al., 1997). It has been noticed that in most cases these adhesions occur along the suture line, moreover at the knots (Mijten et al., 1997a), so the surface of the peritoneum is the key site in adhesion formation but also in prevention (diZerega, 1997).

The pattern used to suture the uterus is suggested to have an influence on the prevalence of adhesions and methods that provide an excellent seal are preferred as the uterus heals by serosal-to-serosal contact. Methods that do so are the Lembert, the Cushing and the modified Cushing patterns. The Lembert pattern requires more suture material, leaves more suture material exposed and takes more time to complete (Newman, 2008). However, the Lembert pattern is the most commonly used (Cattell and Dobson, 1990; Dawson and Murray, 1992; Vaughan and Mulville, 1995). Adhesions occurred in 64% of the cases following the interlocking suture pattern and in 29% following the modified Cushing (Fontijne, 1985). Mijten et al. (1997a) found no difference in adhesion formation between the Lembert and the modified Cushing but revealed a dramatic difference between different surgeons concerning adhesion formation. The latter illustrates once again the need to strictly follow the basic principles of good surgical practice. In an effort to reduce adhesion formation, a lot of therapies have been used. The two major strategies for adhesion prevention or reduction are adjusting the surgical technique and the application of adjuvants (Risberg, 1997). Adjuvants fall into two main categories, drugs and barriers. Most of them have questionable clinical efficacy in human and veterinary medicine (Bostedt and Brummer, 1969; Bruhn, 1981; Parker et al., 1987; Jansen, 1988; Risberg, 1997; Hague et al., 1998; Johns et al., 2001; diZerega et al., 2002; Mettler et al., 2004; Newman, 2008).

## Infertility

The postoperative fertility after a routine CS was suppressed in dairy cows by approximately 15% compared to normally calving animals (Arthur et al., 1989), whereas a study in beef cattle showed a decrease of 26.6% in pregnancy rate when compared with the average herd level (Patterson et al., 1981). The number of services per conception and days open were both increased by CS (Dehghani and Ferguson, 1982; Vandeplassche et al., 1968; Cambell and Fubini, 1990) but the interval to first service and the subsequent gestation length were not significantly influenced (Noakes et al., 1991). Cows (dairy as well as beef) that have been rebred after a CS had an overall pregnancy rate of 60 - 80% with a further loss of 5 to 9% due to abortion (Debackere et al., 1959; Sloss and Dufty, 1980; Patterson et al., 1981; Roberts, 1986; Arthur et al., 1989; Vandeplassche et al., 1968). A 20-year old study in the BB breed showed a pregnancy rate of 75% while 9.7% of recorded pregnancies ended in abortion (Bouters and Vandeplassche, 1986). To attain these pregnancy rates more inseminations were needed (from 1.3 to 2.5). Cattell and Dobson (1990) reported better pregnancy rates in beef cows (91%) compared to dairy cows (72%) after CS and Gschwind et al., (2003) showed that cows that gave birth to a living calf had better pregnancy results than cows which had delivered a dead calf (respectively 68% and 46%).

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# Factors influencing dystocia (Chapter 2.2)

# INTRODUCTION

The definition of dystocia or calving difficulty varies among authors but generally it is defined as a difficult or delayed birth at any stage of labour (Brinks et al., 1973; Oxender and Adams, 1979; Anderson and Bullock, 2000; Mee, 2004). The cow has the highest incidence of dystocia among all domestic animals (3 - 10%; Van Donckersgoed, 1997). In general, dystocia is observed when the size of the fetus is incompatible with the size of the pelvic opening of the cow (Benyshek and Little, 1982; Anderson, 1990; Colburn et al., 1997), defined as fetal-pelvic disproportion (Green et al., 1988). This disproportion can cause extreme difficulties during the parturition, requiring a surgical intervention (Ménissier and Foulley, 1979). Specifically in the DM-BB breed, the sustained phenotypical selection for muscular hypertrophy has led to relative reduction in size of the pelvic area and a higher fetal weight at birth, causing fetal-pelvic discrepancy being the most important indication for CS. Belgian farmers are not willing to take any risk and oblige their veterinarians to perform a CS in case of any doubt during parturition based on the high value of the calf due to the extreme muscularity and the relatively low cost of a CS in Belgium. So, in our country in the DM-BB breed dystocia is not an issue because parturition is managed by elective CS. However, to answer on the ethical concerns of instrumentalisation and make the breed less controversial, selection should be performed to diminish the CS rate. As in Belgium almost all the DM-BB cows calve by CS, there is no possibility to gather information about calving difficulty score and the use of a calving ease index is not the best option in the selection against CS. The solution should be sought in the simultaneous selection on a bigger pelvic area (PA) in the dam and a smaller body size at birth of the calf. As there is only little literature in the DM-BB breed on these two parameters (PA and size of the calf) and other factors influencing parturition and/or dystocia, studies performed in other (beef) breeds concerning these factors are overviewed in this Chapter.

## FACTORS INFLUENCING THE COURSE OF DYSTOCIA

Biological aspects of calving performance are influenced by two components, the first related to the calf and the second to the dam (Philipsson, 1976b). The calf component, often identified as direct effect, is mainly dependent on the size of the calf and is referred to as ability to be born easily. The dam component, identified as maternal or indirect effect, tends to depend mostly on the pelvic area (PA), the maternal preparation for calving and is referred to as ability to give birth easily (Meijering, 1984). From the genetic point of view the two effects generally show an antagonistic relationship, which is a complicating factor in the definition of breeding strategies (Dekker, 1994).

## Dam component

### Breed

Dystocia and calf mortality is considered to be a bigger problem in large-sized breeds (Charolais, Maine-Anjou, Blonde d'Aquitaine and Limousin in France [Ménissier et al., 1981]; Chianina, Marchigianina, Romagnola and Piedmontese in Italy [Ménissier and Foulley, 1979]) compared to small-sized breeds such as Angus and Hereford (Ménissier and Foulley, 1979).

The Belgian Blue (BB) breed is a double muscled (DM) breed and DM animals have a higher frequency of calving difficulties than heterozygous individuals (Arthur, 1995), but no difference was observed between heterozygous and homozygous conventional animals (Casas et al., 1998). This higher frequency of dystocia in DM cattle may be due to a combination of two factors: a direct influence of the calf (Arthur, 1995; Casas et al., 1999) and a maternal influence of the dam (Arthur, 1995). There are different ways in which selection for growth rate and muscularity can influence calving ability as can be seen in Figure 1.

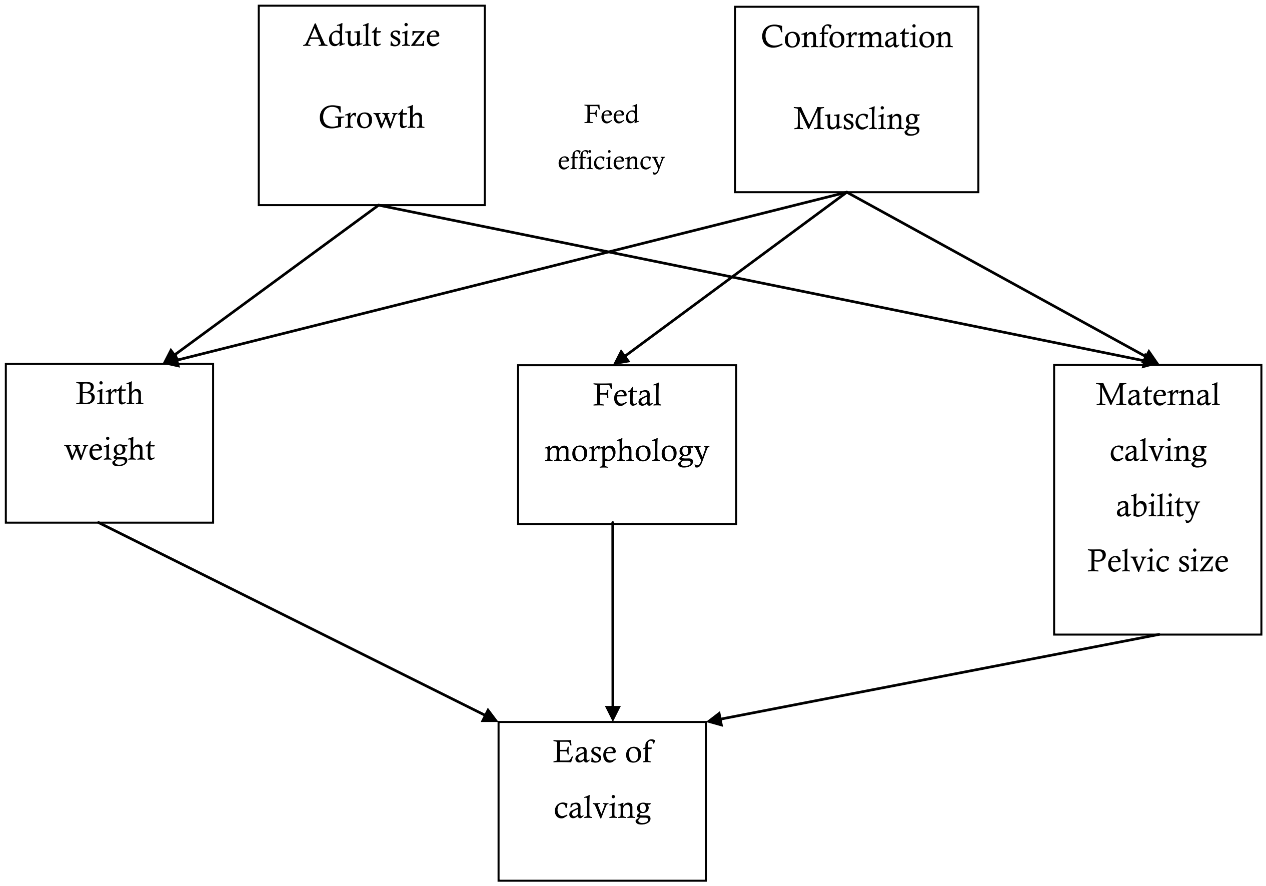


**Figure 1** Influence of selection for growth and muscling on calving performance (after Hanset, 1981).

## Pelvic anatomy

Incompatibility at birth between the size of the calf and the pelvic opening of the mother is the main factor for the occurrence of dystocia. Second to calf birth weight, the PA is responsible for the variability in calving difficulty, being the most important maternal factor (Johnson et al., 1988). The PA must be seen as a threshold trait. If the PA of a female is large enough for the calves that she will have, there would be no advantage in a larger pelvis (Anderson, 1990). The PA can be measured by the use of pelvimetry and has been used to predict dystocia (Bellows et al., 1971a,b; Laster, 1974; Naazie et al., 1989; Deutscher, 1991; Anderson, 1990; Van Donkersgoed et al., 1990; Thompson et al., 1997), or to select and cull heifers with small pelvic dimensions prior to breeding (Houghton and Corah, 1989; Deutscher, 1991; Torell et al., 1995).

In double-muscled animals the PH, PW and PA are significantly smaller compared to non-double-muscled animals (Ménissier and Vissac, 1971). Shanin et al. (1991) found that the proportion of os coxa to the total bone weight is smaller in DM cows. In DM animals there is narrowing of the anterior pelvic plane, accompanied by a convergence of the iliac branches of the hip-bone, and even an accentuation of the pelvic crest (Vissac et al., 1973). Negative-adjusted correlations of shoulder width and back width with inner pelvic size are shown in a study of Coopman et al. (2003) and also indicate that increased muscular conformation within the DM- BB is related to a decrease in inner pelvic dimensions. The same authors, however, also saw that in the DM-BB breed, animals with the same shoulder width could have a large variability in PH.

Pelvic measurements have limited usefulness in predicting dystocia on an individual basis but can be used to predict herd problems (Larson et al., 2004). It might be relevant to compare the age adjusted pelvic measurements of a contemporary group and cull the extremely small PA heifers or at least breed them to high accuracy calving ease bulls. Producers who annually evaluate PA will be able to set a minimum PA that works for their individual operations. Culling heifers with extremely small PAs can be a useful tool to reduce dystocia (Andersen, 2005). Since PA is highly heritable, producers that would like to reduce the incidence of dystocia in their herds should select against small pelvises. But before the PA can be utilized in selection, the heritability and the genetic relationships between PA and other performance characteristics (for example daily weight gain) must be known (Benyshek and Little, 1982) to prevent negative effects of selection towards larger pelvic sizes. Since the heritability of the PA is moderate to high according the study used, selecting heifers and bulls on pelvic size can be beneficial in the increase of the total pelvic dimension (Freking, 2000).

## External measurements

Coopman et al. (2003) demonstrated correlations in the DM-BB breed between external body traits (withers height, live weight and the external distance between the most lateral points of the *tubera coxae*) and internal pelvic sizes and developed models to predict inner pelvic sizes. According to these authors external measurements are much more accessible to obtain a large quantity of data on external body parts used to predict pelvic traits than the direct method of pelvimetry, as no veterinary skills are needed and there is a limited risk for the animal. Bellows et al. (1971a,b) and Ward (1971) also found that some external body measurements were correlated with PA.

In contrast, Brown et al. (1982), Anderson (1990), Deutscher (1991) and de Oliveira et al. (2003) claim there are no external measurements that accurately predict the PA. That is why the PA should be directly measured; it should not be assumed that all large framed females will have large pelvises or that all small females will have small pelvises (Anderson, 1990).

## Age/ parity

Age of the dam also has been demonstrated to be an important contributor to calving difficulty (Wang et al., 2000), especially the difference between multi- and primiparous dams. First calf heifers account for the majority of calving difficulties and associated calf losses (Greiner, 2004), and it is generally known that first and second calf animals experience more calving difficulties compared to mature cows, even though the first and second calf animals produce lower birth weights (BW; Houghton and Corah, 1989; Carnier et al., 2000; Zollinger and Hansen, 2003).

This higher incidence of calving problems in heifers is inevitable despite the fact that most first-calf heifers are observed more closely, and assisted more readily at calving than mature cows (Anderson, 1990). These high rates of calving problems among the first calf heifers are mostly due to the fact that the PA is smaller at first parturition than at subsequent calvings (Anderson, 1990). Green et al. (1988) found that pelvic size increased up to 5 years of age and that pelvic width (PW) is slightly slower in maturation than pelvic height (PH). Multiparous animals have a fully developed skeletal structure and body size and are therefore capable of giving birth to heavier calves (Houghton and Corah, 1989; Zollinger and Hansen, 2003).

Focusing on the heifers, dystocia in two-year-old animals showed to be higher than in three and four-year-old animals (Laster et al., 1973). In general, heifers calving at two years of age will give more live calves throughout the animal's lifetime (Short and Bellows, 1971) and therefore gain more profits. However, animals calving first at two years of age have more difficulties at calving because of a smaller pelvis (Bellows, 1968) and less weight (Cundiff et al., 1974).

## Size

The size of the dam is influenced by several genetic and environmental factors, but has not been demonstrated as a good predictor of dystocia (Benyshek and Little, 1982; Berglund and Philipsson, 1987). However, when the BW of the calf was not included, the size of the dam was a significant factor influencing dystocia (Fagg et al., 1975). Studies of Laster (1974), Houghton and Corah (1989), McGuirck et al. (1998a), Anderson and Bullock (2000), and Zollinger and Hansen (2003) showed that larger cows had larger pelvic dimensions, but also had calves with higher BWs, so it appears that selection for size of the dam alone may be ineffective in reducing calving difficulty because of a correlated response in the size of the fetus (Benyshek and Little, 1982; Deutscher, 1991).

## Condition/Nutrition

Nutrition is another critical factor that affects the reproduction in beef cattle. Nutritional effects may be mediated by affecting the BW of the calf or the size of the heifer (Hickson et al., 2006). Down regulating the size of the fetus by restricting the dam's feed intake during a limited period of pregnancy was suggested to be used as a method to decrease calving difficulties. This should however be without impairing the calf's post-natal growth or the growth and rebreeding performance of the dam because that will lead to the loss of the advantage of decreasing dystocia (Prior and Laster, 1979).

A negative influence of undernourishment on the rate of dystocia in cattle was found by Young (1968) for Devon heifers, by Schultz (1969) for Holsteins and by Bellows et al. (1971a) for Angus heifers. Severe underfeeding, to the extent that the dam loses body condition, has been shown to reduce BW of calves, but not consistently reduces dystocia. The development of the heifer was retarded in some cases and increased the incidence of dystocia although the calf's' birth weight decreased (Meijering, 1984). Undernourishment has been reported to have a greater effect on the BW of calves born to heifers than to older cows (Drennan, 1979). This can be explained by the competition between energy demand for pregnancy and for maternal growth, which is higher in heifers (Drennan, 1979).

Effects of nutrition above requirements and its consequences on dystocia are inconsistent. In many studies no effect was seen (Hodge and Stokoe, 1974; Laster, 1974; Kroker and Cummins, 1979; Bellows et al., 1982). Primiparous beef cows calving with a greater body condition score (BCS) had heavier calves at birth but no increased dystocia (Spitzer et al., 1995). This inconsistency in response may have been due to variability in the growth of the heifers fed at higher levels. Heifers that used the additional energy to increase the size of their frame in proportion to or at a relatively greater rate than the increase in BW of the calf would have experienced a reduced incidence of dystocia caused by feto-maternal disproportion. In contrast, heifers that increased body condition in response to the additional feed may have developed a build-up of fat in the pelvic region that restricted passage of the fetus through the birth canal (Rutter et al., 1983; Meijering, 1984; Rice, 1994). Fat in the pelvic region reduces the lumen and makes the parturition more difficult, leading to fatigue of the musculature of the uterus and retarded involution of the organ (Grunert, 1979).

## Calf component

### Birth weight

All researchers agree that BW of the calf is the major factor causing calving problems (Thomson and Wiltbank, 1983; Johnson et al., 1988; Andersen et al., 1993a,b; Colburn et al., 1997; Thompson et al., 1997; Nix et al., 1998). The BW explains around 50% of the variability in the frequency of difficult calvings (r = 0.6 - 0.8, Freking, 2000). Since BW is heritable, selecting bulls that sire calves with moderate BW can be effective in reducing calving difficulty (Meadows et al., 1994; Freking, 2000). Major difficulties at calving are due to the excessive size of the calf as compared with the PA of the dam, a morphological incompatibility between dam and fetus.

Just as PA, the effect of BW on dystocia should be considered as a 'threshold' type of effect (Philipsson, 1976a; Meijering, 1984; Rice, 1994; Eriksson, 2003). In other words, reducing BW will reduce the incidence of calving difficulties in some herds, but beyond a certain point, continuing to reduce BW will no further reduce dystocia, within a given cow size (Anderson, 1990). The point where BW is just large enough that a slight increase will substantially increase dystocia is called the threshold (Anderson, 1990). A study of Eriksson (2003) showed that the location of this threshold was dependent on the parity and the breed of the dam. In the Angus breed 31 kg seemed to be the BW above which dystocia increased significantly (Berger et al., 1992), for Charolais the threshold was set on 45.5 kg for male calves and 50 kg for female calves (Rutter et al., 1983).

Calf BW is primarily influenced by genotype (sire breed and dam breed), sex of the calf, gestation length and age of the dam (Grunert, 1979). The weight and nutrition of the dam, the season of calving (Dawson et al., 1947) and the temperature (Colburn et al., 1996) also have an influence.

## Calf shape

The difference in calf shape can also account for variation in the incidence of dystocia. McGuirck et al. (1998b) found high genetic correlations between calf size and calving difficulty scores. Increased calving difficulty was associated with larger calves and calves with better conformation (McGuirck et al., 1998b). Observations of the Meat Animal Research Centre show that longer, slimmer Chianina- and Brahman-sired calves provoke less dystocia than thicker-made Charolais- and Maine-Anjou-sired calves while the birth weights were similar (Anderson, 1990). In New Zealand the beef industry focuses on the shape of the shoulders and animals with a wider shoulder were avoided (Cumming, 1999). Research in Germany has demonstrated a high correlation between chest girth at 330 days of age in Simmental sires and calving difficulty of their subsequent progeny (Anderson, 1990). Calf body length and rump were significantly correlated with calving difficulty in 2-year-old French cows (Ritchie and Anderson, 1994). Colburn et al. (1997) found that of the calf sizes, the head circumference and shoulder width appear to be the most important indicators of the degree of dystocia. In addition, Thomson and Wiltbank (1983) demonstrated a significant effect of heart girth of the calf on dystocia. Nugent et al. (1991) demonstrated that proportions of the fetus were not significant as contributors to dystocia once BW had been considered. Meijering (1984) also observed no additional effect of body measurements compared to BW.

The DM beef breeds, like the DM-BB breed, are an extreme example of the influence of calf shape, as a high incidence of calving problems is observed. A study of Casas et al. (1999) indicated that both size and shape of the calf are influencing calving difficulty. Their results show an increase of 0.7% in calving difficulty per kilogram increased BW, but only the homozygous DM calves had a higher difficulty at calving. Coopman et al. (2004) conducted withers height, shoulder width, width of the hind quarter and hearth girth of newborn calves and found that all of these body measurements significantly influenced BW. Width of the hind quarter seemed to be the broadest point of a newborn DM-BB calf and therefore the limiting factor for natural calving.

## Gender

Brinks et al. (1973) in Hereford and Johnson and Berger (2003) in Holstein cattle found that the odds of male calves needing assistance were higher than the odds of female calves. The same results were found in study of Laster et al. (1973) and McGuirck et al. (1998a). In a study of Burfening et al. (1978a) bull calves had gestation lengths about 1 day longer, required 12.7% more assistance at birth and were 3.0 kg heavier at birth. This magnitude of the differences between sexes for percent assisted births and calving ease score was greater in young cows than in older cows (Laster et al., 1973; Burfening et al., 1978b). The odds of an unassisted birth were 1.45 and 2.43 times higher for female calves than for males in heifers and cows, respectively (Berger et al., 1992). Bull calves required 20 and 11% more assistance compared to heifer calves from 2- and 3-year-old cows, respectively (Burfening et al., 1978b). However, when the BW was kept constant, sex of the calf had no effect on calving ease (Laster et al., 1973; Burfening et al., 1978b; Nelson and Beavers, 1982).

## Gestation length

Gestation length is having an indirect effect on calving difficulty as an increase in gestation length is increasing the BW (Zollinger and Hansen, 2003). Gestation length itself is influenced by parity, fetal gender, sire and dam effect, maternal nutrition and climate during the last trimester of gestation (Mee, 2008). Cows delivering a bull calf have a longer gestation length compared to animals delivering a heifer calf (Holland and Odde, 1992). Cold weather during the last trimester has been associated with increased dry matter intake and increased gestation length (Colburn et al., 1997). Research in Nebraska has indicated that gestation length is a trait that can be selected for (Houghton and Corah, 1989). Selection on a shorter gestation period can have two benefits. Besides the subsequently lower BW, there is a beneficial effect on the cows that start cycling earlier after the parturition with a decrease of gestation period (Ritchie and Anderson, 1994; Zollinger and Hansen, 2003). One should avoid shortening the gestation length too much, because it may affect calf viability (Hanset, 1981). However, gestation length had no significant effect on calving difficulty when the BW was constant (Bellows et al., 1971b). Bennett and Gregory (2001) and Ritchie and Anderson (1994) also claimed that selection for a shorter gestation length is less effective compared to selection for BW or calving difficulty score in order to avoid dystocia. Unfortunately, as natural service is common in beef herds, gestation length is rarely recorded.

## CONSEQUENCES OF DYSTOCIA

Dystocia will affect the profitability of the farms generating additional costs compared to normal calving. These costs are not only related to the potential loss of the calf but also to veterinary fees, increased labour of the farmer and health and fertility problems of the cow after dystocia (Albera et al., 2004). According to Rice (1994) long-term consequences of dystocia may include compromised rebreeding of the dam, increased morbidity and mortality of calves from subsequent diseases and calves that become hypogammaglobulinaemic from inadequate or delayed intake of colostrum. Costs were dependent on the sex of the calf and the parity of the dam, with a higher rate of dystocia in male calves from first parity cows (Albera et al., 2004). Dystocia also contributes to a delay in breeding. Forty-five percent of the cows that experienced calving difficulty could be inseminated during a 45 day breeding season compared to 69% percent of the unassisted cows. The pregnancy rates were 69 and 85% for assisted and unassisted cows, respectively (Anderson, 1990). Furthermore, Dobson et al. (2001) found more abnormal progesterone profiles following dystocia, a delayed uterine involution and a delayed onset of luteal activity postpartum.

Dystocia contributes heavily to losses in production in beef cow/calf herds (Anderson and Bullock, 2000). The number of calves lost from calving difficulty exceeded losses from all other causes (Cappel et al., 1998). Research has shown that calves that experience calving difficulty are about four (Laster et al., 1973; Anderson and Bullock, 2000) or five times (Azzam et al., 1993) more likely to be born dead or to die within 24 hours after birth than those born without difficulty. A study of Cappel et al. (1998) showed that the degree of calving difficulty has a pronounced effect upon the calf's ability to adapt to its new environment. Calves that require mechanical assistance and/or surgical intervention express depressed cortical and neutrophil values necessary for the immediate adjustment to their new environment. Besides, their survival changes are further compromised by depressed metabolic adaptation capabilities (Cappel et al., 1998).

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# CHAPTER 3

# AIMS OF THE STUDY

In the double muscled Belgian Blue (DM-BB) breed dystocia is caused by an incompatibility between the size of the calf and the size of its mother's pelvis. Therefore, the delivery of the calf has to be done by Caesarean Section (CS) which gives rise to ethical discussions limiting the international use of this breed for beef production. It is known that both the weight and the size of the calf are very important factors relating to calving ease. On the maternal side the pelvic area is responsible for the largest variability in dystocia. Information about the pelvic size of the dam and the size of the decisive body parts of the calf may allow the obstetrician to more accurately predict the probability of natural calving.

At first, as CS is currently the most common way of delivering a calf in the BB breed in Belgium, we aimed to investigate the difficulties during and the behavioural changes experienced after this surgical procedure and to compare the latter with calving *per vaginam* (= natural calving without or with mild traction) in the same breed. We will try to achieve our aims by answering the following questions (**Chapter 4**):

1. Which difficulties may a veterinarian encounter before and during a CS and what are the risk factors associated with these difficulties (**Chapter 4.1**)?

2. Is there a difference in behaviour and discomfort in DM-BB cows after giving birth *per vaginam* versus per CS (**Chapter 4.2**)?

The second aim of the current thesis was to investigate whether selection towards a higher percentage of calving *per vaginam* is still possible in the DM-BB breed, what specific body measures of the dam and her calf are detrimental for parturition, and what other factors are related with the calving process. We had to answer the subsequent questions (**Chapter 5**):

1. Can the Rice pelvimeter be used to accurately measure pelvic dimensions in DM-BB cows (**Chapter 5.1**)?

2. What is the variation in pelvic size among DM-BB cattle in Belgium in order to estimate the possibilities of selection towards a higher percentage of natural calving (**Chapter 5.2**)?

3. What are the determinant body parts of a DM-BB calf to allow calving *per vaginam* and what is the variation in size of these body parts in the current DM-BB calf population? Are we able to formulate a model to assess the limiting body sizes of the calf in terms of calving ease at the moment of parturition (**Chapter 5.3**)?

4. How large is the fetal-dam disparity present in DM-BB cattle? What is the influence of the type of parturition (delivery by either CS or *per vaginam*) on the pelvic width, pelvic height and pelvic area in DM-BB animals (**Chapter 5.4**)?

5. Is there a difference between pelvic height compared to pelvic diagonal height that can clarify the rare cases in which the calf is born naturally even though theoretically impossible (**Chapter 5.5**)?

# Chapter 4

# The Caesarean Section

# Pre- and operative difficulties during bovine Caesarean Section in Belgium and associated risk factors (Chapter 4.1)

Modified from:

Kolkman I, Opsomer G, Lips D, Lindenbergh B, de Kruif A and De Vliegher S

2009

Pre- and operative difficulties during bovine Caesarean Section in Belgium and associated risk factors.

Reproduction of Domestic Animals (online).

# ABSTRACT

The aim of the present study was to describe the difficulties encountered during Caesarean Section (CS) in practice on mainly double muscled Belgian Blue (DM-BB) cows and to identify associated risk factors. Data were collected using a questionnaire completed by veterinarians of the Ambulatory Clinic of the Faculty of Veterinary Medicine (FVM), Ghent University (Belgium) immediately after performing a CS. Results reveal that the BB breed had fewer severe pre-operative problems than animals of other breeds, most likely due to the fact that CSs in this breed are performed in a very early stage of parturition. Mild as well as severe difficulties were more likely to happen during surgery in cows that had undergone a CS before. Cows at their second or third surgery, had a significantly higher proportion of larger calves and more skin scar tissue was present, both increasing the risk of abdominal wall muscular and uterine bleeding. These factors can all lead to problems with exteriorization and suturing of the uterus, hence special attention is needed when performing a CS on a cow which has experienced the procedure before. The more experienced veterinarians were less likely to report difficulties during the operation than less experienced surgeons.


# INTRODUCTION

Caesarean Section (CS) is a common surgical procedure performed in cattle all over the world with many different techniques used (Arthur et al., 1989; Busch, 1993; Clark, 1994; Frazer and Perkins, 1995; Newman and Anderson, 2005). Indications to perform a CS are: immaturity of the heifer (Newman and Anderson, 2005), incomplete dilatation of the birth canal, irreducible uterine torsion (Schönfelder and Sobiraj, 2006), rupture of the uterine wall before calving, relative foetal oversize and deformities of the calf (Vandeplassche, 1974; Cattell and Dobson, 1990; Dawson and Murray, 1992). Risk factors for CS that were identified in dairy cows are: a single male calf, a long gestation period, and young age at first calving (Barkema et al., 1992).

Whereas in dairy cows a CS is only performed when all other attempts to deliver the cow *per vaginam* have failed, for veterinarians working in Belgium the CS has become a first choice approach at parturition through the expansion of the double muscled Belgian Blue (DM-BB) breed. This beef breed is characterized by an extreme muscular hypertrophy which originates from an anomaly in the myostatin gene, a single autosomal recessive gene that is located on chromosome 2 (Grobet et al., 1998). In DM-BB animals, this gene is missing a segment of 11 nucleotides causing the gene to be inactive, resulting in a deficiency of the genetic restraint on muscular development. Through the sustained phenotypical selection for muscular hypertrophy, an incompatibility between the size of the pelvis (too narrow) of the cow and her calf (oversized) has developed (Kieffer, 1972; Coopman et al., 2003). Consequently, DM-BB calves are almost routinely born by CS: only 5 to 10% are born *per vaginam,* a relatively oversized calf being the most important indication to perform a CS in DM-BB cows (Michaux and Hanset, 1986; Hanset, 2002). This differs substantially from other breeds. In addition, optimal conditions to perform CS are present in Belgium: short distances to the farm, mild winters not hampering accessibility of the herds, ability of the farmers to detect onset of parturition accurately and to provide adequate assistance during the operation, and well trained and skilled bovine veterinarians. Currently, almost 50% of all Belgian farmers own at least one DM-BB cow and a Belgian bovine veterinarian performs on average 500 to 1000 CSs per year.

However, it should not be forgotten that every CS, even the routine elective CS, remains a major abdominal operation performed in a contaminated environment. Nevertheless, the procedure itself is performed under surgical sterility to avoid contamination. Still, it cannot be considered to be without any difficulties and/or complications before, during and after the operation. Preoperative complications can be nervous animals, emphysematous fetus, fetal abnormalities, and uterine inertia, trauma or rupture (Dehghani and Ferguson, 1982; Newman and Anderson, 2005). All kinds of difficulties, e.g. straining, bleeding, rumen prolaps (Newman, 2008), problems with exteriorizing the uterus (Vandeplassche, 1988; Hoeben et al., 1997), adhesions at the time of surgery (Hoeben et al., 1997), excessive uterine trauma, peritoneal cavity contamination, excessive trauma to abdominal wall (Newman and Anderson, 2005), gastrointestinal trauma, inadequate uterine closure (Dehghani and Ferguson, 1982), uterine tears

(Vandeplassche, 1988; Dawson and Murray, 1992) … may occur during the operation, although information on the occurrence of these problems in BB cows is very scarce.

Most studies have investigated difficulties and complications after CS in breeds other than the BB (Seger et al., 1994; Frazer and Perkins, 1995; Vaughan and Mulville, 1995; Newman and Anderson, 2005). In these breeds, the CS is seen as the last resort when all other means to give birth to the calf in a natural way have failed, while DM-BB cows are operated on in an early stage of parturition often without attempting to extract the calf. Study of Hoeben et al. (1997) in the BB breed revealed that the surgeon, parity, increased uterine contractions, the position of the calf and the presences of adhesions were associated with difficulties of exteriorization of the pregnant horn. It is very important that veterinarians are aware of these factors increasing the risk of complications or difficulties (Hoeben et al., 1997) and, as the success rate of a CS mainly depends on the operation technique (Mijten, 1994), it is imperative to perform the surgical procedure *secundum artem*.

The aim of this study was to describe the difficulties encountered during CS mainly in BB cows and to identify associated risk factors. This was achieved by collecting data between January 2005 and July 2006 using a questionnaire completed by the veterinarians of the Ambulatory Clinic of the Faculty of Veterinary Medicine (FVM), Ghent University (Belgium) immediately after CS.

## MATERIALS AND METHODS

### General

Between January 2005 and July 2006 a questionnaire was completed whenever a CS was carried out by one of the 18 veterinarians working in the Ambulatory clinic of the FVM. During all surgeries, one final year veterinary student assisted the surgeon.

The CSs in the DM-BB cows were mainly performed for elective reasons. Indications in other breeds (and in DM-BB) to carry out this operation were oversized calves, abnormalities of the calves and deformations of the birth canal.

## Operation technique

All CSs were performed on the standing cow on the left side as described by Kolkman et al. (2007). In short, all animals routinely received 0.15 mg of clenbuterol-hydrochloride (Planipart®, Boehringer Ingelheim, Belgium) intravenously (IV) in the tail blood vessel 5 minutes before the start of the operation. Aggressive or restless animals were sedated with 0.01 - 0.016 mg/kg xylazine IV (Xyl-M®, VMD, Belgium). Local anaesthesia was achieved by a line block with 3200 - 4800 mg of procaine hydrochloride with adrenaline (Procaine hydrochloride 4%®, VMD, Belgium). After delivery of the calf, the foetal membranes hanging out were removed and the uterus was closed with a synthetic absorbable monofilament (polydioxanone, Monodox®, Michel Frère, Belgium, USP [=United States Pharmacopeia] 2) using a round needle by a single modified Cushing suture pattern, paying special attention not to expose any suture material. When uterine fluids were excessively contaminated or in case there was a risk of leakage, a two-layer closure was performed. In these cases, the modified Cushing suture was followed by a normal Cushing or Lembert. The peritoneum, the muscles, the subcutaneous tissue and the skin were sutured with a synthetic absorbable polyglycolic acid polymer filament (Surgicryl®, SMI, Belgium, USP 2). In heifers, the peritoneum and *musculus (M.) transversus abdominis* were sutured together with the *M. obliquus abdominis internus* using a simple continuous everting suture pattern. In older cows with thicker muscle layers, the *M. obliquus abdominis internus* was sutured separately with a simple continuous pattern. The *M. obliquus abdominis externus* was always sutured separately with a simple continuous pattern. Next, the subcutaneous tissues were sutured using a continuous mattress pattern. Finally, the skin was closed with a continuous interlocking suture.

All animals received antibiotics intra-abdominal (IA) during and intramuscular (IM) after the CS procaine benzyl penicillin (12 000 IU/kg, Duphapen®, Fort Dodge A.H., Belgium). Procaine benzyl penicillin with neomycin-sulphate (10 000 IU/kg benzyl penicillin + 5 mg/kg neomycin-sulphate, Neopen®, Intervet, Belgium) was used when post operative infections were expected (such as recumbency during CS, kicking during CS). At the end 50 IU of oxytocin (Lactipart 10®, Codifar, Belgium) was administered IM to all animals, to produce uterine contractions and stop diffuse bleeding of the uterine wall if present.

Three out of the 18 veterinarians routinely administered epidural anaesthesia (1.5 - 2 ml Procaine hydrochloride 4%®, VMD, Belgium), whereas the other surgeons only administered it when the cow was excessively straining at the start of the operation.

As no stitches had to be removed, the animals were not routinely revisited by the veterinarian. The farmer was advised to administer antibiotics for three days or more (procaine benzyl penicillin [12 000 IU/kg, Duphapen®, Fort Dodge A.H., Belgium] or procaine benzyl penicillin with neomycin-sulphate [10 000 IU/kg benzyl penicillin + 5 mg/kg neomycin-sulphate, Neopen®, Intervet, Belgium]).

## Questionnaire

The address and name of the farmer were noted as well as the ear tag number, the parity, the CS number and breed of the cow, and the identification of the surgeon. As outlined in Table 1, the questionnaire consisted of two sections; the first focussing on pre-operative information and the second on the operation. The questionnaire was filled in by the veterinarian immediately after the CS. The eighteen veterinarians were all trained to record the variables to avoid subjectivity. Afterwards all data were manually entered from the questionnaire into Access 2003 (Microsoft, Corporation).

## Veterinarians

All veterinarians graduated from the FVM in Merelbeke, Belgium. Their age ranged between 25 - 55 years at the start of the study. Seven veterinarians had little experience (≤ 2 years) in bovine practice and performing CS, six had moderate experience (> 2 and < 5 years), and five were highly experienced (≥ 5 years). There were thirteen male veterinarians and five female veterinarians.

**Table 1** Overview of information on difficulties gathered on pre-operative and operative aspects of 1275 Caesarean Sections performed between January 2005 and June 2006

| | |
|---|---|
| **Pre-operative information** | |
| Cow | |
| | Excitation (anxiety or aggressiveness) and posture of cow at arrival, dilatation of the birth canal, status of the allantoic sac, status of the amnionic sac |
| Calf | |
| | Presentation (anterior/posterior), status (alive/dead), size (absolute/relative to mother)[a], presence of foetal parts through cervix |
| General | |
| | Trail traction executed, epidural anaesthesia administered |
| **Operative aspects** | |
| General | |
| | Abdominal wall muscle haemorrhage present, skin scar tissue present, overfilled/tympanic rumen present/ rumen accidentally incised, adhesion(s) present, position of the calf in the uterus (legs or back to the wound/ left or right horn), exteriorization of the uterus possible, rupturing of the uterus while exteriorizing, recumbency during CS, tenesmus, incision of a placentome, avulsion of a placentome, ruptured uterine wall (before, during or after exteriorization of the calf), haemorrhage of uterine wall, rupture in broad ligaments of the uterus |
| Suturing | |
| | Haemorrhage placentome sutured, single uterine wall sutured circular[b], uterus closed with interlocking suture (first layer), number of layers sutured, suturing of the peritoneum, suturing of the muscles, subcutaneous suture, skin suture |

a Estimated by the veterinarian; b This penetrating circular suture can be applied to the uterine wall at both sides of the incision, at one side of the incision or at parts of the uterine wall to stop diffuse haemorrhage

## Data and data management

All data were transferred from Access into Excel 2003 (Microsoft, Corporation) to perform descriptive analyses and were checked for unlikely values. In total 1286 questionnaires were completed in 109 herds, comprising 1275 operations on standing cows. Eleven CSs were performed on recumbent cows and were omitted for analysis. The *full* *dataset* consisted of information on 1275 CSs from cows belonging to these 109 herds. The *reduced dataset*, randomly omitting one CS from cows that underwent two CSs during the study period (n = 93), consisted of information on 1182 CSs. The herds included in the study consisted of beef (n = 60), dairy (n = 19), and mixed herds (n = 30) and were all clientele of the Ambulatory clinic. Ninety-two percent (n = 1091) of the cows were of the DM-BB breed, while the remaining 7.8% (n = 91) of the animals belonged to other breeds (Holstein Friesian (HF), East Flemish double purpose breed (EF), HF x BB crossbreds and EF x BB crossbreds). The DM-BB animals were mainly housed in straw boxes while animals of the other breeds were accommodated in free stalls with cubicles or tie stalls. The majority of farmers owns one or more DM-BB animals or is familiar with the breed, and is used to call for assistance at parturition in an early stage and ask for a CS even in the non BB herds.

Difficulties listed in Table 1 were divided as either mild or severe for further analyses (Table 2). Mild difficulties (MD) were defined as difficulties that need attention but in principle were never life-threatening. Severe difficulties (SD) were defined as difficulties that need special attention because they are potentially life-threatening. All cows were then categorized as having encountered none, mild or severe difficulty during their CS. Animals categorized within the MD-group had one or more MD(s) during CS. From the moment one SD (together with MDs) occurred, the animal was categorized in the SD-group.

## Statistical analyses

First, univariable analyses were performed using the *reduced dataset* (data on 1182 CSs) to study associations between three factors (breed [DM-BB, non-BB], number of CS [1, 2, ≥ 3], the experience of the surgeon [≤ 2 years, > 2 to < 5 years, ≥ 5 years]) and the occurrence of difficulties (e.g. skin scar tissue present/absent [Table 1]; Pearson $\chi^2$ or Fishers Exact test, SPSS 14.0 for Windows, SPSS Inc.). Odds ratios (OR) were calculated when appropriate. The significance level for the analyses was set at $P \leq 0.05$.

**Table 2** Categorisation of some of the operative difficulties encountered during performing Caesarean Section between January 2005 and June 2006 into mild and severe difficulties

| **Mild difficulty** | **Severe difficulty** |
|---|---|
| Abdominal wall muscle haemorrhage | Accidental incision of rumen |
| Overfilled rumen | Pulling off of placentomes |
| Tympanic rumen | Rupture of uterine wall[a] |
| Recumbency during operation | Cutting in/off placentomes |
| Tenesmus without eventration of intestines/uterus | Tenesmus with eventration of intestines/uterus |
| Adhesions between rumen/abdominal wall | Adhesion between intestines/uterus |
| Exteriorization uterus | Haemorrhage in the uterine wall |
| | Rupture in broad ligament with/without bleeding |
| | Laceration of uterus suture |

a Rupture before, during or after exteriorization of the calf

Second, multivariable, multilevel logistic regression analysis was done using the *full dataset* (data on 1275 CSs), adjusting for clustering of multiple CS per cow and multiple cows per herd by including cow and herd as random effects (MlwiN 1.2 Rasbash et al., 2000]). Presence/absence (1/0) of mild (MD) or severe difficulties (SD) per CS were used as outcome variables. Model building was done in two steps. First, univariable associations between the two outcome variables (MD versus no difficulty, SD versus no difficulty) and each of the three aforementioned predictor variables (breed, number of CS, and experience of the surgeon) were analysed separately. In the second step, the significant ($P \leq 0.15$) predictor variables were combined in two multivariable analyses with the two afore mentioned outcome variables. Using backward elimination (significance set at $P \leq 0.05$), the final two models were selected.

# RESULTS

## Descriptive and univariable analyses

Table 3 gives an overview of 1275 CS performed categorized by breed, number of CSs and experience of the surgeon (*full dataset*). No difficulties were reported in 527 (41.3%; DM-BB: 41.9%, non-BB: 33.7%) of the CSs, whereas in 350 (27.5%; DM-BB: 27.6%; non-BB: 26.1%) and 398 (31.2%; DM-BB: 30.4%; non-BB: 40.2%) of the CSs mild and severe difficulties were reported, respectively. Three cows died within 2 days after the operation and necropsy showed two animals died due to bleeding of a placentome and the third animal because of peracute peritonitis.

**Table 3** Descriptive statistics of 1275 Caesarean Sections performed between January 2005 and June 2006

| | Belgian Blue | | | | Non-Belgian Blue[a] | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | n | % within column | % within row | % of total (n=1275) | n | % within column | % within row | % of total (n=1275) | |
| N of Caesarean Section | | | | | | | | | |
| 1 | 529 | 44.7 | 88.3 | 41.5 | 70 | 76.1 | 11.7 | 5.5 | 599 |
| 2 | 359 | 30.3 | 95.7 | 28.2 | 16 | 17.4 | 4.3 | 1.3 | 375 |
| ≥3 | 295 | 24.9 | 98.0 | 23.1 | 6 | 6.5 | 2.0 | 0.5 | 301 |
| Total | 1183 | | | | 92 | | | | 1275 |
| Experience of veterinarian[b] | | | | | | | | | |
| low (7) | 459 | 38.8 | 92.4 | 36.0 | 38 | 41.3 | 7.6 | 3.0 | 497 |
| medium (6) | 214 | 18.1 | 91.8 | 16.8 | 19 | 20.7 | 8.2 | 1.5 | 233 |
| high (5) | 510 | 43.1 | 93.6 | 40.0 | 35 | 38.0 | 6.4 | 2.7 | 545 |
| Total | 1183 | | | | 92 | | | | 1275 |

a Holstein Friesian (HF), East Flemish (EF), HF x BB crossbred and EF x BB crossbreds; b Low: ≤ 2 years, medium: > 2 to < 5 years, high: ≥ 5 years of experience

Upon arrival at the farm almost 5% of the cows were recumbent and nearly 10% were excited (Table 4). DM-BB cows were less likely to be recumbent upon the arrival of the veterinarian at the farm compared with non-BB cows (OR [± 95% Confidence Interval]: 0.17 [0.08 - 0.32]; Table 4). Dilatation of the soft birth canal (vulva as well as cervix) was complete in nearly 80% of the cases. Three percent of the calves had died before surgery was started (3.1% in DM-BB compared to 3.4% in non-BB) and 8.8% were presented in posterior position (three of them in breech presentation). In more than one fifth and in almost two-third of the cases, the allantoic and amniotic sacs were still intact before the operation, respectively. The amnionic sac was more likely to be intact (2.50 [1.64 - 3.85]) and foetal parts were less likely to be present in the birth canal through the cervix (0.58 [0.35 - 0.96]) in BB cows. Attempts to extract the calf (trail extraction) (0.06 [0.04 - 0.11]) and the need to administer epidural anaesthesia (0.56 [0.36 - 0.88]) were not as common in DM-BB animals (Table 4). In cows which had undergone a CS before, the proportion of larger foeti was significantly higher and a trail extraction was significantly less likely to have been performed (Table 4). The degree of experience of the veterinarian was not significantly associated with any of the preoperative difficulties.

Skin scar tissue was more likely to be present in DM-BB animals (3.03 [1.30 - 7.03]; Table 5) and it was more likely to encounter difficulties during the operation in cows that had undergone prior surgery. Significantly more abdominal wall muscular bleeding and skin scar tissue was present and exteriorization of the uterus was more difficult in cows that had a prior CS ($P < 0.01$; Table 5). In almost one out of 10 CSs (8.5%), the surgeon was confronted with an overfilled or tympanic rumen when opening the abdomen (Table 5). The rumen was accidentally incised and needed to be sutured before continuing surgery in five animals. Excessive straining occurred in one fifth of the cases; 4.2% without eventration of any organs while in 5.6% either the rumen, the intestines or the uterus prolapsed. Adhesions of the rumen with the abdominal wall were seen in almost 5%, whereas the uterus was adhered to the abdominal wall in 5.6% of the operations. Recumbency during surgery occurred in 2.3% of all cases (DM-BB: 2.2%; non-BB: 4.6%; Table 5). In one fifth of the CSs the calf was lying with its back towards the abdominal incision (in the right horn; Table 5).

In almost 10% of the cases, problems occurred with exteriorization of the uterus so that the surgeon had to open it in the abdomen (Table 5). A ruptured uterine wall after extraction of the calf was seen in 6.3% of all surgeries (Table 5). Tearing down of the broad ligament (*ligamenta lata*) without bleeding of the middle uterine artery (*arteria uterina*) occurred in three and with arterial bleeding in one of the 1275 operations, both fortunately without fatal outcome. During extraction of the calf, incision in or pulling off of a placentome, tearing in and bleeding of the uterine wall happened more in cows that were operated on the second or subsequent time. While suturing the uterus, tearing in the suture line occurred in 2.7% of the CSs. Closure of the uterus by a double layer suture was needed more frequently in cows that had multiple CS (Table 5). Less experienced (≤ 2 years) veterinarians encountered more pulling off of placentomes and bleeding of the uterine wall. Highly experienced (≥ 5 years) veterinarians closed the uterus using one suture layer rather than using two layers (Table 5).

## Multivariable, multilevel analyses

Mild difficulties were nearly two-times as likely (OR: 1.89 [1.36 - 2.61]) to be present in a second CS animal and 3.6-times (OR: 3.62 [2.48 - 5.28]) as likely in older cows (≥ 3 CS) compared with an animal undergoing its first CS, respectively (Table 6).

Surgeons operating on cows of the DM-BB breed were less likely to encounter severe difficulties compared to non-BB animals in the model adjusting for number of CS (OR: 0.47 [0.27 - 0.81]). In second and higher parity animals, the veterinarian was 2.4-times (1.70 - 3.28) and 6.0-times (4.12 - 8.86) more likely to be confronted with a SD, respectively, compared with a primiparous animal. Highly experienced veterinarians (≥ 5 years) were less likely to encounter difficulties during the operation than less experienced surgeons (OR: 0.36 [0.46 - 0.87]; Table 6).

**Table 4** Overview of the preoperative findings and difficulties and their association with breed and Caesarean Section (CS) number (*reduced* dataset [1182 CS])

| | All | | Breed | | | | Caesarean Section number | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total[a] | | DM-BB | Non-BB | OR[b] | 95 % CI[c] | 1 | 2 | ≥3 | *P* |
| | n | % | n | n | | | n | n | n | |
| Cow is recumbent upon arrival | | | | | | | | | | |
| Yes | 50 | 4.2 | 35 | 15 | 0.17 | 0.08-0.32 | 30 | 9 | 10[f] | NS |
| No | 1132 | 95.8 | 1056 | 76 | | | 514 | 336 | 256[f] | |
| Excitation upon arrival | | | | | | | | | | |
| Yes | 116 | 9.8 | 112 | 4 | 2.49 | NS[d] | 46 | 37 | 32[f] | NS |
| No | 1066 | 90.2 | 979 | 87 | | | 498 | 308 | 234[f] | |
| Dilatation of soft birth canal | | | | | | | | | | |
| Not complete | 920 | 78.6 | 846 | 74 | 0.79 | NS | 424 | 274 | 201[f] | NS |
| Complete | 251 | 21.4 | 235 | 16 | | | 118 | 68 | 65 | |
| Status of calf | | | | | | | | | | |
| Alive | 1144 | 97.0 | 1056 | 88 | 1.09 | NS | 530 | 328 | 260[f] | NS |
| Dead | 36 | 3.1 | 33 | 3 | | | 14 | 16 | 6 | |
| Size of the fetus[e] | | | | | | | | | | |
| Absolute oversize | 630 | 55.1 | 586 | 44 | 1.19 | NS | 248 | 196 | 174[f] | <0.001 |
| Relative oversize | 514 | 44.9 | 472 | 42 | | | 278 | 136 | 86[f] | |
| Position of the calf | | | | | | | | | | |
| Anterior | 1069 | 91.2 | 988 | 81 | 1.17 | NS | 497 | 313 | 234[f] | NS |
| Posterior | 103 | 8.8 | 94 | 9 | | | 44 | 28 | 29[f] | |
| Status of allantoic sac | | | | | | | | | | |
| Intact | 248 | 21.2 | 235 | 13 | 1.67 | NS | 115 | 68 | 64[f] | NS |
| Not intact | 920 | 78.8 | 842 | 78 | | | 425 | 272 | 197[f] | |
| Status of amnionic sac | | | | | | | | | | |
| Intact | 765 | 64.7 | 725 | 40 | 2.50 | 1.64-3.85 | 343 | 222 | 180[f] | NS |
| Not intact | 417 | 35.3 | 366 | 51 | | | 201 | 123 | 86[f] | |
| Presence of foetal parts in birth canal | | | | | | | | | | |
| Yes | 256 | 34.3 | 226 | 30 | 0.58 | 0.35-0.96 | 133 | 78 | 45 | NS |
| No | 492 | 65.8 | 457 | 35 | | | 224 | 152 | 116 | |
| Trail traction | | | | | | | | | | |
| Yes | 68 | 5.8 | 36 | 32 | 0.06 | 0.04-0.11 | 38 | 23 | 7 | 0.036 |
| No | 1114 | 94.3 | 1055 | 59 | | | 506 | 322 | 259[f] | |
| Epidural anaesthesia | | | | | | | | | | |
| Yes | 642 | 54.3 | 581 | 61 | 0.56 | 0.36-0.88 | 307 | 171 | 151[f] | NS |
| No | 540 | 45.7 | 510 | 30 | | | 237 | 174 | 115[f] | |

a Missing values not included; b Odds Ratio (Belgian Blue versus non-Belgian Blue cows); c Confidence Interval; d Not Significant; e Estimated by the veterinarian

**Table 5** Overview of operative findings and difficulties and their association with breed (double muscled Belgian Blue [DM-BB] versus non-BB), Caesarean Section (CS) number and the degree of experience of the veterinarian (*reduced* dataset [1182 CS])

| | | Total[a] | | Breed | | | | Caesarean Section number | | | | Experience of veterinarian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DM-BB | Non-BB | OR[b] | 95 % CI[c] | 1 | 2 | ≥ 3 | *P* | ≤ 2 | > 2 to < 5 | ≥ 5 | *P* |
| | | n | % | n | n | | | n | n | n | | n | n | n | |
| Abdominal wall muscle haemorrhage | | | | | | | | | | | | | | | |
| | Yes | 378 | 32.0 | 356 | 22 | 1.52 | NS[d] | 96 | 125 | 152[f] | <0.001 | | | | NA[e] |
| | No | 804 | 68.0 | 735 | 69 | | | 448 | 220 | 114[f] | | | | | |
| Skin scar tissue | | | | | | | | | | | | | | | |
| | Yes | 198 | 16.8 | 192 | 6 | 3.03 | 1.30-7.03 | 3 | 66 | 125[f] | <0.001 | | | | NA |
| | No | 984 | 83.2 | 899 | 85 | | | 541 | 279 | 141[f] | | | | | |
| Position of the calf | | | | | | | | | | | | | | | |
| | Leg to the wound | 940 | 79.5 | 872 | 68 | 1.35 | NS | 417 | 285 | 217[f] | NS | | | | NA |
| | Back to the wound | 242 | 20.5 | 219 | 23 | | | 127 | 60 | 49 | | | | | |
| Recumbency during CS | | | | | | | | | | | | | | | |
| | Yes | 27 | 2.3 | 23 | 4 | 0.47 | NS | 16 | 8 | 3 | NS | 12 | 7 | 8 | NS |
| | No | 1155 | 97.7 | 1068 | 87 | | | 528 | 337 | 264[f] | | 446 | 212 | 497 | |
| Overfilled rumen | | | | | | | | | | | | | | | |
| | Yes | 100 | 8.5 | 92 | 8 | 0.96 | NS | 44 | 29 | 25[f] | NS | | | | NA |
| | No | 1082 | 91.5 | 999 | 83 | | | 500 | 316 | 241 | | | | | |
| Exteriorization of the uterus possible | | | | | | | | | | | | | | | |
| | Yes | 1082 | 91.5 | 999 | 83 | 1.05 | NS | 512 | 328 | 224[f] | <0.001 | 425 | 195 | 462 | NS |
| | No | 100 | 8.5 | 92 | 8 | | | 32 | 17 | 42[f] | | 33 | 24 | 43 | |
| Incision of placentome | | | | | | | | | | | | | | | |
| | Yes | 141 | 11.9 | 128 | 13 | 0.80 | NS | 52 | 43 | 45[f] | 0.010 | 58 | 33 | 50 | NS |
| | No | 1041 | 88.1 | 963 | 78 | | | 492 | 302 | 221[f] | | 400 | 186 | 455 | |
| Avulsion of a placentome | | | | | | | | | | | | | | | |
| | Yes | 26 | 2.2 | 24 | 2 | 1.00 | NS | 5 | 7 | 14 | <0.001 | 15 | 6 | 5 | 0.045 |
| | No | 1156 | 97.8 | 1067 | 89 | | | 539 | 338 | 252[f] | | 443 | 213 | 500 | |
| Ruptured uterine wall | | | | | | | | | | | | | | | |
| | Yes | 74 | 6.3 | | | NA | | 17 | 21 | 34[f] | <0.001 | 31 | 18 | 25 | NS |
| | No | 1108 | 93.7 | | | | | 527 | 324 | 232[f] | | 427 | 201 | 480 | |
| Haemorrhage in uterine wall | | | | | | | | | | | | | | | |
| | Yes | 61 | 5.2 | | | NA | | 18 | 12 | 28[f] | <0.001 | 32 | 13 | 16 | 0.024 |
| | No | 1121 | 94.8 | | | | | 526 | 333 | 238[f] | | 426 | 206 | 489 | |
| Number of sutures in uterus | | | | | | | | | | | | | | | |
| | One | 999 | 84.5 | | | NA | | 486 | 292 | 197[f] | <0.001 | 363 | 187 | 449 | <0.001 |
| | Two | 183 | 15.5 | | | | | 58 | 53 | 69[f] | | 95 | 32 | 56 | |

a Missing values not included; b Odds Ratio (DM-Belgian Blue versus non-Belgian Blue cows); c Confidence Interval; d Not Significant; e Not Analyzed; f Data do not add up to total as some questionnaires were incomplete

**Table 6** Final multilevel logistic regression models describing the significant risk factors associated with the occurrence of mild (350/877 [816 cows]) and severe (398/926 [866 cows]) difficulties during Caesarean Section performed between January 2005 and June 2006

| **Difficulty** | Breed | β | SE[b] | OR[c] | 95 % CI[d] | *P* |
|---|---|---|---|---|---|---|
| Mild | Non-BB[a] | | | | | NS[f] |
| | DM-BB | | | | | |
| Severe | Non-BB[a] | | | | | < 0.010 |
| | DM-BB | -0.76 | 0.28 | 0.47 | 0.27-0.81 | |
| | Number of Caesarean Section | β | SE | OR | 95 % CI | *P* |
| Mild | 1[a] | | | | | < 0.001 |
| | 2 | 0.64 | 0.17 | 1.89 | 1.36-2.61 | |
| | ≥ 3 | 1.29 | 0.19 | 3.62 | 2.48-5.28 | |
| Severe | 1[a] | | | | | < 0.001 |
| | 2 | 0.86 | 0.17 | 2.36 | 1.70-3.28 | |
| | ≥ 3 | 1.80 | 0.20 | 6.04 | 4.12-8.86 | |
| | Experience of veterinarian | β | SE | OR | 95 % CI | *P* |
| Mild | Low[a,e] | | | | | NS[f] |
| | Medium | | | | | |
| | High | | | | | |
| Severe | Low[a,e] | | | | | < 0.010[g] |
| | Medium | 0.15 | 0.20 | 1.16 | 0.79-1.72 | |
| | High | -0.45 | 0.16 | 0.36 | 0.46-0.87 | |

a Reference category; b Standard Error; c Odds Ratio (= $exp^{\beta}$); d Confidence Interval; e Low: ≤ 2 years, medium: > 2 to < 5 years, high: ≥5 years of experience; f Not Significant, also not in the univariable analyses; g Significance for low experience compared to high experience not for low experience compared to medium experience

# Discussion

This paper is to our knowledge the first one studying a large number of difficulties during rather than after the CS. A number of significant univariable associations (not corrected for potential risk factors or confounders) between breed, number of CS and degree of veterinary experience with different preoperative and operative findings and difficulties were identified. Multivariable models showed that DM-BB cows had significantly fewer severe difficulties during CS in comparison with non-BB cows, whereas this breed effect could not be demonstrated for mild problems.

In Belgium, thorough selection towards muscular hypertrophy in the DM-BB breed resulted in cows being unable to calve *per vaginam* and CSs are performed routinely. As a result, CSs are performed by highly experienced veterinarians who typically carry out between 500 and 1000 CSs each year. Additionally, DM-BB owners are well skilled in detecting parturition at an early stage.

As the promodori in this breed are not explicit, the temperature method is commonly used and the animals are closely observed every two hours, even at night. The early detection of parturition is confirmed in the present study by the fact that less animals of the DM-BB breed were recumbent at the time the veterinarian arrived at the farm suggesting that the majority of the DM-BB animals were in labour for a shorter period of time before the start of the operation. Also, in BB cows the amniotic sac was intact more often and foetal parts were not present in the birth canal upon vaginal examination. Epidural anaesthesia was used less frequently in DM-BB animals, probably because of the absence of severe straining due to the relatively early stage of parturition in which the surgery was done in these animals. Because some veterinarians tended to administered epidural anaesthesia routinely, the difference between DM-BB and non-BB cows would have been larger if an epidural anaesthesia was only administered to straining animals.

Breed was chosen as a risk factor to see whether it was associated with the occurrence of difficulties during CS, although we did not expect breed differences. Rather breed reflected an elective (DM-BB) versus non-elective (non-BB) CS. On the other hand, through the fact a lot of farmers own one or more DM-BB animals or are familiar with the breed, they are used to call for assistance at parturition in an early stage and ask for a CS even in the non BB herds. Then again, some farmers and veterinarians will wait a little longer to see whether a normal calving is possible.

In this study nearly one out of three CSs was accompanied by a severe difficulty reported by the veterinarian. Still, only three out of the 1275 CSs (0.2%) had a fatal outcome. The average death rate within a week after CS in dairy cows, typically operated at a very late stage, is reported to vary between 1.5% (Barkema et al., 1992) and 14% (Boucard et al., 1994), which is much higher than in this study including a majority of DM-BB. Other studies performed in non-BB animals also showed lower cow survival in dairy cattle (Sloss and Dufty, 1977; Roberts, 1986; Vandeplassche, 1988; Arthur et al., 1989; Cattell and Dobson, 1990). DM-BB cows typically are protected from suffering from a severe difficulty during surgery because surgery in these cows is performed at an early stage and due to the fact that farmers breeding the DM-BB breed are highly trained in detecting early parturition. As a result of the latter, the animal is not straining yet, the incision of the abdominal wall is easier, the exteriorization will be less complicated, and there is lesser risk of incision in the wrong place of the uterus. Nevertheless, we are fully aware that the postoperative outcome in our study is limited for comparison with other study as the emphasis of this study was on difficulties before and during the CS.

In DM-BB cows with an increasing number of previous CSs, an attempt to extract the calf was performed less often. Because of the high economic value of the double-muscled calves and the relatively low charge for a CS, Belgian farmers are not willing to take risks and usually expect their veterinarian to perform a CS in case of any doubt to deliver a live calf. For that same reason, veterinarians will hardly ever carry out an trail extraction when facing a calving DM-BB cow which had previously undergone a CS. Omitting an trail extraction has in this typical situation several advantages such as diminished to no straining during surgery, a lower probability of recumbency during the operation, and a reduced contamination risk of the uterus. The latter is important to avoid complications after surgery such as peritonitis or wound infection (Mijten et al., 1996).

In animals which had previously calved by CS, more difficulties were encountered during the operation. DM-BB cows were more likely to have skin scar tissue than non BB cows. The occurrence of excessive skin scar tissue and abdominal wall muscular bleeding also increased as result of the increase in the number of CSs. As DM-BB cows generally have 2-3 CS in a life time, one would expect more difficulties in that breed. Still, lower prevalence of severe problems was seen in the DM-BB breed compared to non-BB animals when adjusting for the number of CSs. The combination of operating at an early stage during parturition and the operation being performed by very experienced veterinarians is probably the reason for the excellent results in favour of the BB breed. The surgeon’s technical skills are mentioned to be among the best preventive factors against difficulties such as problems with exteriorization of the uterus (Mijten et al., 1997).

One of the most common intra-operative complications is difficulties with exteriorization of the uterus. Of the three risk factors analysed, only the number of CSs had an association with exteriorization difficulties. In the study of Hoeben et al. (1997) in BB animals, the surgeon had trouble with the exteriorization in 26.4% of all CSs and in 5.8% of the cases it was completely impossible to exteriorize the uterus. Increased parity, increased uterine contractions, posterior presentations and adhesions between the uterus and the abdominal wall were progressively more significantly associated with the degree of difficulty to exteriorize the uterus.

We realise that a difference in perception of difficulties between inexperienced and highly experienced veterinarian may have influenced our results. More experienced veterinarians (≥ 5 years) might have underreported difficulties whereas the opposite could be true for less experienced (≤ 2 years) surgeons. However, there was also variation within the experience categories of the veterinarian. But, in general it is accepted that the experienced veterinarian encounter fewer difficulties during surgical interventions. Besides that, we believe that the questionnaire minimized the risk of bias as it consisted only of closed-ended questions (yes/no or categories).

## CONCLUSIONS

During a CS in the bovine, mild and/or severe operative difficulties can be expected. As nearly all DM-BB calves are delivered by CS, farmers and veterinarians should be aware of factors that influence the risk of encountering difficulties, such as multiple CS, as this will help them to minimize the occurrence of problematic situations. Performing a CS at an early stage during parturition is a standard procedure in DM-BB cows which significantly reduces the odds of encountering problems before and during surgery. Having had a prior CS is associated with an increased risk for mild and severe difficulties. Highly experienced vets are less frequently confronted with severe difficulties although they may also underreport difficulties in comparison with less experienced colleagues. Future studies should investigate postoperative complications in relation to the difficulties encountered during surgery.

## Acknowledgements

The authors thank all the veterinarians, students and farmers for their willingness to cooperate. Special thanks goes to S. Ribbens (UGent) and S. McKenna (UPEI) for critically reading this paper.

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# ASSESSMENT OF DIFFERENCES IN SOME INDICATORS OF PAIN IN DOUBLE MUSCLED BELGIAN BLUE COWS FOLLOWING CALVING *PER VAGINAM* VERSUS CAESAREAN SECTION (CHAPTER 4.2)

Modified from:

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2008

Assessment of differences in some indicators of pain in double muscled Belgian Blue cows following naturally calving versus Caesarean Section.

Reproduction of Domestic Animals (online).

# Abstract

The present paper describes a study of the behaviour of double muscled Belgian Blue cows (DM-BB) during the *peripartum* period in order to assess the differences in pain perception in cows calving *per vaginam* versus cows delivering by Caesarean Section (CS). In one herd a total of 30 multiparous cows, of which 17 delivered by CS and 13 calved *per vaginam*, were closely observed at approximately 1 month before calving and at days 1, 3 and 14 after parturition. The main behavioural indicators of pain were alertness, transition in posture from standing to lying and vice versa, aggressive behaviour, vocalization, rumination quality, reaction on wound and vulva pressure, and the percentage of visible eye-white.

The main significant differences were lower overall activity and more transition in posture in animals that delivered by CS than in cows that calved naturally. Less time was spent on eating and ruminating in the CS group, their total resting time was longer and their total standing time was shorter. These significant differences were only observed on the first day after calving. Cows of the CS group reacted significantly more when pressure was put on the left flank on the first, third and fourteenth day after calving, whereas animals that calved *per vaginam* showed more reaction when pressure was put on the area around the vulva, but only on the first day.

Based on the results of the present study, we can conclude that there are some significant short-term behavioural differences between DM-BB cows that calve *per vaginam* and those that deliver by CS, but in general, the differences are subtle and of short duration.

# Introduction

The double muscled Belgian Blue (DM-BB) cattle breed is valued for its extreme muscularity and superior carcass and meat quality. Unfortunately it is also criticized for its calving difficulties (Lips et al., 2001). In Belgium, where the cost of a Caesarean Section

(CS) is very low and the price of the calf relatively high, where veterinary practitioners can easily be reached and are very experienced in performing CS, 95 to 99.9 % of the DM-BB cows are delivered by CS (Hanset, 2002). In many cases practising veterinarians carry out a very basic gynaecological examination when they are confronted with a DM-BB cow in labour and start to perform a CS immediately. Therefore, the CS in double muscled cows is often referred to as an elective CS. This is currently experienced as an example of animal instrumentalisation which in some countries causes an aversion towards this breed. This complaint is based on the general belief that delivery per CS causes more pain and discomfort than delivery *per vaginam*. Two questions arise: does a correctly performed CS under local anaesthesia cause significantly more pain and distress than natural delivery and which proportion of cows experiences chronic pain as a consequence of post-operative complications (Webster, 2002)? Although veterinarians in Belgium are very well experienced in performing a CS, it remains a major abdominal operation performed in a contaminated environment and hence, it cannot be considered to be a sterile surgical procedure. As the success rate of CS and thus its impact on animal welfare mainly depends on the operation technique, it is imperative to perform the surgical procedure according to recognised best practice (Mijten, 1994).

An objective assessment of pain and discomfort in animals is known to be very difficult. Pain, stress and distress produce similar behavioural, biochemical and physiological adaptations, finally leading to the well known 'fight or flight' reaction which is based on a stimulation of the hypothalamic-pituitary-adrenal (HPA) axis. Practical experience has shown that pain in cattle is usually linked to typical clinical signs and behavioural changes such as a significant decrease in food intake and grooming. Ruminants in significant pain often appear dull and depressed, hold their heads low, and show little interest in their surroundings (Phillips, 2002). Common alterations in physiology that indicate pain can be monitored, such as heart rate (Lay et al., 1992), respiratory rate, body temperature (Mellor and Stafford, 1999), increase in blood pressure (Jourdan et al., 2001) and changes in digestive system (bodyweight loss, variation in faeces volume) or locomotory system (tremors, hyperaesthesia; Morton and Griffiths, 1985). In response to a stimulus, animals can show modifications in attitude (immobility) or in motor activity (jumping, withdrawal of a limb; Jourdan et al., 2001). Severe pain often results in a rapid, shallow respiration and grunting or grinding of teeth might be heard (Flecknell and Waterman-Pearson, 2000). Therefore, pain can be assessed by observing these physiological responses while monitoring the animals' behaviour (Molony et al., 1995; Molony and Kent, 1997; Grandin, 1998, 2001; Sandem et al., 2002, 2005). Molony et al. (1995) used restlessness, foot stamping/kicking, tail wagging, easing quarters and head turning to assess acute pain after different methods of castration of calves. Postural changes or changes in locomotor activity like rolling, jumping, easing quarters, licking and biting at the side of damage were assessed by Molony and Kent (1997) in their study of the responses of lambs and calves to castration and of lambs to tail docking.

In general, studies on behavioural responses to pain have their limits, as behavioural responses to pain are difficult to measure and show marked differences between different species. These differences reflect the unique behavioural repertoire of the species (Sanford et al., 1986). Nevertheless, responses of related species to similar stimuli can also differ. For instance, lambs and calves castrated with rubber rings exhibit different behaviours (Mellor et al., 1991; Mellor and Stafford, 1999) and, experts found CS to be more painful in cows than in ewes (Fitzpatrick et al., 2002). An animal's age and its experience may also influence behavioural responses to particular procedures. Hormone-related differences have been well documented, as have the effects of late pregnancy and parturition. During oestrus, late pregnancy and immediately after parturition, the nociceptive threshold shows an apparent increase (Cook, 1997, 1998). On the other hand, assessing behavioural responses is non invasive and thus not harmful for the animals in contrast to invasive methods such as measuring plasma cortical levels. Furthermore, the blood sampling itself causes stress which may significantly affect the results (Queyras and Carosi, 2004).

To assess pain and discomfort in cattle following surgery, the most indicative signs to monitor were stated to be anorexia, vocalisation and grinding of the teeth (Watts, 2001). The heart rate, respiratory rate, blood cortical levels and (withdrawal) reaction following palpation of the wound are also known to be reliable indicators of postoperative pain in recently operated cattle (Watts, 2001).

The aim of the present study was to examine differences in pain and discomfort in DM-BB cows after giving birth *per vaginam* versus CS.

# MATERIAL AND METHODS

## Animals and management

The study was conducted from December 2005 until March 2006 on a BB herd with an uncommonly large fraction of cows giving birth *per vaginam*. Thirty multiparous cows were included in the study, 13 of which calved *per vaginam* while the other 17 were delivered by CS. All animals included in the study were characterized by an extreme muscularity (double muscled, S carcass animals; SEUROP carcass classification system of the European Community [2003-10-03/37]) and were kept in tie-stalls, tethered by neck chains. Calves were housed in small boxes in the tie-stall behind the cows. One compartment of the tie-stall contained four calves and four cows, allowing the calves to suckle all four cows. All animals were well acclimatized to the shed before observation took place. The feeding regimen, consisting of corn silage and concentrates in the morning and hay in the evening, was identical for all participating cows. However, cows that were delivered by CS were not fed during the first 24 hours following surgery to prevent coalescence of the rumen and peritoneum.

At the moment of parturition, the veterinarian decided in accord with the farmer whether a CS was necessary. Before each delivery the cow was laid down and a trial extraction was performed to check the possibility of natural calving using the force of one man. The trial extraction was positive if the metacarpal joints could be pulled out for at least one hand's breadth and when the nose of the calf was clearly visible. In case of a positive trial extraction, the calf was pulled out by the farmer, by the farmer and the vet or with the help of a calf aid at the cow's place in the tie-stall. Caesarean Sections were performed in a specifically designed CS box by two different veterinarians according to the surgical technique described by Kolkman et al. (2007). The procedure was performed under local anesthesia on the left flank of a standing cow. No post-operative pain relief was administered. The calf was immediately brought to a clean box behind the mother in the tie-stall. First, the farmer helped the calf to suckle its own mother while after that all four calves were allowed to suckle the four cows in the compartment ad libitum.

Complications after both delivery types (e.g. tearing after extraction, retained placenta, and wound infection) were treated according to recognised best practices by the veterinarians.

## Observations

One month before the expected day of calving (D-30), and on the first (D1), third (D3) and 14$^{th}$ (D14) day after calving, the animals were closely observed. Observations were conducted three times a day: one hour after each meal (i.e. 9 AM and 8 PM) and at 2 PM, each session lasting 45 minutes. The time point of first observation depended on the moment of calving: when parturition occurred during the late evening or night, the observation started the next morning at 9 AM; when the calving took place during the morning, the observation started at 2 PM and when the partus occurred during the afternoon, the observation started at 8 PM.

To give the animals the opportunity to acclimatize to the presence of the observer, observations started half an hour after the observer assumed his position in the shed. Observations were carried out by five different observers using the Observer® 5.0 software package (Noldus Ltd, 2003, The Netherlands). The five observers were trained intensively on how to use this software package, and to make them familiar with the definitions used (Table 1) and the procedures applied (e.g. pressure testing at the CS wound and the vulva), in order to guarantee standardization of the results. The inter-observer reliability was checked through a t-test and the observers were balanced equally between the cows that were delivered *per vaginam* and by CS.

**Table 1** Descriptions of behaviour recorded during the experiment

| **Behaviour** | **Description** |
|---|---|
| Independent variables | |
| number of animals | ear number of the animal |
| observer | the person who observed |
| presence of food | concentrate (C): full (F), half full (HF) or nothing (N); hay (H): full, half full or nothing |
| day | *prepartum* day (D-30), day 1 (D1), 3 (D3) or 14 (D14) *post partum* |
| number of calving/Cs | the number of CS or natural calvings the cow already experienced before |
| moment of observation (MO) | morning (M), afternoon (A), evening (E) |
| the present calving | Caesarean Section (CS), naturally calving (N) or not relevant (NR; *pre partum period)* |
| reaction on pressure | reaction after firm pressure on the left flank, the right flank (control) or the vulva (performed after the observation) |
| General activity | |
| overall activity | index of general activities |
| limb movement | movements of front or hind limbs |
| ear flicking | vigorous movement of one or both ears: independent of shaking of the head |
| nose licking | cleaning of the muzzle |
| licking itself | licking its own body except the wound |
| look at/sniff at neighbour | looking or sniffing at its neighbour |
| Pain indicators | |
| alertness | |
| reactivity on noise | the observer makes a loud noise ie. played a mobile telephone tune before the observation starts and scores the reaction of the cow |
| mean alertness | overall score of the mean impression of alertness |
| transition in posture | number of times a cow stood up and laid down; each unit scored included both the act of rising and lying down |
| aggressive behaviour | number of times a cow behaved aggressively against her environment, calf or neighbour |
| vocalisation | vocalisation occurrence of each vocal sound was recorded, this includes sound made towards her calf, loud and soft |
| lip curl | curling of the upper or both lips, including flehmen; flehmen is defined as curling of the upper lip combined with head elevation |
| rumination quality | the mean number of chewing per bolus |
| flank pressure | giving pressure on the left flank (operation side) and on the right flank (control); difference is made between no reaction (0) and reaction after firm pressure (1) |
| vulva pressure | giving firm pressure on the vulva on both sides; difference is made between no reaction and reaction after firm pressure |
| eye white | assessed by evaluation of the overall eye white during the 45 minutes; no eye white, eye white seen once or twice; eye white seen more than twice |
| Activity budget | |
| eating | total time spent eating |
| rumination | total time spent ruminating |
| lying (left or right) | total time spent in ventral recumbency with legs tucked in and the head up or down, either to one side or directly in front |
| standing | total time spent standing |
| leaning | time spent resting with the nose on the border of the groove of the chain that is used |

The inclusion of two different veterinarians that performed the CS and five different observers may have had an influence on the outcome of the results. To minimize the bias caused by the veterinarians, they were carefully instructed to use the same criteria when performing the trial extraction and to carry out the CS (Kolkman et al., 2007). It was an ergonomic choice to incorporate five observers instead of one but variations between their observations were reduced by carefully training them before the experiment started. Bias caused by including several veterinarians and observers was furthermore limited since both 'veterinarian' and 'observer' were included as a fixed factor in the statistical model.

## Statistical analysis

All statistical analyses were performed by using R software (version 2.6) for the explorative analysis and the SAS procedures MIXED, GMIMMIX or NLMIXED (version 9) for the mixed models. For the statistical assessments, all behavioural indicators were summed per day to compensate for the circadian pattern. The CS and *per vaginam* animals were both clustered to minimize the effect of individual variations between animals. According to Molony and Kent (1997) clustering behavioural scores has statistical advantages over using individual behaviours. On the other hand, there is always a danger of exaggerating effects if the incidences of dependent behaviours are summed (Molony et al., 1995). Therefore, "general activity" should not be used as the sole pain or welfare indicator.

Explorative statistical analyses were performed by a non-parametric Wilcoxon-test and a Fisher exact test on all four observational days to compare animals that calved by CS with animals that calved by vaginal delivery. In order to take the clustered nature of the data (4 times measurements per animal) in account, statistical analysis was carried out based on using a mixed model including a random effect for animal. The fixed effects of these models are treatment and the day of observations. The response is one of variables which describe the activity of the animal (reaction on noise, eye white, wound and vulva pressure). Both the veterinarian and the observer were taken into account in the mixed model. The animals were divided into two treatment groups: delivery by CS versus calving *per vaginam*. By using this model, it was possible to compare the time evolution between the two treatment groups as well as to look within each group for significant differences in the activity of the cows between the *post partum* observation days (D1, D3, D14) and the *pre partum* observation day (D-30).

# Results

## General results

Almost 60% of the CS animals were of second parity (58.8%) while of the natural calvers group the majority had calved five times or more (61.5%; Data not shown). No wound infections were noticed after CS. Three cows retained the placenta (2 after CS and one after natural calving) while one animal suffered from a vaginal laceration after extraction.

A total of 30 calves was born of whom 6 died within the first days after parturition. These deaths were not linked to the parturition but due to a diarrhoea epidemic. In Table 2 the gender of the calves are summarized per type of calving.

**Table 2** Gender of the calves born by CS or *per vaginam*

| | | Amount | |
|---|---|---|---|
| | | Alive | Dead[a] |
| *Caesarean Section* | Male | 6 | 2 |
| | Female | 8 | 1 |
| *Calving per vaginam* | Male | 6 | 1 |
| | Female | 4 | 2 |

a Deaths within 48 hours, these deaths were not linked to parturition but due to a diarrhoea epidemic

## **Comparison between the *per vaginam* and the CS group**

Before calving (D-30), there was no significant difference in general activity, the activity budget, and in the relief of pain measured by using pain indicators between the naturally calving animals and the ones that were delivered by CS. The overall results of the time evolution only show significant differences in reaction on wound pressure for the CS group ($P < 0.01$) and pressure on the vulva for the naturally calving group ($P < 0.01$). Animals that were delivered by CS had significantly more reaction during the whole observation period when pressure was put on their left flank compared to animals that delivered *per vaginam*, whereas the latter animals showed more reaction when the area around the vulva was touched.

### Day one post partum

After a CS, animals had significantly ($P < 0.05$) less limb movements, and had more transitions in posture ($P < 0.001$) in comparison to cows that calved *per vaginam* (Table 3). In the CS group, the rumination quality was lower and less time was spent eating ($P < 0.001$; Table 3). Results also demonstrated a difference in total resting and standing time ($P < 0.001$), the resting time being longer and the standing time shorter within the CS group. When lying down, CS animals laid more on their right site ($P < 0.001$; Table 3). Finally, cows of the CS group reacted significantly more when pressure was put on their left flank, whereas animals that calved naturally showed more reaction when the area around the vulva was touched ($P < 0.05$; Table 3).

### Day three post partum

There was only a significant difference in the time spent eating ($P < 0.05$) and the reaction of the animal to wound pressure ($P < 0.05$). Animals delivered by CS spent more time eating ($P < 0.05$) and reacted more upon pressure on the left flank (Table 4).

### Day fourteen post partum

Animals in the CS group did not only show a more sensitive reaction after pressure on the left flank, they also showed more interest in their neighbour by sniffing ($P < 0.05$). Vocalisation, both loud and soft, occurred more frequently in the naturally calving group ($P < 0.05$; Table 5).

## Calving *per vaginam* group

### General activity

No significant differences in general activity were seen on D1, D3 and D14 compared to observations made before parturition (D-30; Table 6).

### Pain indicators

On D1 and D3 after calving less reaction to noise was noticed in comparison with D-30 ($P < 0.05$). The number of times an animal stood up and laid down, was higher on D3 ($P < 0.05$) and D14 ($P < 0.001$) after parturition than before calving (Table 6). On D1 and D3, the cows behaved less aggressively compared to D-30 ($P < 0.05$). Vocalisations had significantly increased on D1 and D14, compared to D-30 ($P < 0.05$; Table 6).

### Activity budget

The time spent ruminating, was shorter on D14 than before calving ($P < 0.05$; Table 6).

**Table 3** Comparison of general activity, pain indicators and activity budget between the *per vaginam* and CS group on the first day after calving (D1; 3 x 45 min observation)

| Observations | CS<br>N = 17 | *Per vaginam*<br>N = 13 | Probability<br>(Mixed Model or $\chi^2$) |
|---|---|---|---|
| **General activity (#)** | | | |
| overall activity | 251 ± 134 | 388 ± 214 | NS[a] |
| limb movements | 214 ± 126 | 349 ± 192 | **0.042*** |
| ear flicking | 2.9 ± 4.0 | 1.7 ± 2.2 | NS |
| nose licking | 9.4 ± 6.5 | 13.2 ± 16.5 | NS |
| licking itself | 4.5 ± 5.0 | 5.3 ± 4.9 | NS |
| look at/sniff at neighbour | 20.5 ± 15.4 | 18.2 ± 16.0 | NS |
| **Pain indicators (#)** | | | |
| transition in posture | 5.5 ± 2.0 | 3.7 ± 0.9 | < **0.001**** |
| aggressive behaviour | 0.7 ± 1.7 | 0.9 ± 2.6 | NS |
| vocalisation (loud and soft) | 24.6 ± 31.3 | 49.2 ± 91.0 | NS |
| vocalisation loud | 3.2 ± 5.1 | 3.2 ± 5.1 | NS |
| vocalisation soft | 20.3 ± 28.6 | 15.7 ± 16.2 | NS |
| lip curl | 0.59 ± 1.50 | 0.38 ± 0.65 | NS |
| rumination quality | 47 ± 18 | 66 ± 13 | < **0.001**** |
| reaction to noise | | | |
| - reaction | 29% | 31% | NS |
| - no reaction | 71% | 69% | |
| wound pressure left | | | |
| - reaction | 94% | 31% | **0.016*** |
| - no reaction | 6% | 69% | |
| wound pressure right | | | |
| - reaction | 6% | 15% | NS |
| - no reaction | 94% | 85% | |
| vulva pressure | | | |
| - reaction | 12% | 62% | **0.014*** |
| - no reaction | 88% | 38% | |
| eye white | | | |
| - no eye white | 12% | 8% | NS |
| - eye white seen once or twice | 41% | 31% | |
| - eye white seen more than twice | 47% | 62% | |
| **Activity budget (in sec)** | | | |
| eating | 595 ± 602 | 1998 ± 775 | < **0.001**** |
| rumination | 1680 ± 1264 | 2471 ± 1578 | NS |
| lying (left or right) | 4802 ± 1948 | 2372 ± 2472 | < **0.001**** |
| lying left | 1421 ± 1755 | 1174 ± 1993 | NS |
| lying right | 3382 ± 2209 | 1198 ± 1994 | < **0.001**** |
| standing | 3292 ± 1945 | 5728 ± 2472 | < **0.001**** |
| leaning | 107 ± 277 | 78 ± 154 | NS |

$x \pm s$ represents the mean ± 1 StD; * $P < 0.05$; ** $P < 0.001$; a Not Significant

**Table 4** Comparison of general activity, pain indicators and activity budget between the *per vaginam* and CS group on the third day after calving (D3; 3 x 45 min observation)

| Observations | CS<br>N = 17 | *Per vaginam*<br>N = 13 | Probability<br>(Mixed Model or $\chi^2$) |
|---|---|---|---|
| **General activity (#)** | | | |
| overall activity | 294 ± 94 | 377 ± 155 | NS[a] |
| limb movements | 231 ± 78 | 326 ± 142 | NS |
| ear flicking | 6.8 ± 18.4 | 5.8 ± 9.2 | NS |
| nose licking | 11.2 ± 6.6 | 12.0 ± 9.5 | NS |
| licking itself | 9.7 ± 5.4 | 7.3 ± 8.9 | NS |
| look at/sniff at neighbour | 35.8 ± 25.2 | 25.8 ± 28.8 | NS |
| **Pain indicators (#)** | | | |
| transition in posture | 4.8 ± 1.6 | 4.4 ± 0.9 | NS |
| aggressive behaviour | 0.4 ± 1.3 | 1.1 ± 2.2 | NS |
| vocalisation (loud and soft) | 31.0 ± 26.0 | 25.0 ± 25.0 | NS |
| vocalisation loud | 5.9 ± 10.6 | 3.5 ± 5.9 | NS |
| vocalisation soft | 11.1 ± 14.9 | 14.9 ± 18.9 | NS |
| lip curl | 1.41 ± 3.710 | 0.23 ± 0.44 | NS |
| rumination quality | 64.9 ± 8.9 | 67.5 ± 9.4 | NS |
| reactivity on noise | | | |
| - cow reacts | 24% | 23% | NS |
| - cow does not react | 76% | 77% | |
| wound pressure left | | | |
| - cow reacts | 82% | 31% | **0.029*** |
| - cow does not react | 18% | 69% | |
| wound pressure right | | | |
| - cow reacts | 18% | 31% | NS |
| - cow does not react | 82% | 69% | |
| vulva pressure | | | |
| - cow reacts | 6% | 31% | NS |
| - cow does not react | 94% | 69% | |
| eye white | | | |
| - no eye white | 24% | 23% | NS |
| - eye white seen once or twice | 41% | 23% | |
| - eye white seen more than twice | 35% | 54% | |
| **Activity budget (in sec)** | | | |
| eating | 103 ± 960 | 1171 ± 719 | **0.012*** |
| rumination | 3531 ± 1303 | 3438 ± 1465 | NS |
| lying (left or right) | 2865 ± 1792 | 2336 ± 2266 | NS |
| lying left | 1148 ± 1552 | 1025 ± 1734 | NS |
| lying right | 1718 ± 1658 | 1311 ± 1935 | NS |
| standing | 5235 ± 1791 | 5764 ± 2266 | NS |
| leaning | 21.8 ± 78.2 | 190.7 ± 418.5 | NS |

$x \pm s$ represents the mean ± 1 StD; * $P < 0.05$; a Not Significant

**Table 5** Comparison of general activity, pain indicators and activity budget between the *per vaginam* and CS group on the fourteenth day after calving (D14; 3 x 45 min observation)

| Observations | CS<br>N = 17 | *Per vaginam*<br>N = 13 | Probability<br>(Mixed Model or $\chi^2$) |
|---|---|---|---|
| **General activity (#)** | | | |
| overall activity | 305 ± 181 | 372 ± 113 | NS[a] |
| limb movements | 242 ± 159 | 332 ± 116 | NS |
| ear flicking | 1.2 ± 1.5 | 0.6 ± 0.8 | NS |
| nose licking | 10.3 ± 5.9 | 15.3 ± 11.5 | NS |
| licking itself | 9.3 ± 8.2 | 6.5 ± 5.5 | NS |
| look at/sniff at neighbour | 41.6 ± 33.6 | 17.7 ± 33.1 | **0.029*** |
| **Pain indicators (#)** | | | |
| transition in posture | 4.5 ± 1.1 | 5.2 ± 1.9 | NS |
| aggressive behaviour | 1.4 ± 2.8 | 1.8 ± 2.2 | NS |
| vocalisation (loud and soft) | 16.8 ± 24.6 | 80.9 ± 199.6 | **0.024*** |
| vocalisation loud | 0.9 ± 1.9 | 12.60 ± 34.65 | **0.037*** |
| vocalisation soft | 11.4 ± 19.8 | 45.3 ± 102.2 | **0.020*** |
| lip curl | 0.38 ± 0.65 | 0.70 ± 1.06 | NS |
| rumination quality | 58 ± 13 | 65 ± 11 | NS |
| reactivity on noise | | | |
| - cow reacts | 31% | 40% | NS |
| - cow does not react | 69% | 60% | |
| wound pressure left | | | |
| - cow reacts | 85% | 30% | **0.033*** |
| - cow does not react | 15% | 70% | |
| wound pressure right | | | |
| - cow reacts | 23% | 30% | NS |
| - cow does not react | 77% | 70% | |
| vulva pressure | | | |
| - cow reacts | 15% | 30% | NS |
| - cow does not react | 85% | 70% | |
| eye white | | | |
| - no eye white | 23% | 40% | NS |
| - eye white seen once or twice | 31% | 20% | |
| - eye white seen more than twice | 46% | 40% | |
| **Activity budget (in sec)** | | | |
| eating | 2356 ± 1313 | 1923 ± 1114 | NS |
| rumination | 2339 ± 1501 | 1927 ± 992 | NS |
| lying (left or right) | 2743 ± 1473 | 2412 ± 1570 | NS |
| lying left | 519 ± 874 | 1267 ± 1461 | NS |
| lying right | 2224 ± 1437 | 1145 ± 1183 | NS |
| standing | 5357 ± 1473 | 5688 ± 1570 | NS |
| leaning | 16.7 ± 60.4 | 182.5 ± 251.7 | NS |

$x \pm s$ represents the mean ± 1 StD, * $P < 0.05$; a Not Significant

## Caesarean Section group

### General activity

Results from the mixed models show a significant difference in overall activity on D1 ($P < 0.01$) and D3 ($P < 0.05$) in contrast with observations one month before calving (Table 6). As for the general activity, first of all the limb activity was lower on all three days *post partum* compared to D-30 ($P < 0.05$). Secondly, the animal was licking itself (including its nose) less often on D1 and flapping its ears more often on D3 in comparison to D-30 ($P < 0.05$; Table 6).

### Pain indicators

Table 6 reveals more transitions in posture on D1 than on D-30 ($P < 0.001$). The rumination quality had significantly decreased on D1 and D14 compared to D-30 ($P < 0.001$). Observations on D1 ($P < 0.01$), D3 ($P < 0.001$) and D14 ($P < 0.05$) mention less reaction to noise than on D-30 (Table 6).

### Activity budget

The activity pattern of the animals shows some significant differences of the resting, ruminating, standing and eating time on D1 (Table 6a,b). Animals that calved via CS lay down more and spent less time standing on D1 in contrast with observations on D-30 ($P < 0.001$). When lying down, the right side was used more ($P < 0.001$). Time spent ruminating was less on D1 in comparison with D-30 ($P < 0.01$; Table 6).

**Table 6a** Comparison of general activity, pain indicators and activity budget before (D-30) and after (D1, D3, D14) parturition within the *per vaginam* group (3 x 45 min observation)

| Observations | D-30-D1 | | D-30-D3 | | D-30-D14 | |
|---|---|---|---|---|---|---|
| ***Per vaginam group*** | change | *P* value | change | *P* value | change | *P* value |
| **General activity (#)** | | | | | | |
| overall activity (instances) | -41.0 | NS[a] | -51.0 | NS | -61.0 | NS |
| limb movements | -24.0 | NS | -47.0 | NS | -49.0 | NS |
| ear flicking | 1.2 | NS | 5.3 | NS | 0.7 | NS |
| nose licking | -4.3 | NS | -5.5 | NS | -2.0 | NS |
| licking itself | -1.0 | NS | 1.0 | NS | 1.0 | NS |
| look at/sniff at neighbour | -12.4 | NS | -4.8 | NS | -12.8 | NS |
| **Pain indicators (#)** | | | | | | |
| reaction to noise | -2.1 | **0.033**** | -2.5 | **0.016*** | -1.6 | NS |
| transition in posture | 0.6 | NS | 1.3 | **0.027*** | 2.1 | **< 0.001***** |
| aggressive behaviour | -2.1 | **0.018*** | -1.9 | **0.027*** | -1.2 | NS |
| vocalisation (loud and soft) | 49.0 | NS | 24.0 | NS | 83.0 | **0.004**** |
| vocalisation loud | 12.0 | **0.024*** | 4.0 | NS | 14.0 | **0.019*** |
| vocalisation soft | 15.0 | NS | 14.0 | NS | 45.0 | **0.002**** |
| lip curl | 0.4 | NS | 0.2 | NS | 0.7 | NS |
| rumination quality | -2.5 | NS | -1.3 | NS | -5.5 | NS |
| eye white | -0.3 | NS | 0.4 | NS | 1.1 | NS |
| **Activity budget (in sec)** | | | | | | |
| eating | 433 | NS | -395 | NS | 317 | NS |
| rumination | -772 | NS | 195 | NS | -1347 | **0.012*** |
| lying (left or right) | -743 | NS | -780 | NS | -721 | NS |
| lying left | -65 | NS | -214 | NS | 82 | NS |
| lying right | -679 | NS | -566 | NS | -754 | NS |
| standing | 743 | NS | 780 | NS | 721 | NS |

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; a Not Significant

**Table 6b** Comparison of general activity, pain indicators and activity budget before (D-30) and after (D1, D3, D14) parturition within the CS group (3 x 45 min observation)

| Observations | D-30-D1 | | D-30-D3 | | D-30-D14 | |
|---|---|---|---|---|---|---|
| **Caesarean group** | change | *P* value | change | *P* value | change | *P* value |
| **General activity (#)** | | | | | | |
| overall activity | -187.0 | **0.004**** | -144.0 | **0.024*** | -129.0 | NS |
| limb movements | -168.0 | **0.005**** | -151.0 | **0.011*** | -134.0 | **0.035*** |
| ear flicking | 1.5 | NS[a] | 5.4 | **0.032*** | 0.6 | NS |
| nose licking | -7.4 | **0.024*** | -5.6 | NS | -6.6 | NS |
| licking itself | -4.0 | **0.036*** | 11.0 | NS | 1.2 | NS |
| look at/sniff at neighbour | -9.1 | NS | 6.3 | NS | 12.1 | NS |
| **Pain indicators (#)** | | | | | | |
| reaction to noise | -2.5 | **0.008**** | -2.8 | **0.005**** | -2.4 | **0.015*** |
| transition in posture | 1.7 | **< 0.001***** | 1.0 | NS | 0.7 | NS |
| aggressive behaviour | -0.8 | NS | -1.0 | NS | -0.1 | NS |
| vocalisation (loud and soft) | 24.0 | NS | 30.0 | NS | 16.0 | NS |
| vocalisation loud | 3.0 | NS | 6.0 | NS | 1.0 | NS |
| vocalisation soft | 19.0 | NS | 10.0 | NS | 10.0 | NS |
| lip curl | 0.2 | NS | 1.0 | **0.020*** | 0.0 | NS |
| rumination quality | -23.0 | **< 0.001***** | -4.0 | NS | -11 | **< 0.001***** |
| eye white | -0.8 | NS | -0.2 | NS | -0.4 | NS |
| **Activity budget (in sec)** | | | | | | |
| eating | -1304 | **< 0.001***** | 204 | NS | 520 | NS |
| rumination | -1351 | **0.002**** | 500 | NS | -709 | NS |
| lying (left or right) | 2460 | **< 0.001***** | 523 | NS | 338 | NS |
| lying left | 144 | NS | -130 | NS | -826 | NS |
| lying right | 2317 | **< 0.001***** | 653 | NS | 1152 | NS |
| standing | -2283 | **< 0.001***** | -341 | NS | 151 | NS |

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; a Not Significant

# Discussion

## Comparison between the delivery *per vaginam* and CS group

The main differences in overall activity and activity budget between the two groups of cows were observed primarily on D1 (see Table 3 versus Table 4 and 5). Cows that underwent CS spent less time eating and ruminating, had more transitions in posture (from lying to standing or vice versa) and a longer resting time in comparison to naturally calving cows. CS animals also showed less limb movements (and an associated tendency for lower overall activity) on D1, but this is presumably due to the highly significant difference in resting time.

The differences in eating and rumination time can be explained by the farm management since the farmer did not feed the CS animals during the first day after surgery to prevent adhesions between rumen and peritoneum. On D3, when food was available, eating time was higher in CS cows than in naturally calving cows, possibly to compensate for the period of food deprivation. A higher frequency of transitions on D3 from standing to lying and vice versa could indicate an attempt to alleviate discomfort due to pain. Alternatively, this behaviour could have increased due to a higher drive to forage. The higher resting time and decreased standing time in CS cows on the first day post partum, can be interpreted as a probable pain indicator. Food deprivation cannot be invoked as an alternative explanation in this case, as food deprived cattle is motivated to spend more energy in their search for food (Schütz et al., 2006), which hence should decrease their time spent lying (Metz, 1985).

On D1 the CS group laid down more on their right side ($P < 0.001$), but contradictorily, this was not observed during the subsequent days, and they did not lay down less on their left side (even at D1). This relative shift to the right side seems to indicate that the wound side is more painful.

Cows of the CS group reacted significantly more when pressure was put on the left flank on D1, D3 and D14, whereas naturally calving animals only showed more reaction on D1 when the area around the vulva was pressed. These results suggest that both parturition types provoke some pain and discomfort i.e. when the wound side for the CS group and the vulva area for the naturally calving group was squeezed. Pain after pressure apparently subsides faster in animals of the naturally calving group. Watts (2001) also used force applied onto the area around the surgical side to assess the severity of pain after CS and other surgery. Contrary to the results of the present study, Watts (2001) found no response to palpation after 60 to 72 hours after surgery.

## Comparison of the behaviour before versus after calving in both groups

There was a significant increase in the overall loud and soft vocalization on D14 in comparison to D-30 in the naturally calving group. This increase was not noticed in CS cattle. Previous research has indicated that vocalizations are an indicator of stress (Dunn, 1990; Warris et al., 1994; White et al., 1995; Grandin, 1998). In the present study, each vocal sound was recorded including the sounds made towards the calf, loud and soft. Instead of vocalization by stress, the increase observed can also be due to a better dam-calf bonding in naturally calving cows. This hypothesis may also explain the decrease in aggressive behaviour towards the neighbour cow and her calf, seen in the naturally calving group.

Both groups showed less reaction to a loud noise on D1-14 compared to D-30. Although this could indicate depression in these animals it can be suggested that it is more likely that animals got accustomed to the noise used in the experiment.

In the CS group there are more highly significant ($P < 0.001$) differences in the time budget of D1 compared to that of D-30. Less time was spent eating and ruminating which was probably related to feed withdrawal. Reduced standing and increased lying time (principally on the right side, may indicate reduced welfare [pain]). The fast recovery to a normal pattern on D3 however indicates that this effect was of a short duration. Compared to the period before parturition rumination quality in CS cows was decreased on D1, which is not surprising given the food deprivation. However, the CS cows also show a lower rumination quality on D14 in comparison to D-30, which is difficult to explain by the food deprivation alone. The reduced feed intake on D1 may also partially explain why CS animals have a lower (overall and specific) activity on D1 while this is not so for naturally calving animals. This can only be a partial explanation since overall activity (i.e. frequency of limb movements, ear flicking, etc….) on the third day post partum (D3) in CS cows is still significantly lower than basal levels (D-30), although the activity budgets i.e. time spent in different activities, had resumed basal levels (D-30) by then.

## General discussion

The goal of the present study was to objectively examine whether delivery per CS causes more pain and discomfort than delivery *per vaginam* in DM-BB cows. The observations were restricted to only one species and furthermore, to one specific phenotype within one breed on one farm. It can therefore be assumed that observed behavioural differences are mainly due to individual variation and the experimental treatments. The choice of farm and animals was limited as the observations had to include naturally calving S-carcass DM-BB cows. The authors have only been able to locate a single farm with a sufficient percentage of DM-BB cattle that calves by vaginal delivery (30 - 50% annually versus the DM-BB breed average of 0.15 - 0.5%). These limitations (small amount of animals and only one herd) may have caused some bias, but on the other hand, they minimize variation due to genetic and management differences. Therefore, we assume that differences found in the present study can be attributed to the method of parturition.

## Conclusion

Our results indicate some statistically significant short-term behavioural differences between naturally calving and CS cows. Rumination quality, flank and vulva pressure and activity budget are the most likely parameters, indicating the discomfort in BB cows following naturally calving or CS. The practical circumstances under which this study was conducted (especially the management on D1) may partially explain the observed behavioural differences. Nevertheless, results indicate an increased discomfort in cows that underwent CS.

It remains to be clarified whether the statistical differences indeed indicate biologically relevant differences in pain experiences and – thus – reduced welfare. In any case, this study shows that the behavioural differences observed in cows that underwent a correctly performed CS under local anaesthesia, are predominantly subtle and of short duration.

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# Chapter 5

# The ability to calve naturally in the double muscled Belgian Blue breed

# THE MATERNAL POINT OF VIEW: EVALUATION OF THE RICE PELVIMETER FOR MEASURING PELVIC AREA IN DOUBLE MUSCLED BELGIAN BLUE COWS (CHAPTER 5.1)

Modified from:

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2009

Evaluation of the Rice pelvimeter for measuring pelvic area in double muscled

Belgian Blue cows.

Livestock Science 121, 259-266.

# ABSTRACT

The accuracy of the Rice pelvimeter for measuring pelvic area of double muscled Belgian Blue (DM-BB) cattle was investigated by comparing measurements in the live animal with these obtained from the same animal after slaughter. Pelvic measurements (pelvic width [PW], pelvic height [PH] and pelvic area [PA]) from 466 BB cows aged 2 - 10 years old and of an excellent carcass qualification (S and E in the SEUROP classification) were measured with the pelvimeter approximately 12 hours prior to, and by graded ruler within 2 hours after, slaughter. The mean difference of measurements between living and dead cattle were -0.2 cm for PW (95% limits of agreement -2.5 - 2.1 cm), and 1.2 cm for PH (95% limits of agreement -1.8 - 4.1 cm). The correlation coefficient between all pelvic measurements was between 0.46 - 0.59 ($P < 0.001$). The age of the animals influenced only PH whilst carcass weight had an association with all the components of the pelvis (PA, PH and PA). There was a significant correlation between the pelvimetric measurements of the birth canal in living cattle obtained using a Rice pelvimeter compared to actual measurements obtained from the carcass. The Rice pelvimeter is a suitable tool for assessing accurate pelvic skeletal conformation and to select animals in this breed with a larger birth canal and hence less dystocia problems.


# INTRODUCTION

After many years of selection for the double muscled characteristic, the double muscled Belgian Blue (DM-BB) breed is well known for its high killing out percentage, carcass conformation and good eating quality. Consequently, the BB bull is used widely as a terminal sire in both beef and dairy herds (Lips et al., 2001). This selection for the double muscled (DM) conformation has created incompatibility between the extreme fetal muscle development and growth and the pelvic canal of the dam.

As a result, there is a high incidence of dystocia and surgical management of parturition in the pure breed. Such elective Caesarean Sections (CSs) pose serious ethical questions which limits the use of this exceptional breed for beef production to a large extent.

Dystocia is an important factor associated with stillbirths, particularly in the beef herd. The disparity between fetal oversize and the dimensions of the birth canal is an important common cause of dystocia (Rice and Wiltbank, 1972). Johnson et al. (1988) showed that calf birth weight and maternal pelvic area (PA) accounted for most of the variation in calving difficulty. To increase the PA without decreasing the conformation and the size of these cows, selection in the dam directly for increased PA should be considered.

Pelvimetry may offer an accurate method for measuring pelvic conformation and hence the PA, to determine whether the calf can be delivered naturally *per vaginam* (Laster, 1974; Morrison et al., 1986; Johnson et al., 1988; Naazie et al., 1989; Basarab et al., 1993; Glaze et al., 1994; Murray et al., 1999, 2002). The practical application of pelvimetry for identifying heifers with an increased risk of dystocia is controversial. Deutscher (1978; 1988; 1989) used the pelvimeter to select heifers with a lower risk for dystocia prior to the breeding season. Similarly, Johnson et al. (1988) correctly predicted dystocia rate in 67% of Hereford heifers. In contrast, Basarab et al. (1993) considered that knowing PA was not a useful tool to predict dystocia because 86% of supposedly difficult calvers subsequently calved easily and Van Donkersgoed et al. (1990, 1993) were of a similar opinion.

In the DM-BB breed, the size of the birth canal has also been identified as a limiting factor in calving ease. In order to select the maternal trait of larger PA and to reduce dystocia in practice, we should be able to measure it on live animals. This is done by measuring animals with a Rice pelvimeter. Murray et al. (1999, 2002) performed pelvimetry in adult DM-BB cows in Belgium and the UK, but no observations were made on the suitability of measuring PA to predict and reduce dystocia rates in calving heifers. It has never been questioned whether the Rice pelvimeter can be used to measure accurately the PA of DM-BB cows. The pelvis of these animals has a somewhat different shape in comparison with other beef breeds, associated with a decrease in overall body size, including pelvic height, through years of selection for hypermuscularity (Kieffer, 1972; Coopman et al., 2003).

If measurements with the Rice pelvimeter are accurate, they may be used to measure growth of the PA in young animals relative to time. Furthermore, some factors which influence pelvic development in juvenile cattle could be investigated, in order to advise farmers to modify their heifer rearing programs and reduce dystocia in calving heifers.

The aim of the present study was to determine whether the Rice pelvimeter could be used to predict accurately pelvic dimensions in DM-BB cows by comparing values obtained by the Rice pelvimeter with those taken from the same cattle in the abattoir.

# MATERIALS AND METHODS

## Animals and accommodation

Data were collected during 2005 and 2006 at an abattoir in Flanders from female DM-BB cattle. All carcasses were weighed and classified by an authorized inspector. Within the SEUROP carcass classification system of the European Community (2003-10-03/37; Table 1) BB cattle fall into the S category with only some cattle having an E classification. Officially this system scores six conformation grades further divided in sub grades, reflecting small distinctions in muscularity within the respective grade. Besides conformation grades, all animals were also assessed for fatness (Table 1).

At weekly visits to the abattoir, an ante-mortem examination was carried out within 12 hours prior to slaughter and pelvic height and width measured using a Rice pelvimeter. The carcass pelvic measurements were obtained in the refrigerator within two hours of slaughter and the cold carcass weight (CW), its carcass classification (CC), and the birth date of the animals were recorded.

**Table 1** SEUROP carcass classification according to the European Community 2003-10-03/37

| Conformation characteristics | Grade | Sub grade | Fatness characteristics | Grade |
|---|---|---|---|---|
| Extreme muscularity | S | +<br>=<br>- | Extreme fat | 5 |
| Excellent muscularity | E | +<br>=<br>- | Fat | 4 |
| Very good muscularity | U | +<br>=<br>- | Moderate fat | 3 |
| Good muscularity | R | +<br>=<br>- | Light fat | 2 |
| Moderate muscularity | O | +<br>=<br>- | Low fat | 1 |
| Poor muscularity | P | +<br>=<br>- | | |

## Measurements

A Rice pelvimeter (Lane Manufacturing, 2075 So. Balentia St., Unit C, Denver, Colorado, USA) with an accuracy of 0.25 cm was used to measure internal pelvic height and width in live cattle. The choice of the Rice pelvimeter was based on its good accuracy in other breeds, low price and easy application. Before the measurements, low epidural analgesia was administered using 2 ml of 4% procaine hydrochloride (Eurovet®, Belgium); there is nil meat withholding time for this drug. As a result, the pelvimeter measurements could be obtained in cattle adapting a normal stance during rectal manipulation. The closed pelvimeter was slowly introduced into an empty rectum and the pelvic height (PH) measured by opening the device within the pelvic canal between the pubic *symphysis* and the sacral vertebrae (Figure 1). The pelvic width (PW) defined as the horizontal distance between the shafts of the *ilium* at the widest point was measured similarly; the ends of the pelvimeter were placed on the *tubercula psoadica* of the *ilium* in the pelvic entrance (Figure 2). Both PW and PH were measured three times consecutively by the same technician and the resulting mean value was used for further analyses. After slaughter, the PH and PW were measured directly on the carcass by means of a graduated ruler. The perpendicular distance between pubic *symphysis* and the ventral part of the *sacrum* for pelvic height were obtained from both carcass halves and the mean was used for further analyses. The PW was estimated by adding the distance of the *tubercula psoadica* of the *ilium* to the middle of the carcass of both halves of the carcasses. The pelvic area (PA) was then calculated by multiplying pelvic height and width. All measurements were obtained by the same researcher.

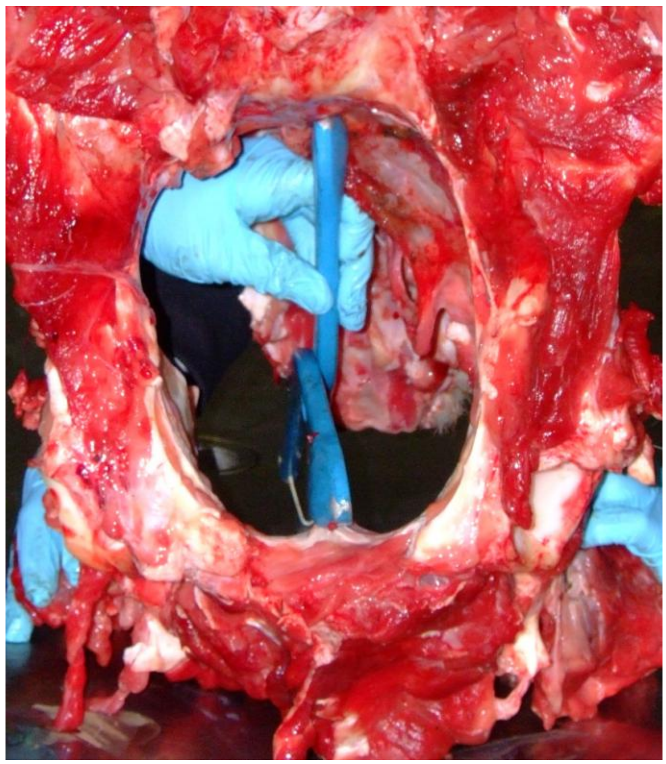

**Figure 1** Position of the Rice pelvimeter in the pelvic entrance for measuring pelvic height

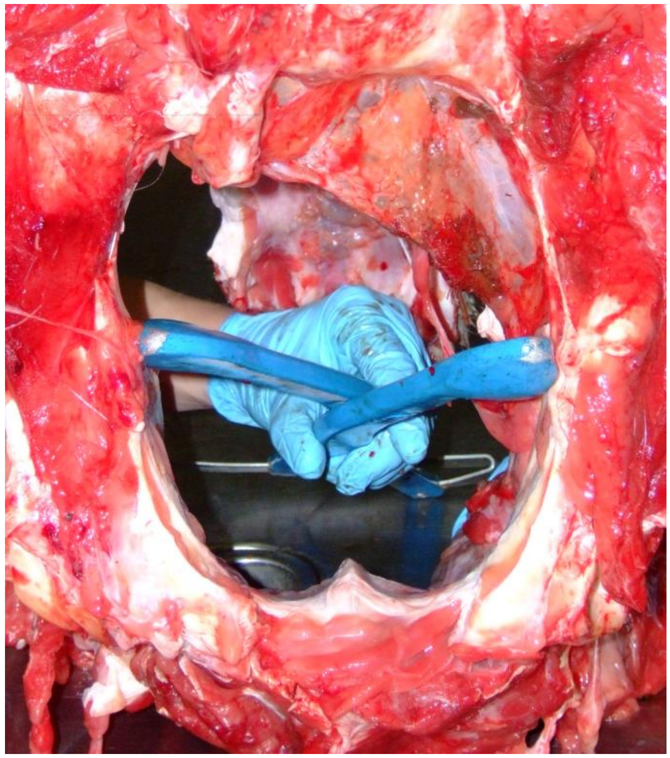

**Figure 2** Position of the Rice pelvimeter in the pelvic entrance for measuring pelvic width

## Statistical analyses

Using SPSS 14.0 for Windows, the dataset was tested for normality using the Kolmogorov-Smirnoff test and by controlling the Q-Q plots. For data distributed normally, a paired t-test examined differences between the pelvimetric and carcass measurements. Assessment of agreement between the two methods was obtained (Bland and Altman, 1986; 1999), using a simple plot of the difference between the ante- and post-mortem measurements against the calculated mean of carcass and pelvimetric measurements together. As the differences were normally distributed, the 95% limits of agreement were calculated as the mean difference ± $1.96s_d$. To check whether a lack of agreement was associated with poor repeatability of the measuring techniques used, a one-way ANOVA was used to estimate the within-subject variance and through this compare the standard deviations (within-subject standard deviation = $(\text{variance})^{1/2}$) of the two different methods (carcass and pelvimetric measurements) to see which is more repeatable.

We used the within-subject standard deviation instead of other approaches (e.g. variation coefficient) to test the repeatability because of the possibility to compare with the limits of agreement. The *repeatability coefficient* was calculated from the expression: $1.96\sqrt{2}\ s_w$ where $s_w$ = standard deviation within (Bland and Altman, 1999).

Correlations between the pelvimetric and carcass measurements were investigated using the Pearsons correlation coefficient on the complete dataset and on subsets describing the different conformation and fatness grades. No correlation coefficient was assessed for fatness grade 1 as there were too few animals in this category. A general linear model was used to assess whether factors such as age, carcass weight, conformation and fatness were associated significantly with the difference between the carcass and the pelvimetric measurements. Every single factor was analysed in a univariable model and factors with a probability smaller than 0.20 were used in a backward analysis conducting a multivariable model $Y = \beta_0 + \beta_1 x + \dots + \beta_k x + \varepsilon$ (Y: dependant variable; $\beta_0$: y-intercept of regression line; $\beta_1, \dots, \beta_k$: regression coefficients; $\varepsilon$: unexplained, random error).

# Results

## Descriptive statistics

During the two years 466 DM-BB cows aged 2 - 10 years old were measured, 244 of which growing (2 - 5 years old) and 222 were mature cows (6 - 10 years old). Of these, 401 (86%) had an S classification whilst 65 animals (14%) had an E classification. Within the S category, 275 (69%) of the animals belonged to '+', 65 animals (16%) to '=' and 61 (15%) animals to the subdivision '-'. Fifty-five animals (85%) of the 65 E classified cattle were categorized in the subdivision '+', while 6 animals (9%) belonged to the subdivision '=' and 4 (6%) to the subdivision '-'. Within the classification based on the degree of fatness, 2 animals (S and E category) belonged to the low fat category (1), 455 to the light fat category (2), and 11 to the moderate fat category (3).

The pelvimetric measurements of growing animals showed a mean PW, PH and PA of 15.8 ± 1.2 cm, 19.3 ± 1.2 cm and 306.0 ± 36.2 $cm^2$ respectively. Adult cows measured a PW of 16.6 ± 1.2 cm, a PH of 19.5 ± 1.4 cm and a PA of 326.2 ± 40.8 $cm^2$. When comparing these data with the measurements obtained from the carcasses, significant differences for all three pelvic dimensions were noted, for growing cattle: PW = 15.6 ± 1.2 cm, PH = 20.0 ± 1.5 cm and PA = 312.7 ± 38.1 $cm^2$; for mature cows: PW = 16.4 ± 1.1 cm, PH = 21.1 ± 1.3 cm and PA = 346.7 ± 35.4 $cm^2$ ($P < 0.01$). The mean and the standard deviation of all measurements related to age at slaughter are shown in Table 2. In general, measuring pelvic width by pelvimetry resulted in higher numbers compared to the carcass measurement, while the pelvimetric pelvic height tended to be smaller compared to these obtained from the carcass. The older the animal, the larger the difference between ante- and post-mortem measurements. That for pelvic height (0.8 - 1.8 cm) was larger than for pelvic width (0.1 - 0.8 cm).

Results similar to the complete dataset for pelvic width and height were obtained after separating the two conformation grades (S and E) (Table 3). Within the fatness categories significant differences between the pelvimetric and carcass measurements were seen but only in cattle graded in the light fatness category, resulting in bigger pelvic width and smaller pelvic height measured with the Rice pelvimeter compared to the carcass measurements (Table 3; $P < 0.001$). From the numeric values in this table there was no difference in discrepancy between the pelvimetric and the carcass measurements among the conformation grades E and S. The leaner the carcass, the bigger the discrepancy between the two methods of measurement.

**Table 2** The mean ± StD of pelvic width (PW), pelvic height (PH) and pelvic area (PA) measured by Rice pelvimeter and after slaughter (carcass measurements) related to age at slaughter (years) and carcass weight (CW)

| | | **Method of measurement** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Pelvimetric** | | | **Carcass** | | | |
| Age | n | PW (cm) | PH (cm) | PA (cm) | PW (cm) | PH (cm) | PA (cm) | CW (kg) |
| 2 | 5 | 15.1 ± 1.98 | 18.7 ± 1.57 | 283.6 ± 56.60 | 15.3 ± 2.34 | 19.2 ± 1.98 | 295.9 ± 70.46 | 452.5 ± 79.75 |
| 3 | 40 | 14.9 ± 1.04 | 18.6 ± 1.42 | 278.5 ± 36.65 | 14.8 ± 0.96 | 18.5 ± 1.36 | 273.3 ± 30.03 | 438.3 ± 42.42 |
| 4 | 90 | 15.6 ± 1.05* | 19.2 ± 1.18* | 300.8 ± 31.87* | 15.4 ± 1.01 | 20.0 ± 1.22 | 308.6 ± 31.42 | 470.6 ± 36.44 |
| 5 | 109 | 16.4 ± 1.11* | 19.6 ± 1.01* | 321.3 ± 31.67* | 16.1 ± 1.01 | 20.6 ± 1.37 | 331.4 ± 31.54 | 493.9 ± 49.50 |
| 6 | 100 | 16.6 ± 1.22 | 19.4 ± 1.45* | 321.9 ± 42.23* | 16.4 ± 1.05 | 20.8 ± 1.24 | 340.7 ± 33.62 | 510.5 ± 45.36 |
| 7 | 67 | 16.5 ± 1.12 | 19.6 ± 1.37* | 324.9 ± 38.56* | 16.4 ± 1.07 | 21.2 ± 1.40 | 348.6 ± 35.19 | 518.0 ± 51.83 |
| 8 | 31 | 16.5 ± 1.29 | 19.6 ± 1.21* | 324.8 ± 39.01* | 16.2 ± 0.98 | 21.4 ± 1.33 | 347.3 ± 34.81 | 505.7 ± 42.69 |
| 9 | 17 | 17.2 ± 1.16 | 19.8 ± 1.04* | 340.9 ± 34.90 | 16.5 ± 1.01 | 21.6 ± 1.35 | 356.3 ± 34.59 | 507.5 ± 48.70 |
| 10 | 7 | 18.1 ± 1.20 | 20.4 ± 1.31* | 369.3 ± 40.06 | 17.6 ± 1.47 | 22.0 ± 1.21 | 387.6 ± 42.27 | 530.4 ± 60.71 |

**Table 3** The mean ± StD for pelvimetric and carcass pelvic width (PW) and pelvic height (PH) related to conformation and fatness grades

| Independent variable | Grade | n | Measurement | Method of measurement Pelvimetric (cm) | Carcass (cm) | Significance |
|---|---|---|---|---|---|---|
| *Conformation* | E | 65 | PW | 16.0 ± 1.20 | 15.8 ± 1.03 | NS[a] |
| | | | PH | 19.2 ± 1.31 | 20.2 ± 1.60 | <0.001 |
| | S | 401 | PW | 16.3 ± 1.30 | 16.0 ± 1.21 | <0.001 |
| | | | PH | 19.4 ± 1.28 | 20.6 ± 1.51 | <0.001 |
| *Fatness* | 1 | 2 | PW | 16.3 ± 1.06 | 16.5 ± 0.21 | NS |
| | | | PH | 19.5 ± 2.12 | 21.4 ± 2.97 | NS |
| | 2 | 453 | PW | 16.2 ± 1.30 | 16.0 ± 1.19 | <0.001 |
| | | | PH | 19.4 ± 1.30 | 20.5 ± 1.53 | <0.001 |
| | 3 | 11 | PW | 16.3 ± 1.01 | 16.2 ± 1.16 | NS |
| | | | PH | 19.7 ± 0.82 | 20.2 ± 1.45 | NS |

a Not Significant

## Limits of agreement

The difference between the pelvimetric and carcass measurements for pelvic width (Figure 3) was -0.2 cm (95% limits of agreement are -2.5 cm and 2.1 cm). Similarly, for pelvic height the difference was 1.2 cm (95% limits of agreement between -1.8 cm and 4.1 cm (Figure 4).

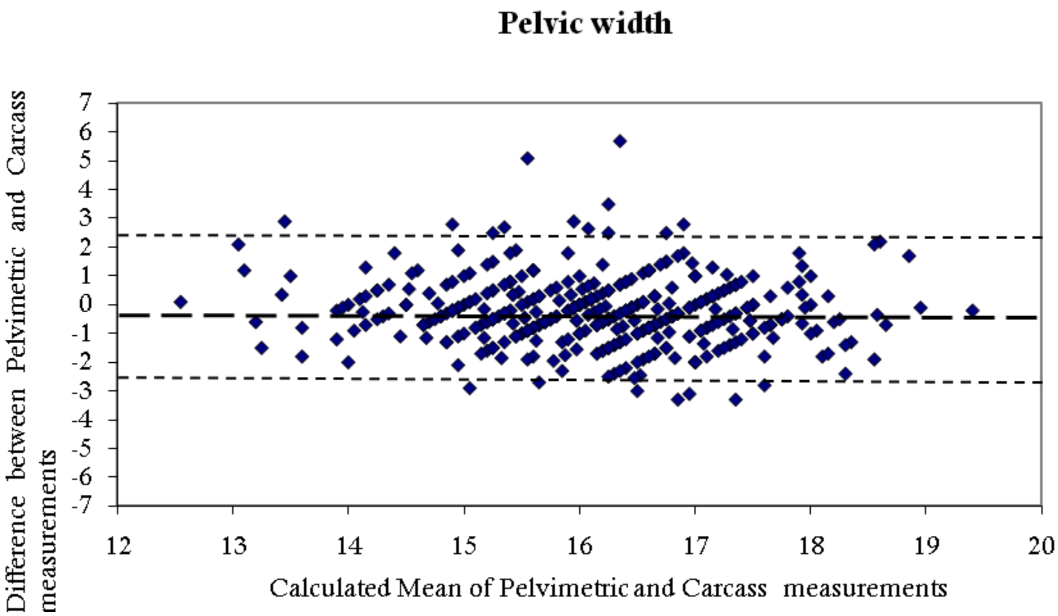


**Figure 3** Limits of agreement between the mean difference for pelvimetric and carcass measurements for pelvic width (cm), and 95% limits of agreement (cm)

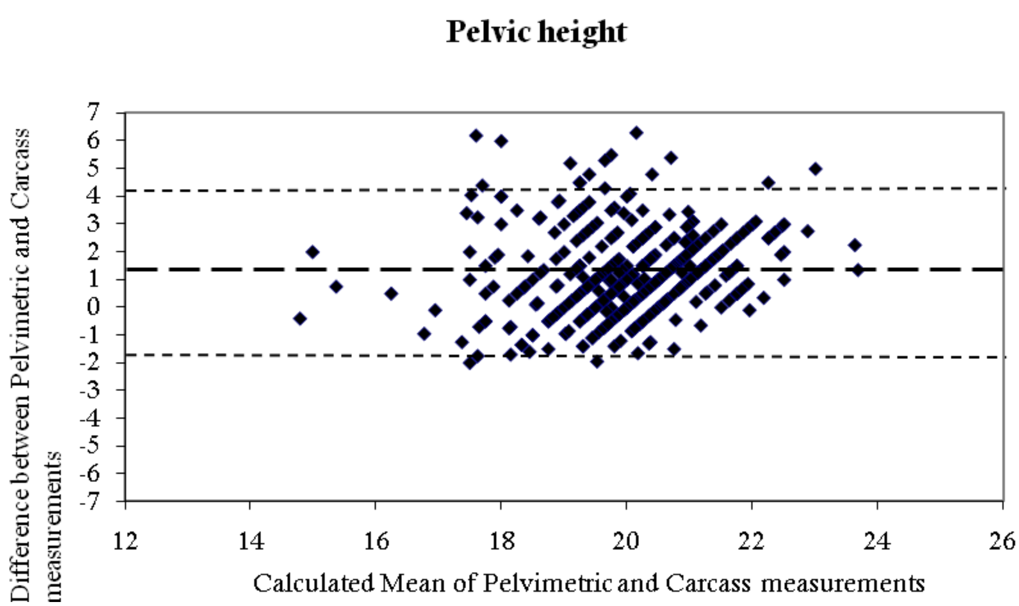


**Figure 4** Limits of agreement between the mean difference for pelvimetric and carcass measurements for pelvic height (cm), and 95% limits of agreement (cm)

The measurement of pelvic height on the carcass had a within subject variance of 0.303 and a *repeatability coefficient* of 1.5 cm. For the pelvimetric pelvic height, the within subject variance was 0.173 with a *repeatability coefficient* of 1.2 cm. A comparison of the *repeatability coefficient* of pelvic height measured on the carcass with the limits of agreement, shows that the limits of agreement (-1.8 - 4.1 cm) for pelvic height are considerably wider than the *repeatability coefficient* for the carcass measurements. Since, the pelvimetric pelvic height *repeatability coefficient* falls within the limits of agreement, these results show that the repeatability of both methods was good.

## Correlations and general linear models

The Pearsons correlation coefficient between pelvimetric and carcass measurements on the whole dataset was moderate albeit significant (PW: r = 0.56; $P < 0.001$; PH: r = 0.46; $P < 0.001$, PA: r = 0.59; $P < 0.001$).

In the whole dataset, age was moderately correlated with the pelvimetric pelvic width (r = 0.41; $P < 0.001$) and poorly with pelvic height (r = 0.20; $P < 0.001$) and correlated moderately with the carcass measurements (PW: r = 0.41; PH: r = 0.47; $P < 0.001$). Regarding carcass weight, the correlations with the pelvimetric and carcass measurements were moderate, albeit significant (Pelvimetric PW: r = 0.39; Pelvimetric PH: r = 0.28; Carcass PW: r = 0.49; Carcass PH: r = 0.47; $P < 0.001$).

Table 4 investigated correlations between the two methods related to age; growing cattle had better correlations between pelvimetric and carcass measurements than mature cattle, suggesting an influence of age on the discrepancy between the two methods.

After subdividing the dataset in conformation and its sub grades (Table 5), Pearsons correlation showed that the highest correlation coefficient was in animals of extreme conformation (S = category) for pelvic width and in animals of the excellent conformation (E = category) for pelvic height. Cattle in the moderate fatness category show higher correlation coefficients for pelvic width and height compared to cattle in the light fatness category and compared to the total dataset.

**Table 4** Correlation (r) between pelvimetric and carcass measurements for pelvic width (PW) and pelvic height (PH) related to age

| Age (years) | | Carcass measurements 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PW | PH | PW | PH | PW | PH | PW | PH | PW | PH | PW | PH | PW | PH | PW | PH | PW | PH |
| **Pelvimetric measurements** | PW | **0.96**$^{**}$ | | **0.53**$^{**}$ | | **0.63**$^{**}$ | | **0.32**$^{**}$ | | **0.30**$^{**}$ | | **0.51**$^{**}$ | | **0.55**$^{**}$ | | 0.15 | | 0.41 | |
| | PH | | 0.70 | | **0.70**$^{**}$ | | **0.33**$^{**}$ | | **0.38**$^{**}$ | | **0.37**$^{**}$ | | **0.37**$^{**}$ | | **0.59**$^{**}$ | | 0.40 | | 0.38 |

**Table 5** Correlations (r) between the pelvimetric and carcass measurements of pelvic width (PW) and pelvic height (PH), in relation to conformation grades and sub-grades

| | | | Carcass measurements | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Conformation Grade | Sub grade | - | | = | | + | |
| | | | PW | PH | PW | PH | PW | PH |
| **Pelvic measurements** | E | PW | 0.401 | -0.203 | 0.526 | 0.645 | **0.527**$^{**}$ | 0.403 |
| | | PH | 0.706 | 0.815 | 0.803 | **0.876**$^{*}$ | 0.290$^{*}$ | **0.390**$^{**}$ |
| | S | PW | **0.347**$^{**}$ | 0.316$^{**}$ | **0.696**$^{**}$ | 0.418$^{**}$ | **0.593**$^{**}$ | 0.371$^{**}$ |
| | | PH | 0.068 | **0.320**$^{*}$ | 0.561$^{**}$ | **0.471**$^{**}$ | 0.290$^{**}$ | **0.487**$^{**}$ |

The influence of the variable factors age, carcass weight, conformation and fatness grades on the discrepancy between carcass and pelvimetric measurements were assessed in a general linear model. Only the carcass weight had a significant influence on pelvic width differences, whereas age and carcass weight both had a significant influence on the pelvic height and area differences, resulting in the models listed in Table 6.

**Table 6** General Linear Model for difference in pelvic width (PW), pelvic height (PH) and pelvic area (PA)

| | F-value | *P*-value |
|---|---|---|
| *Difference PW* = -1.003 + 0.003 *CW*[a] | $F_{CW} = 4.512$ | $P < 0.05$ |
| *Difference PH* = -3.137 + 0.225 *Age (years)* + 0.005 *CW (kg)* | $F_{Age} = 27.860$ | $P < 0.001$ |
| | $F_{CW} = 11.504$ | $P < 0.001$ |
| *Difference PA* = -72.727 + 2.509 *Age (years)* + 0.135 *CW (kg)* | $F_{Age} = 5.235$ | $P < 0.05$ |
| | $F_{CW} = 13.639$ | $P < 0.001$ |

a Carcass Weight

# DISCUSSION

In the present study we assessed the efficacy of the Rice pelvimeter for the measurement of several pelvic dimensions in live DM-BB cows. This was done by comparing these pelvimetric measurements with those obtained from the carcass two hours after slaughter. The results show small significant differences in PW, PH and PA; measurements obtained from living cattle were generally less than those obtained after slaughter.

The agreement between the two methods of measurements was moderate to good, being -0.2 (-2.5 - 2.1) cm for PW and 1.2 (-1.8 - 4.1) cm for PH. Even if the two methods agree, a poor repeatability of the one can still lead to poor agreement between the methods. If the 95% limits of agreement are similar or smaller compared to the *repeatability coefficient,* the lack of agreement between the methods can be explained by a lack of repeatability. If the limits of agreement are wider than the *repeatability coefficient* would indicate, there must be other factors reducing the agreement between the two measuring methods (Bland and Altman, 1999). Generally this can indicate that the one method is likely to differ from the other, in this case a possibly explanation can be the removal of fat and connective tissue after the carcass is split as discussed below. In our study, the pelvimetric PH *repeatability coefficient* fell within the limits of agreement.

Generally, the PW measured with the pelvimeter is larger than the carcass measurement. For PH, the carcass measurements show higher values compared to those of the pelvimeter. The difference between the two methods is larger for PH than PW. These small significant statistical difference in pelvic dimension are not always biological relevant to the decision an obstetrician has to make in the field. For example, the differences in PA are around 20 $cm^2$, which is only 7% of the total pelvic dimension. "It is difficult, if not impossible, to indicate a precise percentage of difference in PA that would guarantee biological relevant as this also depends on factors such as the calf dimensions, pelvic inclination, and general management. Further research will be necessary to investigate the influence of the above factors on the required PA."

There may be several reasons for the differences mentioned above; for example that measurements in a living animal, affected by muscular tone and normal stance, intrapelvic fat and connective tissue differ from carcass measurements influenced by relaxation of connective tissue and muscle *post mortem* due to the pendulous position of the hanging carcass. After the carcass is split in two halves a large amount of pelvic fat and connective tissue is removed. Logically this would lead to bigger discrepancies between the two methods of measurements in animals of a fatter grade, but our results show larger differences ($P < 0.05$) in leaner carcasses. Another reason which can explain the existence of a disagreement between the two methods of measurement is the hypermuscularity of the DM-BB which might lead to compression of the pelvic entrance and pelvic canal. The muscular hypertrophy gene (*mh*-gene) is known as a monogenic trait characterized by general hyperplasia of skeletal muscle, particularly of the hindquarters, the back and the shoulders, accompanied by a relative decrease in the size of the viscera and length of the limb bones (Arthur et al., 1988). Comparison of the PA of cattle of the DM-BB breed with other beef breeds assent this decrease (Bellows et al., 1971, Deutscher, 1988, Johnson et al., 1988, Murray et al., 1999, 2002; Coopman et al., 2003). The average fetal weight at birth for the DM-BB breed is also higher, making the discrepancy between the dam and her calf even bigger. Ménissier and Vissac (1971) demonstrated a significantly smaller pelvic height, width and area in double muscled animals compared to non-double muscled animals. Results of our study do not support this hypothesis since cattle in the less muscled E-category did not differ significantly compared to these in the S-category. The general linear model comparing differences in pelvic height between the pelvimetric and carcass measurements shows some influence of hypermuscularity on the measurements' accuracy. Coopman et al. (2003) found a good correlation between internal pelvic measurement and live weight, and his multiple regression models show that live weight, among other traits, was a good estimator of internal pelvic sizes.

Correlation between the two methods of measurements was moderate albeit significant for both PW and PH. The variation between the two methods can also be explained by other factors. The growth pattern of the pelvis and its relation to age has been described by Brown et al. (1972). In this present study, younger animals gave better correlations compared to the complete dataset and to adult cows. Influence of age on pelvimeter measurements was also suggested by Murray et al. (1999) who found a higher correlation of age with PH ($r^2$ = 0.37), PW ($r^2$ = 0.42) and PA ($r^2$ = 0.45) in adult cows. Overall, results suggest that the age of cattle should be taken in account. Van Donkersgoed et al. (1990) found that the positive predicting value of PA measurements for dystocia was lower in young cattle, whereas Basarab et al. (1993) found that heifer age, irrespective of PA, body weight and hip height, was an important trait in predicting dystocia. Discriminant analyses carried out by Morrison et al. (1985) indicated the influence of age of the cow in addition to precalving PA; other factors were conformation and fatness grades, and CW, as shown in the general linear model analysis of this study. For PW, only the CW had a significant influence, whereas age and CW both had a significant influence on PH and PA differences. The best correlation for PW occurred in cattle with extreme conformation, whereas that for the PH was found in cattle of excellent conformation. Since DM-BB cows have an S conformation, the correlation for PW is better than that for PH. Besides age, conformation and fatness grades, the moderate correlation between the measurements can also be explained by straining of the animals, the removal of the fat and connective tissue after splitting the carcass and the hypermuscularity of the DM-BB breed.

In Belgium, because of the high value of the calves and the relatively low price of the CS, nearly all DM-BB cows are nowadays delivered by CS. However, ethical criticism of this method of managing parturition is increasing. Selection for the *mh*-gene has caused general hyperplasia of skeletal muscle accompanied by a relative reduction in the comparative size of the viscera and length of the limb bones (Arthur et al., 1988). Coopman et al. (2003) indicated that the increased muscular conformation within the DM-BB animal is related to a decrease in inner pelvic dimension. Other genes besides the *mh*-gene are involved in the hypermuscularity but their number, location and function is unknown. Genetic improvement during the last ten years has produced improvement to muscling score and meaty type in the BB breed in Belgium, whilst height and length traits have decreased. An improvement for rump slope, chest width, tail set and PW were offset by a slight decrease for pelvis and body length (Hanset, 2004, 2005). Years of selection for hypermuscularity have created a decrease in overall body size including PH. As genetic selection is continuous process, a new goal would be to reduce the antagonistic effect between muscle growth and dystocia managed by CS. Selection for bigger pelvic sizes and the simultaneous use of bulls giving calves with lower birth weight and shorter gestation periods may be the only solution in this breed. Pelvimetry might enable dam selection for ease of calving, based on pelvic conformation. Based on the results of the present study it is clear that variation in pelvic measurement is not due inaccuracy of measurement.

## CONCLUSION

Our results show a significant however small difference in pelvic dimensions measured by means of the Rice pelvimeter when compared to measurements on the carcass. A moderate to good agreement between the two methods was found. According to these results pelvimetry is presumed to be a useful tool for veterinarians and farmers to select animals in the DM-BB breed with a larger birth canal and hence less dystocia problems.

Knowing the PA of DM-BB animals, a stockholder can preselect cows that might calve naturally, breeding from a bull that produces calves with lower birth weight and shorter gestation periods. Besides, the Rice pelvimeter can be used to follow the growth of the PA in young animals longitudinally. Such a study could investigate those environmental factors that may influence pelvic growth of cattle.

## ACKNOWLEDGEMENTS

We greatly acknowledge Mr. Lieven Boone of the slaughterhouse to allow us to measure the animals in the abattoir and for the given information on the animals.

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# THE MATERNAL POINT OF VIEW: PELVIC DIMENSIONS IN PHENOTYPICALLY DOUBLE MUSCLED BELGIAN BLUE COWS (CHAPTER 5.2)

Modified from:

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Pelvic dimensions in phenotypically double muscled Belgian Blue cows.

Reproduction of Domestic Animals (to be submitted).

## Abstract

Some anatomical characteristics of Belgian Blue (BB) cattle, such as withers height (WH), heart girth (HG), the distance between the two *tubera coxae* (TcTc) and the distance between the two *tubera ischiadica* (TiTi) were compared to the internal pelvic measurements of width, height and area. Herds in Flanders presented 507 cows and heifers for measuring. Mean values were 58.9 ± 6.2 cm for TcTc, 14.6 ± 2.3 cm for TiTi, 15.2 ± 2.1 cm for pelvic width (PW), 18.8 ± 1.9 cm for pelvic height (PH) and 288.5 ± 60.9 $cm^2$ for pelvic area (PA). There was a significant correlation between type of calving (CS or calving *per vaginam*) and WH ($P$ < 0.05), TcTc ($P$ < 0.05), TiTi ($P$ < 0.001), PH and PA ($P$ < 0.001). Cows that calved *per vaginam* had larger body and pelvic measurements compared to animals that were delivered by Caesarean Section (CS). The external pelvic value TcTc had a higher correlation (r = 0.58 - 0.63) with the internal pelvic measurements than the TiTi (r = 0.22 - 0.28). The correlation between other external body measures such as HG and WH were even higher (r = 0.69 - 0.74 for HG and r = 0.67 - 0.74 for WH).

Measuring internal pelvic parameters and to a lesser extent external body parameters for cows of this breed may assist selecting cows that can calve *per vaginam* and may reduce the dependence in elective CS for developing its conformational characteristics.

## Introduction

The Belgian Blue (BB) breed is characterized by a double-muscled (DM) phenotype typified by a deficiency in the myostatin (*mh*) gene (Grobet et al., 1998; Lips et al., 2001). Compared to other cattle breeds it possesses less bone and fat, more muscle and a higher muscle-bone ratio (Shanin and Berg, 1985). The breed is known also for its excellent meat quality and superior killing out percentage. These traits associated with the DM phenotype have been achieved only after introducing the Caesarean Section (CS) for routine management of parturition into bovine practice (Vandeplassche, 1974). This extreme conformation has been related to a reduction in inner pelvic dimensions (Arthur et al., 1988). Pleiotropic effects of the *mh*-gene have been suggested as a major cause of underdevelopment of the maternal birth canal as is regularly noticed in the field in calving DM-BB cows (Coopman et al., 2003). Murray et al. (1999) however found that the pelvic area of BB cows is 12% larger than estimated. The 81% dystocia rate in BB herds which allowed cows the opportunity to calve naturally was not associated with the maternal pelvic conformation but with the significant impact of large fetal size and conformation (Noakes, 1997; Murray et al., 1999).

Dystocia or calving difficulty has been studied in other beef and dairy breeds and Calving Ease Estimated Breeding Values (EBV's) are commonly used to improve the ease of calving. The mean three sources to calculate this Calving Ease EBV's are calving difficulty score, birth weight (BW) and gestation length. By far the most important of these sources is calving difficulty score and this should be measured at birth by visually scoring females on a scale of 1 – 4 (1 = calving without help - 4 = CS) (Kriese et al., 1994; Meadows et al., 1994; McGuirk et al., 1998; Splan et al., 1998; Luo et al., 1999). As in Belgium the parturition in the DM-BB breed is managed by CS routinely, a calving difficulty score is not usable and hence the focus should be on other factors affecting parturition to allow the best possible genetic improvement for ease of calving. To select towards natural calvings in the BB breed, the focus must be laid on reducing the BW and the degree of fetal muscular hypertrophy of the shoulders and hindquarters, in combination with increasing the pelvic area (PA) of the DM-BB dam.

For the assessment of internal pelvic dimensions a pelvimeter has been be successfully used in other breeds (Johnson et al., 1988). However, the literature regarding pelvic measurements in the DM-BB breed is not extensive. Murray et al. (1999) used this technique to describe DM-BB cows in the United Kingdom; cows that were given the opportunity to calve *per vaginam* had a significantly larger pelvic height (PH) and area than animals that those whose parturition was managed by CS and significant correlations between internal and external pelvic measurements and age were described. Furthermore, cows in nine herds in Flanders (Belgium) have been compared with DM-BB cows in the UK; although there were no significant differences in pelvic sizes (PH and pelvic width [PW]) between cows farmed in either country, cows bred in the UK where calving *per vaginam* was common, had significantly larger internal PH and PA (Murray et al., 2002). In the same study external measurements of some specific pelvic dimensions seemed reasonable estimators of internal pelvic size (Murray et al., 2002). However, no other body measurements such as withers height or heart girth were obtained this study to assess their relation with the internal pelvic size. Coopman et al. (2003) did include body weight and withers height and found out that these body parameters together with the distance between the two *tubera coxae* (TcTc) were relatively good estimators of internal pelvic sizes. However, in the latter study these internal pelvic measurements were performed on the carcass and not on living animals.

This present study explored the variation in internal and external pelvic measurements and body dimensions of DM-BB cattle in Belgium irrespective of how their parturition was managed. Besides, correlations between these measurements and age and type of calving were determined to create a model that estimated the internal PH, PW and PA based on different external body measurements. The different pelvic dimensions (PH, PW and PA) of the dataset were then used to predict the likelihood of calving *per vaginam*.

# MATERIALS AND METHODS

## Animals

Internal and external pelvic measurements and several body measurements (see below) were obtained between 2005 - 2007 from 507 heifers and cows in 27 DM-BB herds located in Flanders (Belgium). All animals were characterized by an extreme muscularity, classified as ‘S’ according to the SEUROP carcass classification system of the European Community [2003-10-03/37]) and were included only once. In most herds parturition was managed by CS routinely, but occasionally one or two cows calved *per vaginam*, mostly by accident. One farm had an unusually high incidence of delivery *per vaginam* of around 30 - 40%, due to the fact that the farmer selected towards natural calving. An animal was characterized as “calved *per vaginam*” the moment she calved without help or with slight traction during one of her parturitions.

## Measurements

A Rice pelvimeter (Lane Manufacturing, 2075 So. Balentia St., Unit C, Denver, Colorado, USA) was used to obtain the internal PW and PH measures, based on its proven accuracy (Johnson et al., 1988), its low price and ease of use. Before measuring, epidural anaesthetic was administered using 2 ml of 4% procaine hydrochloride [VMD®, Belgium], to reduce straining of the heifer/cow during the procedure and to obtain pelvic measurement whilst the animal was standing normally during rectal manipulation. After the faeces were removed from the rectum, the pelvic entrance was located and the closed pelvimeter was slowly introduced. The PH and PW were measured according to the method described by Chapter 5.1 and the PA was calculated as the product of these values.

External measurements were obtained from the standing animal. Body weight (BoW) was taken with a calibrated scale (if present). Withers height (WH) was measured with the animal standing on a clean concrete floor and with its head up using a calibrated meter. The heart girth (HG) was measured using a tape placed immediately behind the elbows. TcTc was defined as the distance between the dorso-lateral extremities of both *tubera coxae*, and values obtained using callipers. The distance TiTi was measured using a graduated ruler between the caudo-medial aspects of each *tuber ischiadicum*. Near term cattle were not examined as the presence of the fetus within the pelvic entrance made accurate measurements almost impossible.

## Statistical methods

All cows were identified and their measurements recorded in an Excel spread sheet (Microsoft Office Excel, 2007), cleaned and explored and checked by SPSS 16.0 for Windows (SPSS Inc. 233 S. Wacker Drive, Chicago). The variables were tested for normality with the Kolmogorov-Smirnov test and by the Q-Q plots. Animals between 9 and 12 years of age were regrouped within the animals of 8 years for further analyses (referred to as the 8+ group) as the group was rather small.

Simple correlations between the different external and internal measurements were analysed using the Pearson correlation coefficient; also, within management of parturition. Partial correlations were corrected for age and type of calving.

Single associations between each separate body measure and age of the mother and type of calving (CS - calving *per vaginam*) were investigated using a multivariate mixed ANOVA with herd as a random factor (SAS 9_2).

The influence of external measurements and age on the inner pelvic dimensions was investigated using a mixed multivariable general linear regression model. First univariable ANOVA was performed for the internal pelvic dimensions (PW, PH and PA) with every single factor (BoW, WH, HG, TcTc, TiTi and age) separately with herd as random factor. Only factors with a $P < 0.20$ were taken into the model. Whenever a high correlation between two factors existed ($r > 0.60$), the biological most relevant factor was chosen for further analyses. The significance level for the analyses was set at $P < 0.05$.

Finally, generalized estimating equation methods in SPSS 16.0 for Windows (SPSS Inc. 233 S. Wacker Drive, Chicago) were used to estimate the likelihood of naturally calving of the obtained dataset by the use of the internal pelvic dimensions (PW, PH and PA).

# Results

More than 10% of the animals (56) had calved *per vaginam* at least once. The age of the animals ranged from 2 to 12 years with a mean of 5. The mean external (pelvic and body) and internal measures of the 507 DM-BB cows are given in Table 1, whereas Table 2 overviews the same data divided by age (in years) and type of calving. In all body and internal measurements a large variation was noticed between and within age categories. The variation in PA within each age category is shown in Figure 1.

**Table 1** The mean, standard deviation (StD), minimum (Min) and maximum (Max) value of age, external (BoW = body weight, WH = withers height, HG = heart girth, TcTc = distance between the *tubera coxae*, TiTi = distance between the *tubera ischiadica*) and internal measurements (PW= pelvic width, PH = pelvic height, PA = pelvic area) of 507 DM-BB heifers and cows

| | | Mean | StD | Min | Max |
|---|---|---|---|---|---|
| Age | years | 5.0 | 1.7 | 2.0 | 12.0 |
| BoW | kg | 672.8 | 136.9 | 365.0 | 998.0 |
| WH | cm | 126.9 | 6.8 | 100.0 | 150.0 |
| HG | cm | 208.5 | 16.9 | 144.0 | 280.0 |
| TcTc | cm | 58.9 | 6.2 | 28.0 | 71.5 |
| TiTi | cm | 14.6 | 2.3 | 8.0 | 26.0 |
| PW | cm | 15.2 | 2.1 | 8.0 | 20.0 |
| PH | cm | 18.8 | 1.9 | 11.0 | 23.0 |
| PA | cm | 288.5 | 60.9 | 99.0 | 440.0 |

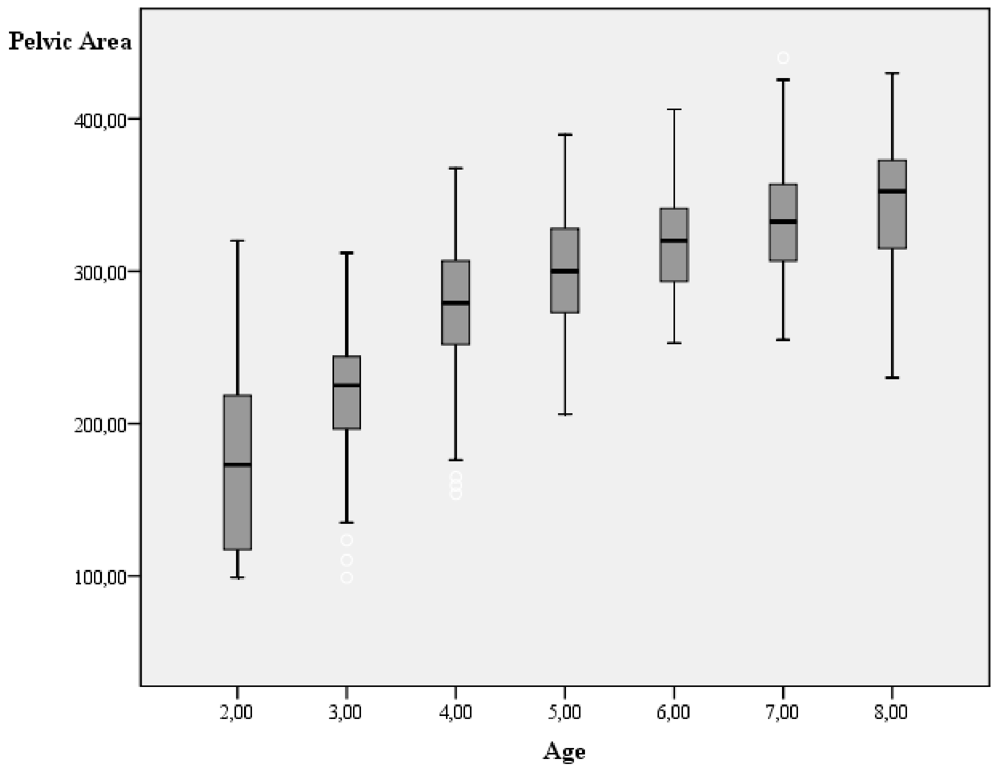


**Figure 1** A box plot showing the median pelvic area (cm$^2$) and the variation for different age categories (in years) of the 507 DM-BB animals

Simple and partial correlations and simple correlations per class between the external (body and pelvic) and internal pelvic sizes are illustrated in Table 3 (corrected for age) and 4 (corrected for type of calving). The TcTc showed a higher correlation with the internal measurements than TiTi. Surprisingly, the correlations between other body measures such as HG and WH were even higher. Partial correlations corrected for age (r = -0.32 - 0.91) and type of calving (r = 0.12 - 0.95) were lower compared to the simple correlations of the total dataset (r = 0.28 - 0.95). The simple correlations seen in animals calving *per vaginam* were also lower compared to those from animals that have calved by CS.

**Table 2** The mean and standard deviation of external and internal measurements divided in type of calving for cows (CS = Caesarean Section, *PV* = *per vaginam*) ranged from 2 till 8+ years

| | | | **External measurements**[b] | | | | | **Internal measurements**[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age[a] | Parturition | N | BoW (kg) | WH (cm) | HG (cm) | TcTc (cm) | TiTi (cm) | PW (cm) | PH (cm) | PA (cm) |
| 2 | *CS* | 12 | | 118.7 ± 5 | 194.3 ± 17 | 50.0 ± 4 | 14.7 ± 2. | 12.3 ± 2 | 15.0 ± 2 | 188.6 ± 58 |
| | *PV* | | | | | | | | | |
| 3 | *CS* | 90 | 486.3 ± 81 | 119.7 ± 5 | 193.3 ± 12 | 53.5 ± .5 | 13.7 ± 2 | 13.0 ± 2 | 17.0 ± 2 | 222.0 ± 43 |
| | *PV* | | | | | | | | | |
| 4 | *CS* | 88 | 592.1 ± 62 | 125.6 ± 5$^{*}$ | 205.8 ± 11 | 58.4 ± 5 | 14.7 ± 2 | 14.7 ± 2$^{*}$ | 18.6 ± 1 | 273.5 ± 42$^{*}$ |
| | *PV* | 7 | | 130.2 ± 5 | 207.7 ± 14 | 59.5 ± 6 | 16.2 ± 4 | 15.9 ± 1 | 19.6 ± 1 | 311.8 ± 18 |
| 5 | *CS* | 90 | 677.8 ± 90 | 127.5 ± 4$^{**}$ | 212.5 ± 14 | 59.9 ± 5 | 14.9 ± 2 | 15.6 ± 1 | 19.2 ± 1$^{*}$ | 300.0 ± 40$^{*}$ |
| | *PV* | 5 | | 132.9 ± 3 | 222.0 ± 9 | 57.2 ± 9 | 15.3 ± 2 | 16.7 ± 1 | 20.3 ± 1 | 339.6 ± 31 |
| 6 | *CS* | 69 | 730.8 ± 76 | 139.5 ± 4$^{**}$ | 216.6 ± 11 | 61.9 ± 4 | 14.6 ± 2 | 16.2 ± 1$^{*}$ | 19.3 ± 1$^{**}$ | 314.1 ± 33$^{**}$ |
| | *PV* | 10 | | 133.6 ± 3 | 220.3 ± 8 | 62.7 ± 2 | 15.4 ± 3 | 17.0 ± 1 | 20.5 ± 1 | 348.9 ± 31 |
| 7 | *CS* | 53 | 782.4 ± 897 | 132.0 ± 5 | 222.7 ± 12 | 63.3 ± 5 | 15.3 ± 2 | 16.6 ± 2 | 19.9 ± 1$^{*}$ | 329.8 ± 40 |
| | *PV* | 14 | 810.0 | 130.1 ± 6 | 219.0 ± 9 | 61.9 ± 3 | 15.5 ± 2 | 16.8 ± 2 | 20.6 ± 1 | 345.6 ± 41 |
| 8+ | *CS* | 49 | 770.3 ± 87 | 131.9 ± 6 | 222.0 ± 10 | 63.0 ± 4 | 15.3 ± 2 | 17.0 ± 1 | 20.0 ± 1$^{**}$ | 342.5 ± 39 |
| | *PV* | 20 | 866.0 | 133.6 ± 7 | 217.6 ± 15 | 63.4 ± 5 | 15.4 ± 4 | 16.6 ± 2 | 21.0 ± 1 | 347.5 ± 50 |
| Total | *CS* | 451 | 666.2 ± 133 | 126.6 ± 6$^{***}$ | 208.4 ± 16$^{***}$ | 59.0 ± 6$^{**}$ | 14.6 ± 2$^{**}$ | 15.1 ± 2$^{***}$ | 18.6 ± 2$^{***}$ | 248.8 ± 57$^{***}$ |
| | *PV* | 56 | 882.7 ± 82 | 132.1 ± 6 | 217.3 ± 12 | 61.1 ± 5 | 15.6 ± 3 | 16.6 ± 2 | 20.6 ± 1 | 342.7 ± 40 |

a the number of animals of 9 (9 animals), 10 (12 animals), 11 (2 animals) and 12 (2 animals) years of age was rather small, so these animals were regrouped within the animals of 8 years (referred to as the 8+ group); b BoW = body weight, WH = withers height, HG = heart girth, TcTc = distance between the *tubera coxae*, TiTi = the distance between the *tubera ischiadica*; c PW = pelvic width, PH = pelvic height, PA = pelvic area; * $P < 0.05$, ** $P < 0.01$, ***$P < 0.001$, Significant differences between CS and *PV* assessed by a multiple mixed ANOVA

**Table 3** Simple correlations (r; diagonally above) and partial correlations adjusted for age (r; diagonally below) between the body measurements (body weight [BoW], withers height [WH], heart girth [HG], distance between the *tubera coxae* [TcTc], distance between the *tubera ischiadica* [TiTi], pelvic width [PW], pelvic height [PH], pelvic area [PA])

| Age | | External measurements | | | | | Internal measurements | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BoW | WH | HG | TcTc | TiTi | PW | PH | PA |
| External measurements | BoW | | 0.865** | 0.798** | 0.596** | 0.316** | 0.709** | 0.355** | 0.650** |
| | WH | 0.605** | | 0.781** | 0.682** | 0.338** | 0.715** | 0.672** | 0.740** |
| | HG | 0.760** | 0.623** | | 0.804** | 0.453** | 0.711** | 0.689** | 0.741** |
| | TcTc | 0.263** | 0.484** | 0.687** | | 0.373** | 0.614** | 0.581** | 0.627** |
| | TiTi | 0.197** | 0.237** | 0.393** | 0.287** | | 0.281** | 0.217** | 0.263** |
| Internal measurements | PW | 0.401** | 0.495** | 0.496** | 0.366** | 0.158** | | 0.747** | 0.954** |
| | PH | -0.324** | 0.434** | 0.471** | 0.326** | 0.074** | 0.557** | | 0.903** |
| | PA | 0.213** | 0.518** | 0.530** | 0.368** | 0.124** | 0.916** | 0.828** | |

**Table 4** Simple correlations (r; diagonally above), partial correlations adjusted for type of calving (r; diagonally below) and correlations per class (CS – *per vaginam* [*PV*]; diagonally below) between the nine body measurements (body weight [BoW], withers height [WH], heart girth [HG], distance between the *tubera coxae* [TcTc], distance between the *tubera ischiadica* [TiTi], pelvic width [PW], pelvic height [PH], pelvic area [PA])

| **Type of calving** | | External measurements | | | | | | Internal measurements | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BoW | WH | HG | TcTc | TiTi | PW | PH | PA |
| External measurements | BoW | *Partial* | | 0.865** | 0.798** | 0.596** | 0.361** | 0.709** | 0.355** | 0.650** |
| | | *CS* | | | | | | | | |
| | | *PV* | | | | | | | | |
| | WH | *Partial* | 0.779** | | 0.781** | 0.682** | 0.338** | 0.715** | 0.672** | 0.740** |
| | | *CS* | 0.780** | | | | | | | |
| | | *PV* | 0.673 | | | | | | | |
| | HG | *Partial* | 0.853* | 0.754** | | 0.804** | 0.453** | 0.711** | 0.689** | 0.741** |
| | | *CS* | 0.860* | 0.746** | | | | | | |
| | | *PV* | a | 0.698** | | | | | | |
| | TcTc | *Partial* | 0.565** | 0.654** | 0.788** | | 0.373** | 0.614** | 0.581** | 0.627** |
| | | *CS* | 0.589** | 0.637** | 0.782** | | | | | |
| | | *PV* | a | 0.561* | 0.568** | | | | | |
| | TiTi | *Partial* | 0.266** | 0.275** | 0.406** | 0.329** | | 0.281** | 0.217** | 0.263** |
| | | *CS* | 0.284** | 0.260** | 0.378** | 0.291** | | | | |
| | | *PV* | 0.291 | 0.207 | 0.335** | 0.284* | | | | |
| Internal measurements | PW | *Partial* | 0.682** | 0.678** | 0.677** | 0.579** | 0.217** | | 0.747** | 0.954** |
| | | *CS* | 0.686* | 0.701** | 0.698* | 0.585** | 0.183** | | | |
| | | *PV* | a | 0.274* | 0.245 | 0.238 | 0.222 | | | |
| | PH | *Partial* | 0.272** | 0.616** | 0.645** | 0.539** | 0.123** | 0.709** | | 0.903** |
| | | *CS* | 0.310** | 0.634** | 0.657** | 0.533** | 0.125** | 0.734** | | |
| | | *PV* | -0.512 | 0.121 | 0.161 | 0.133 | -0.192 | 0.217 | | |
| | PA | *Partial* | 0.613* | 0.698** | 0.706** | 0.592** | 0.182** | 0.950** | 0.883** | |
| | | *CS* | 0.624* | 0.723** | 0.728** | 0.599** | 0.165** | 0.953** | 0.897** | |
| | | *PV* | -0.512 | 0.265* | 0.263* | 0.239 | 0.239 | 0.910** | 0.601** | |

a Cannot be computed because at least one of the variables is constant; * Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

Using multivariate mixed ANOVA a significant association was found between type of calving and WH ($P < 0.05$), TcTc ($P < 0.05$), TiTi ($P < 0.001$), PH and PA ($P < 0.001$). DM-BB cows that had given birth *per vaginam* generally had larger body and pelvic measures compared to animals that were delivered by CS (Table 2). Age was significantly associated with all the body measurements ($P < 0.001$). An increase in age corresponded with an increase in body measurements.

External body measurements and age were correlated to internal pelvic dimensions as shown above (Table 3 and 4). Models for PW, PH and PA describing the relation with external measurements of the entire sample of cows are designated by the equations (e.a. PW = -2.72 - 2.27 Age + 0.03 HG + 0.10 WH) given in Table 5. Only age, HG and WH remained significant in all three models. Correlation coefficients of the models were 65% for PW, 65% for PH and 72% for PA. Table 3 and 4 already revealed a higher importance of WH and HG compared to TcTc and TiTi, in order to predict internal measurements.

Figure 2, 3 and 4 show the probability of calving *per vaginam* by the use of PW, PH, and PA. When the maximum value of 20.0 cm for PW in the present dataset was used, a probability for calving *per vaginam* was estimated at 49.3% (95% Confidence Interval [CI]: 29.3 - 69.5%; Figure 2), whereas with the minimum measured PW (8.5 cm) the probability for calving *per vaginam* was reduced to 0.4% (95% CI: 0.0 - 2.4%; Figure 2). The mean PW found in the present dataset (15.2 cm; Table 1) corresponds with a chance of calving *per vaginam* of 8.7% (95% CI: 3.8 - 18.9%; Figure 2). For the PH, the minimum (11.0 cm; Table 1) and maximum (23.0 cm; Table 1) values measured, gave a probability of calving *per vaginam* of 0.0% (95% CI: 0.0% - 0.0%) and 79.8% (95% CI: 53.5 - 93.1%), respectively (Figure 3). With the mean PH (18.8 cm; Table 1) measured in this dataset the chance of calving *per vaginam* was 4.7% (95% CI: 2.3% - 9.1%; Figure 3). For the PA, the probability of calving *per vaginam* was 6.6% (95% CI: 2.9 - 14.0%), 0.0% (95% CI: 0.0% - 0.5%) and 69.7% (95% CI: 45.3% - 86.5%; Figure 4) with corresponding mean (288.5 $cm^2$), minimum (99.0 $cm^2$) and maximum (444.0 $cm^2$) values (Table 1).

**Table 5** Equations to predict the pelvic width (PW), the pelvic height (PH) and the pelvic area (PA) from body measures (HG = heart girth; WH = withers height) and age using a mixed multi variable general linear regression model

| | Parameter[a] | Estimate | Std. Error | *P* |
|---|---|---|---|---|
| PW | Intercept | -2.72 | 1.64 | NS[b] |
| | Age (years) | | | |
| | 2 | -2.27 | 0.43 | <0.001 |
| | 3 | -1.68 | 0.28 | <0.001 |
| | 4 | -0.84 | 0.24 | 0.001 |
| | 5 | -0.38 | 0.26 | NS |
| | 6 | -0.04 | 0.24 | NS |
| | 7 | -0.10 | 0.24 | NS |
| | HG (cm) | 0.03 | 0.01 | <0.001 |
| | WH (cm) | 0.10 | 0.16 | <0.001 |
| PH | Intercept | 3.03 | 1.53 | <0.05 |
| | Age (years) | | | |
| | 2 | -3.48 | 0.41 | <0.001 |
| | 3 | -1.82 | 0.27 | <0.001 |
| | 4 | -0.08 | 0.22 | <0.001 |
| | 5 | -0.56 | 0.22 | <0.05 |
| | 6 | -0.72 | 0.22 | <0.01 |
| | 7 | -0.44 | 0.22 | <0.05 |
| | HG (cm) | 0.02 | 0.01 | <0.001 |
| | WH (cm) | 0.09 | 0.01 | <0.001 |
| PA | Intercept | -244.23 | 43.26 | <0.001 |
| | Age (years) | | | |
| | 2 | -85.62 | 11.46 | <0.001 |
| | 3 | -60.78 | 7.49 | <0.001 |
| | 4 | -32.71 | 6.36 | <0.001 |
| | 5 | -18.76 | 6.13 | <0.01 |
| | 6 | -13.74 | 6.30 | <0.05 |
| | 7 | -9.59 | 6.31 | NS |
| | HG (cm) | 0.87 | 0.18 | <0.001 |
| | WH (cm) | 3.02 | 0.41 | <0.001 |

a Example of equations for 2 year old animal => b Not Significant

PW = -2.72 - 2.27 Age + 0.03 HG + 0.10 WH

PH = 3.03 - 3.48 Age + 0.02 HG + 0.09 WH

PA = -244.23 - 85.62 Age + 0.87 HG + 3.02 WH

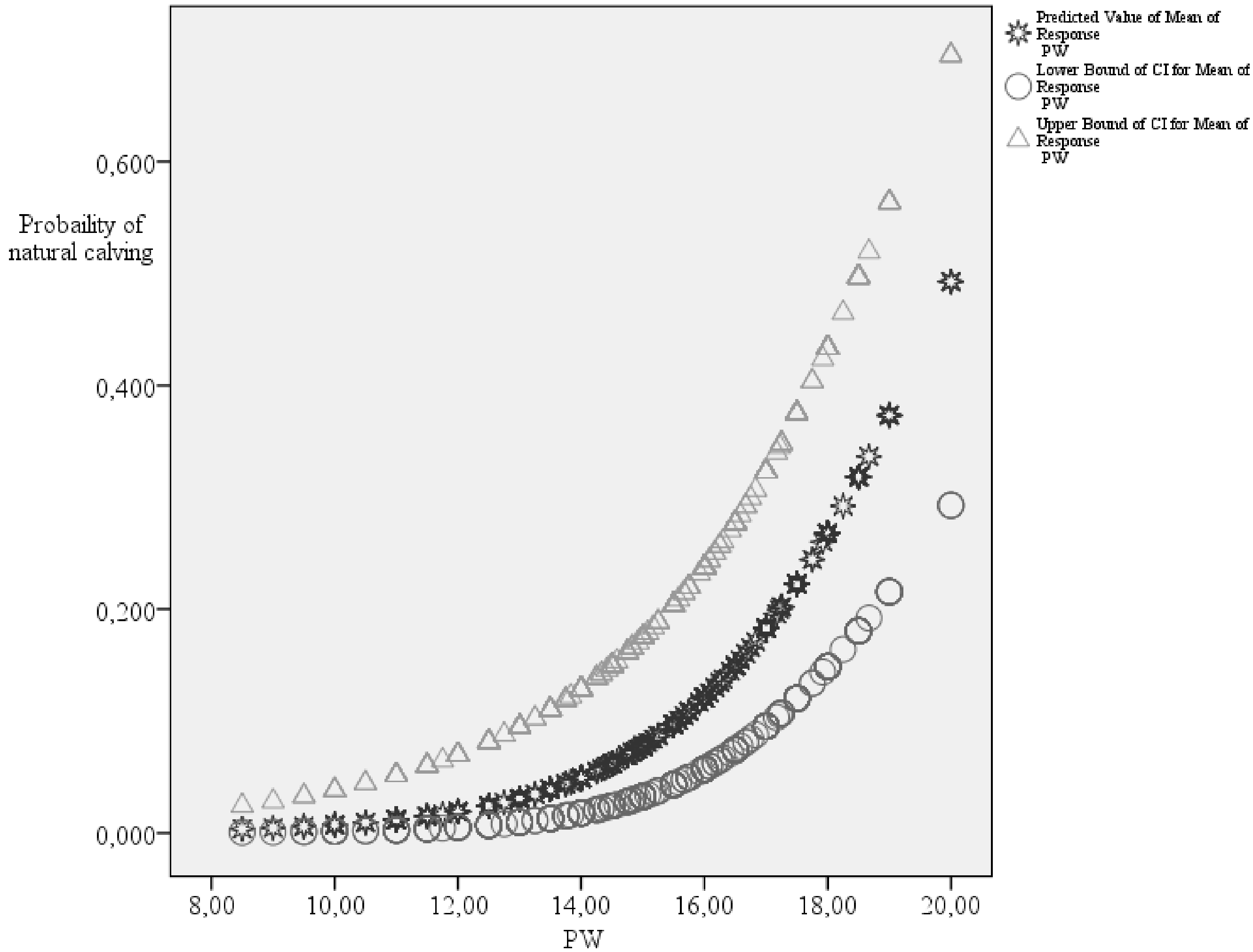


**Figure 2** Probability of calving *per vaginam* based on the pelvic width (PW in cm), with the predicted value, the lower and upper bound of the 95% Confidence Interval (CI) assessed by a generalized estimating equation method

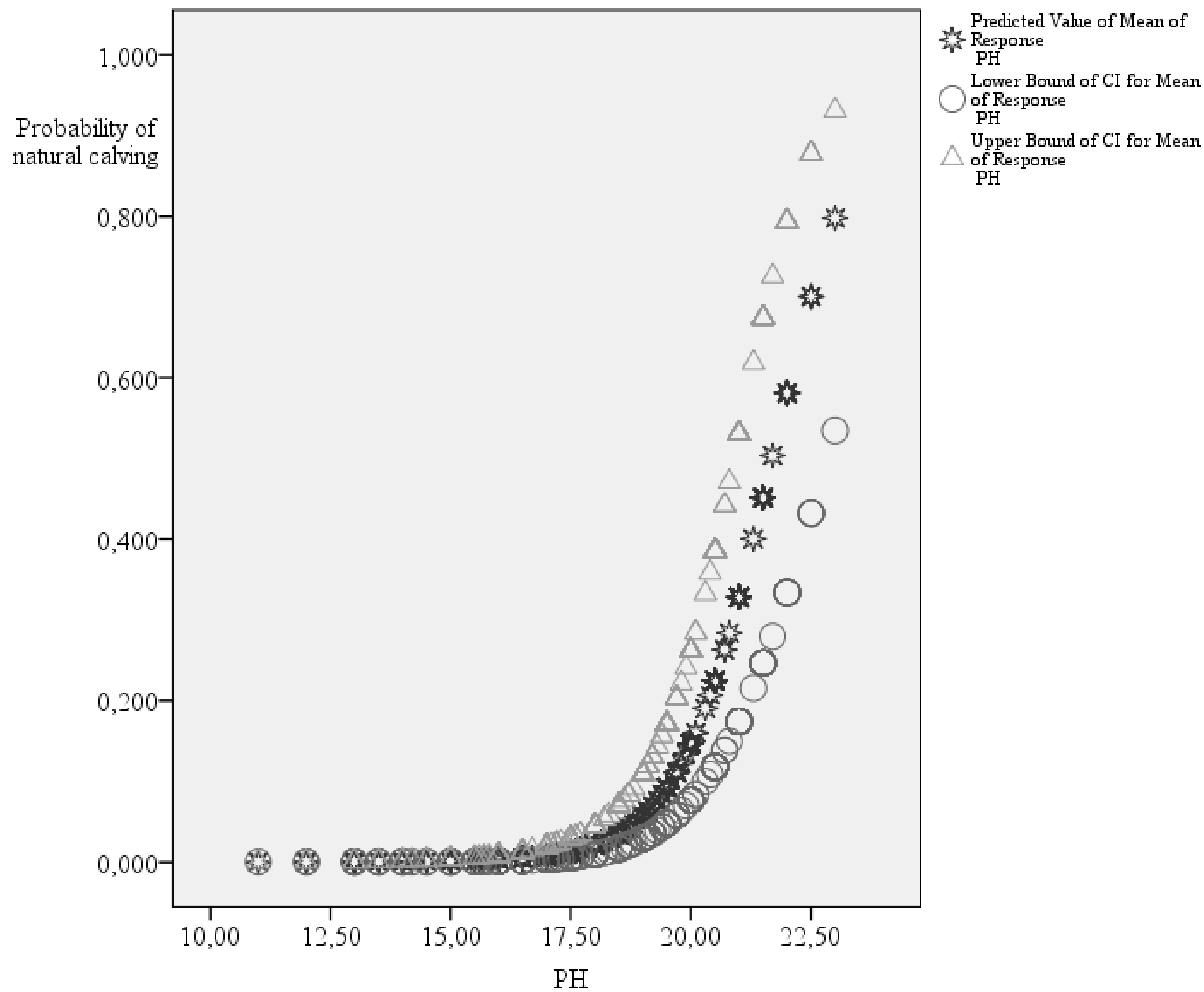


**Figure 3** Probability of calving *per vaginam* based on the pelvic height (PH in cm), the predicted value, the lower and upper bound of the 95% Confidence Interval (CI) assessed by a generalized estimating equation method

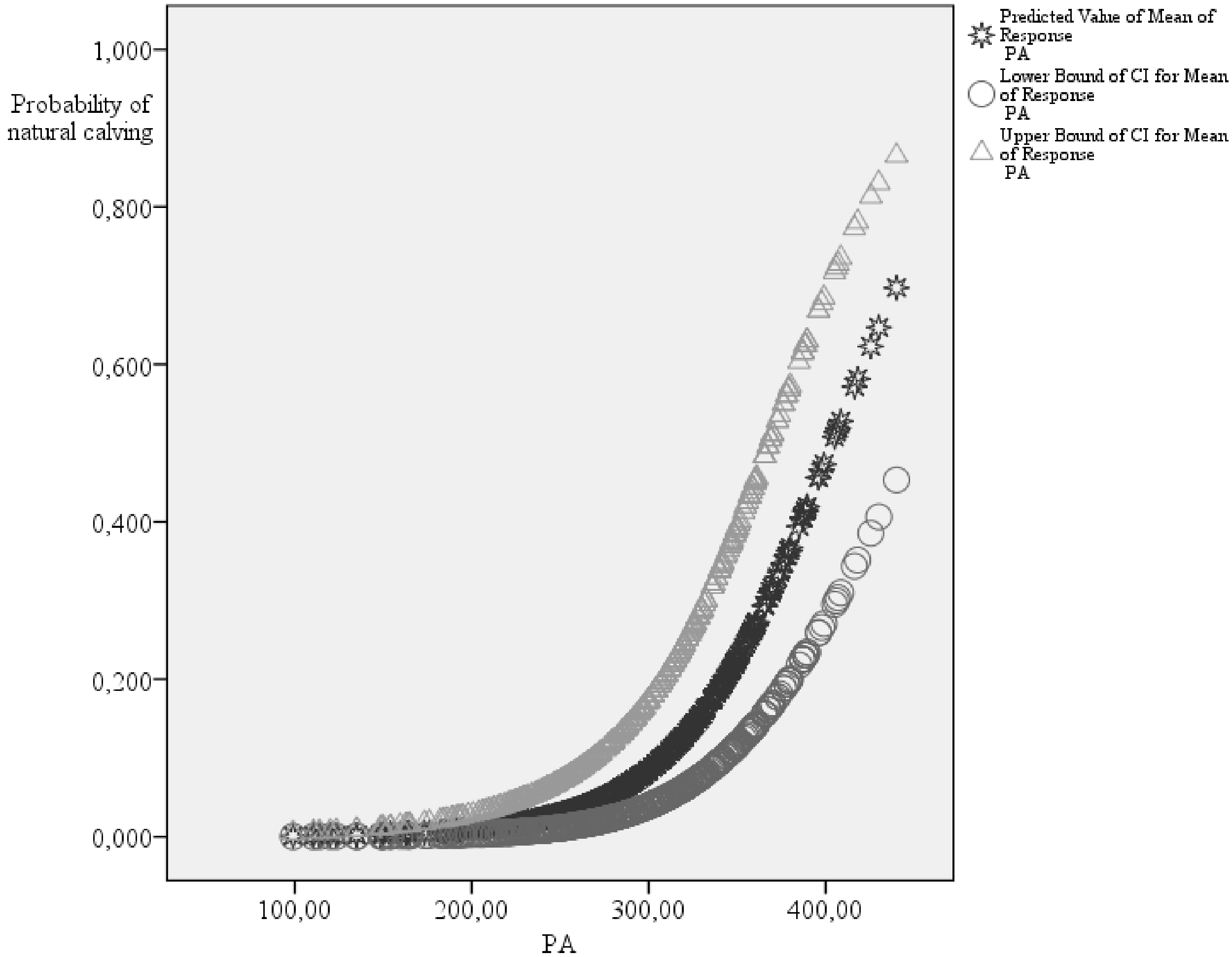


**Figure 4** Probability of calving *per vaginam* based on the pelvic area (PA in $cm^2$), the predicted value, the lower and upper bound of the 95% Confidence Interval (CI) assessed by a generalized estimating equation method

# DISCUSSION

The objective of this study was to explore the variation among the different internal and external pelvic measurements in the phenotypically DM-BB cows, which may open opportunities to select for less dystocia within this breed. Selection towards an increase in PA is only feasible if there is a substantial variation for this trait among the animals of the DM-BB breed in combination with a moderate to high heritability for this specific trait. Heritability for pelvic size is known to be moderate to high (0.43 - 0.59 for PH, 0.36 - 0.82

for PW and 0.53 - 0.68 for PA) in Simmentals (Benyshek and Little, 1982) and other breeds (Morrison et al., 1986; Green et al., 1988). In Angus and Hereford it has furthermore been shown that selection to increase the PA can be accomplished without causing significant increases in cow size (Morrison et al., 1986). Even so, a small increase the body weight would not necessarily be unfavourable in the DM-BB breed as it will result in higher meat production per animal and thus higher revenues if conformation is retained. For the DM-BB population explored in the present study, the mean PW, PH and PA were 15.2 ± 2.1 cm, 18.8 ± 1.9 cm and 288.5 ± 60.9 $cm^2$ respectively. Our results demonstrate a substantial variation in the pelvic sizes (Tables 1 and 2, Figure 1 for PA), so together with a known high heritability for these sizes in other breeds, selection towards an increase in pelvic size in DM-BB cows may still be possible. Moreover, the differences for these traits between animals calving *per vaginam* versus delivered by CS are rather small, namely 1.5 and 2.0 cm for PW and PH respectively (Table 2), illustrating that the gain in pelvic size needed is surely not unreachable. The latter difference is not present in each age category and it can be seen that in some cases animals that calved by CS have pelvic sizes in the order of those of animals that calve *per vaginam*, which suggest more DM-BB animals may calve *per vaginam* when given the opportunity.

Other groups have been studying the pelvic dimension in the DM-BB breed (Coopman et al., 2003, 2004; Murray et al., 1999, 2002). Coopman et al. (2003, 2004) measured pelvises only on the carcass and found a mean PH of 23 (17 - 29) cm in female DM-BB carcasses. The smaller PH found in our study (mean: 18.8 cm), is not a result of age differences as the animals in the study of Coopman et al. (2003, 2004) ranged between 1 and 12 years (compared to 2 - 12 years in our study), but can possibly be explained by the measuring method applied as in the DM-BB a small discrepancy was shown between pelvimetry and slaughterhouse measurements (Chapter 5.1). Another potential explanation is the genetic improvement which occurred during the last ten years in the DM-BB breed in Belgium resulting in a higher muscling score and meaty type, whilst decreasing height and length (Hanset, 2004, 2005). The same author showed that improvements for rump slope, chest width, tail set and PW were counteracted by a slight decrease for pelvis and body length. Murray et al. (1999, 2002) – who measured DM-BB cows both in the UK and in Belgium, either by CS or by delivery *per vaginam*, found a mean PA of 325.7 ± 45.00 $cm^2$ for the Belgium group (CS were used exclusively to manage parturition) and 324.7 ± 57.0 $cm^2$ for the UK group (which included cows that were allowed to calve naturally). The difference in PA with the data found in our study (mean PA: 288.5 $cm^2$) cannot be explained by the parturition management as the PA in Murray's Belgian group is still larger. Although among the British DM-BB cows, selection towards natural calving had been rigorously performed, resulting in a larger PA (Murray et al., 2002). There is an age discrepancy between the animals examined in both studies possibly explains part of the difference, as Murray et al. (1999, 2002) measured animals that had calved at least once, while in our experiment also pre-calving heifers were included (n = 17). The present difference in the PA between our study and that of Murray et al. (1999, 2002) again suggests a decrease in the pelvic dimension due to genetic improvement during the last 10 years.

The best estimators to predict internal pelvic sizes in our study were not external pelvic measures (TcTc and TiTi) but WH and HG. This partly confirms the observations of Coopman et al. (2003) that the best estimators of inner pelvic sizes were live weight, WH and TcTc. In contrast, Murray et al. (2002) only used external pelvic measurements in order to predict the internal pelvic sizes. However, based on the pooled dataset, we can say that the influence of external pelvic measurements demonstrated to be too low to be used in the final model. Using the HG and WH in the models described in Table 5, a farmer can estimate the inner pelvic dimensions correctly with a reliability of 65% for PW, of 65% for PH and 72% for PA, which is merely moderate. Still approximately 30% of the variation in inner pelvic sizes has to be explained by other (unknown) factors or even coincidence. Consequently, internal measurements by pelvimetry seem to be the best option to reduce dystocia. In contrast with other authors (Coopman et al., 2003, 2004; Murray et al., 1999, 2002) we believe that pelvimetry is an accessible and reliable method for breeders who wish to successfully select for natural calvings (Chapter 5.1). To obtain knowledge about the variation in pelvic size within his herd, the breeder/farmer can ask the assistance of a veterinarian to perform pelvimetry. Applying this technique in the frame of a veterinary herd health program merely brings along extra costs and efforts. Furthermore, the authors think that when pelvimetry is performed by a skilled person, it can be considered completely harmless and without any adverse effect on the animals' welfare. In fact, the procedure can be compared with pregnancy diagnosis or artificial insemination. The use of pelvic measurements including pelvimetry to predict dystocia on an individual basis is however limited since a lot of other factors contribute to the ease of calving, but it can be used to predict herd problems (Larson et al., 2004). The best way is to compare the pelvic measures within a cohort of equally aged animals and avoid breeding the heifers with an extremely small pelvis or breed them with high accuracy easy calving bulls. Producers who annually evaluate pelvic sizes will be able to set minimal borderlines that work for their individual operation.

A significant association was found between the body measurements and age, which confirms the findings of other authors (Brown et al., 1982; Basarab et al., 1993). Van Donkersgoed et al. (1990) found that the positive predictive value of pelvic area measurements to estimate the risk for dystocia was also lower in young cattle, whereas Basarab et al. (1993) found that heifer age, irrespective of PA, body weight and hip height, was an important trait in predicting dystocia. Overall, farmers using PA should better take the age into account. Age adjusted values can be used to allow producers to compare the differences in pelvic size between animals (Deutscher, 1988). To predict the adult PA of DM-BB heifers, knowledge of the pelvic growth pattern within the DM-BB breed should be gathered like in other breeds. Green et al. (1988) found that pelvic size increased up to 5 years of age and that PW is slightly slower in maturation than PH (in Angus, Brangus, Hereford, Red Angus and Simmental breeds). Multiparous cows have a mature skeletal structure and body size and are therefore capable of giving birth to heavier calves (Houghton and Corah, 1989; Zollinger and Hansen, 2003). An ongoing study, in which we are investigating pelvic growth in female DM-BB animals, will provide us with data about the rate and the duration of this growth. So, estimating at what age a DM-BB animal will be able to calve is still difficult as the age of maturation of the PA in this breed is not known and pelvic sizes in the adult cows (> 6 years) in our data set gives probabilities of calving *per vaginam* of only 15 - 20% (figure 2, 3 and 4). Furthermore, other factors besides the PA of the dam contribute to calving ability and thus to the estimation of calving *per vaginam* of the individual animal.

# CONCLUSION

Considering the existing variation in the DM-BB pelvic dimension and high heritability estimates of pelvic sizes (in other breeds; Benyshek and Little, 1982; Morrison et al., 1986; Green et al., 1988), selection towards larger pelvic sizes in this breed must be possible. Therefore, Estimated Breeding Values (EBV's) for pelvic measurements should be determinated. Gathering the information to determine these EBV's can be effortlessly done as pedigree animals are already registered and pelvimetry data can relatively easy be added. However, BB breeders should be encouraged to register these data as soon as possible as the PA already decreased 37 $cm^2$ (difference in PA between animals measured by Murray et al. In 2002 and the animals measured in the present study) in 6 years through the selection towards better muscled animals. Simultaneously, the focus within selection for decreasing dystocia should also be on lower birth weight and decreased muscular conformation at birth in the DM-BB calf. Taking the bulls' EBVs for these traits into account at the same time will help in decreasing the number of CSs in the DM-BB population.

# ACKNOWLEDGEMENTS

We greatly acknowledge Prof. A. de Kruif and Prof J. Mee for reviewing the manuscript.

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# THE CALF'S POINT OF VIEW: ANALYSIS OF BODY MEASUREMENTS OF NEWBORN PUREBRED BELGIAN BLUE CALVES (CHAPTER 5.3)

Modified from:

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2009

Analysis of body measurements of newborn purebred Belgian Blue calves.

Animal (accepted for publication).

# Abstract

At calving, animals of the double muscled Belgian Blue (DM-BB) breed are compromised by the incompatibility in size and shape of the dam and her calf, resulting in a very high incidence of dystocia problems. To clarify which body parts of the calf are of decisive importance to allow natural delivery and to investigate both the mean value as well as the variation among these body sizes within this breed (variation being an important condition for selection), measurements of nine body parts (body weight at birth [BW], body length [BL], length of the head [LH], shoulder width [SW], hip width [HW], heart girth [HG], withers height [WH] and the circumference of the fetlock of both the front [CFF] and the hind leg [CFH]) were assessed in 147 newborn DM-BB calves on 17 farms. Simple and partial correlations were assessed and we examined whether environmental factors (gender of the calf, parity of the cow, type of calving, season of birth and time of measurement after birth) were significantly associated with these specific calf measurements. The mean BW was 49.2 ± 7.1 kg. The average BL was 56.4 ± 4.5 cm and the mean LH 24.4 ± 2.3 cm. Measurements obtained for SW and HW were 22.4 ± 2.2 cm and 22.9 ± 2.1 cm respectively, while the mean WH was 71.1 ± 4.7 cm. Measurements of circumferences revealed a CFF of 17.9 ± 1.1 cm, a CFH of 18.0 ± 1.0 cm and a mean HG of 78.0 ± 5.4 cm. Partial correlations of the BW with eight body measurements were significant ($P < 0.01$) and ranged between 0.17 - 0.85, 0.42 - 0.88 and 0.24 - 0.88 when corrected for gender, parity and type of calving, respectively. BL ($P < 0.01$) and the CFF and CFH ($P < 0.001$) are larger in bull calves than in heifer calves. Calves born via Caesarean Section (CS) had broader SW ($P < 0.01$) and HW ($P < 0.01$) when compared with calves born after natural calving (defined as born *per vaginam* without assistance or with slight traction). Sizes of calves born out of multiparous cows were generally larger than of calves born out of heifers (SW: $P < 0.001$; HW: $P < 0.05$). As SW and HW are the broadest points of a BB calf, they are both candidates for being the limiting measures for calving ease, but the difference between HW and SW for the total dataset was not different from zero ($P > 0.05$). In contrast to male calves where also no significant difference (between HW and SW) could be found, in female calves the difference between HW and SW was significantly different from zero ($P < 0.001$),

thus in female calves the HW is the most limiting factor of the calf's body. The significant variation in some body measures between the calves and the strong correlation within these sizes raises the possibility of selection towards smaller calves aiming to limit the dystocia problem in the BB breed. Furthermore, based on our results we were able to build equations for the farmer to use at the moment of calving containing the LH, the CF and the calf's gender to estimate SW and HW, the limiting body parts of the calf to be born naturally. Together with the knowledge of the pelvic size of the dam, this information gives the obstetrician or the farmer a more accurate prediction of the probability of natural calving at parturition.

## Introduction

In cattle, dystocia is most frequently due to feto-maternal, or more specifically feto-pelvic disproportion (Mee, 2008). Generally, there is a close correlation between the calf's birth weight (BW) and the probability of dystocia (Bellows et al., 1971a,b; Laster, 1974; Anderson and Bullock, 2000; Wang et al., 2000; Zollinger and Hansen, 2003), since it explains around 50% of the variability in the frequency of difficult calvings (Meijering, 1984; Freking, 2000). Johanson and Berger (2003) demonstrated that the odds of dystocia increased by 13% by every kilogram increase of birth weight. Other factors that have been reported to influence the incidence of dystocia are: the calf's body conformation (Morrison et al., 1985) and gender, its sire, the dam's age and pelvic area (PA; Laster, 1974; Bellows and Short, 1978), her weight and body condition (Berry et al., 2007) and finally some environmental effects such as the ambient temperature (Brinks et al., 1973; Anderson, 1990; Colburn et al., 1997). In addition, inadequate heifer growth and development, abnormalities in hormone profiles during pregnancy and at parturition or abnormal position of the calf at the time of birth will also cause dystocia (Berger et al., 1992; Anderson and Bullock, 2000). As well as the importance of the BW, the body conformation of the calf has also been suggested as significantly contributing to the ease of calving. In the study of McGuirk et al. (1998), an increase in dystocia was associated with larger calves and calves with a better conformation (more developed muscles). More specifically amongst body measurements, the calf's head circumference and shoulder width (SW) appeared to be the most important predictors of the likely severity of dystocia (Colburn et al., 1997). In addition the dimension of the calf's heart girth (HG) seemed to have a significant association with dystocia (Thomson and Wiltbank, 1983). Hindson (1978) indicated that in this context, specific measurements of the size of the fetal thorax would possibly be a better predictor than fetal BW.

In a study by Arthur et al. (1988), which was performed in double muscled cattle breeds, no significant association between the BW of the calf and of the weight and body condition score of the dam, and the incidence of dystocia could be demonstrated. As the muscular hypertrophy significantly increases the width of the fore and hindquarters of the double muscled calves, these authors suggested that this typical conformation significantly contributes to the incidence of dystocia, maybe even more than BW. Furthermore the latter was supported by the fact that the incidence of dystocia increase when double muscled animals are mated to produce calves with muscular hypertrophy. At parturition, dystocia in double muscled Belgian Blue (DM-BB) breed is mainly due to feto-maternal disproportion mostly caused by the double-muscled phenotype of the calf, originating from a deletion in the *mh*-gene (Grobet et al., 1997, 1998; Kambadur et al., 1997, McPherron and Lee, 1997, Karim et al., 2000). This *mh*-gene – which is responsible for the regulation of muscular growth – is blocked in its function, resulting in enhanced muscular development of mostly shoulder, loin and hindquarter regions, resulting in animals with an excellent carcass conformation, but with the disadvantage of a significantly increased incidence of dystocia (Olivier and Cartwrigth, 1968). Cases of severe dystocia requiring a caesarean operation are usually those caused by a disproportion between shoulders, hip or rump of the fetus and the anterior pelvic canal or pelvic opening of the double muscled dam (Ménissier and Foulley, 1979).

According to the opinions of skilled herdsmen and veterinarians in Belgium, attempts to deliver DM-BB calves *per vaginam* frequently results in dystocia due to so-called 'hip lock' and the subsequent death of a valuable calf, and in some cases also of the dam. As a consequence in general veterinary practice, elective caesarean operations (CS) are performed in 95 - 99% of DM-BB calvings, without any attempt to deliver *per vaginam* in the

DM-BB in Belgium at calving, sire selection based on calving score index can't be done as the tools for constructing such indices in the DM-BB breed do not yet exist. According to the veterinary practitioners who attend such calvings so-called 'hip-lock', mainly occur at the birth of purebred female DM-BB calves, as these calves are said to have relatively smaller fore, and a significantly larger hind, quarters. Only a very limited number of studies on body measurements and BW of DM-BB calves have been described (West, 1997; Fiems et al., 2001; Coopman et al., 2004). Since the routine use of elective CS has prevented selection of sires and dams for ease-of-calving, improvements in the numbers of normal calvings can only be achieved by attempting to reduce the BW and size of the calf, and the selection of dams with a larger than normal pelvis.

The aim of the present study was to investigate the weight and the body size of newborn DM-BB calves to determine whether there is enough variation within the population to still select for a smaller calf at birth. In addition, we aimed to find associations between several environmental factors (gender, parity of the cow, type of calving, season of birth and time of measurement after birth) and the body sizes measured, and to calculate simple and partial correlations between these body measurements. All these analyses were performed to search for a model to assess the most limiting body sizes of the calf at the moment of parturition using both obtainable body measurements of the calf (such as fetlock circumference) as well as environmental factors (age of the dam, gender of the calf [can be determined by ultrasound during gestation]) that are available at the moment of parturition. In the field this model can then be used at the moment of parturition to estimate the size of the calf. Together with information of the PA of the particular dam this model will give the farmer or veterinarian a more accurate estimation of the possibility of natural calving. Finally, a model to predict the likelihood of calving naturally using the circumference of the fetlock (the only body part accessible at parturition) was tested on our dataset.

# MATERIAL AND METHODS

## Animals and housing

During the all the months of the autumn, winter and spring of 2006 - 2007 body dimensions of 155 DM-BB calves, were recorded on 15 commercial farms, one experimental farm and at the Department of Reproduction, Obstetrics and Herd Health of the Faculty of Veterinary Medicine (FVM) of the Ghent University (Belgium). Data from 147 calves (120 born by CS and 27 per vaginam) were found to be suitable for further analysis. The other 8 calves were removed as 5 of them were dead at or within hour after birth and 3 were not 100% DM-BB calves. Eighty calves (54.4%) were male and sixty-seven (45.6%) female. There were no twins included in the study and all the calves were full term at birth. The calves were delivered from 27 heifers and 120 multiparous cows. Only one heifer calved naturally. Two technicians performed the measurements: one on the commercial farms, and the other in the FVM and on the experimental farm. Both technicians got a training period before starting their measurements.

The DM-BB is managed very intensively with minor variations in nutrition during winter and summer. As it a breed with a relatively short intestinal system compared to other breeds it has to be fed with a very high energy and protein diet to reach the levels for maintenance and growth. Normally animals remain inside until the first calving at around the age of 24 - 26 months. Older animals do go out on the pasture but are also fed with maize silage en concentrates. In our study the animals were housed inside during the whole period of the study, fed by a mixture of maize and grass silage. The husbandry differed between farms. In the experimental farm the animals are housed in loose housing systems until a couple of days before parturition. For better observation they were moved to a tie stable. In 14 of the commercial farms the animals were housed in loose housing systems until the parturition started. In the other commercial farm the animals were housed in a tie stall the whole winter period. At the FVM, the animals arrived a couple of days before partition and were tethered. In four commercial farms and at the FVM the calves were allowed to suckle until weaning at 3 months of age, while in the other eleven commercial farms and in the experimental farm the calves were separated from their mother immediately after birth and fed with milk replacers. In 14 farms the calves were born following natural mating, while in 1 farm all cows were artificially inseminated. In two other farms both artificial and natural breeding were used. In all the farms except one CS was used systematically as a management policy without performing trial traction. In five of these farms calves were born naturally occasionally, defined by born per vaginam without assistance or with slight traction.

## Measurements

The BW, body length (BL; Figure 1b), length of the head (LH; Figure 1a), shoulder width (SW; Figure 1a), hip width (HW; Figure 1a), heart girth (HG; Figure 1b), withers height (WH; Figure 1b) and the circumference of the fetlock of both the right front (CFF) and hind leg (CFH) of the calves were recorded within 72 hours after birth, but not before the calf had stood without assistance to standardize our measurements. Since a calibrated balance was only available in the experimental farm and in the FVM, the BW was only recorded in 45 calves. The calves were weighed immediately after birth, before being completely dry. All the measurements took place on the calf standing on a concrete floor. The BL was defined as the linear distance along the vertebral column from the cranial edge of the lateral *tuberosity* of the *humerus* to the first coccygeal vertebra. The LH was measured as the distance from the mucocutaneous junction of the *planum nasolabiale* to the caudal border of the *os frontalis*. For both these measurements a flexible measuring tape was used. With the calf standing, the SW was measured as the linear distance between the lateral *tuberosity* of the left and right *humerus*. The HW was measured as the linear distance between the *trochanter major* of the left and right *femur*. Both these conformational traits were measured with a pair of callipers, specially designed and calibrated for this use, which were placed on the shoulder- or hip area and pressed as hard as possible. As the animals of the BB breed are double-muscled, it is important to mention that it is not possible to measure from bone to bone and that the muscles have been included especially when measuring the SW and the HW. The HG was assessed as the circumference around the chest measured just caudally to the front legs using a measuring tape. The WH was defined as the linear distance from the dorsal end of the scapula to the floor. The fetlock circumference was determined by placing the measuring tape around the fetlock of the right fore (CFF) and hind leg (CFH), respectively. All measurements were made to the nearest 0.5 cm and performed thrice on the same animal. The calculated average was used for further analyses.

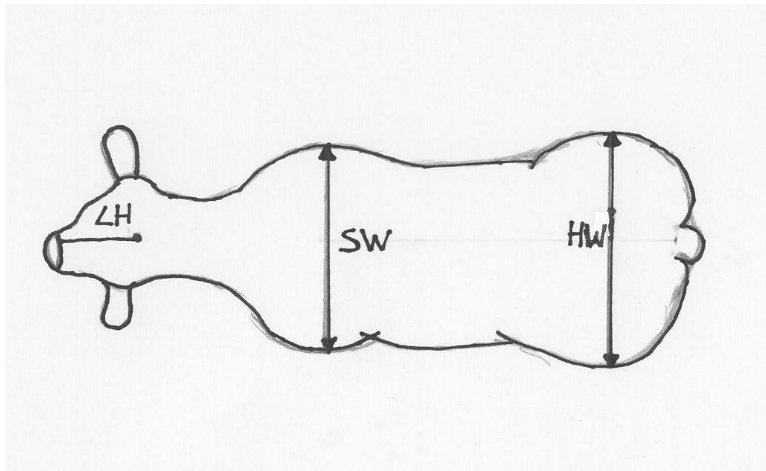


**Figure 1a** Diagram of the performed body measurements, dorsal view from a calf with the length of the head (LH), the shoulder width (SW) and the hip width (HB)

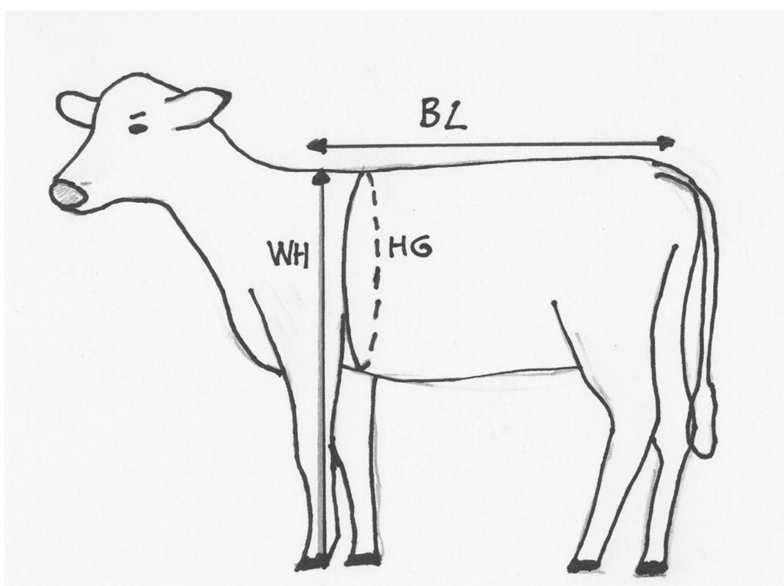


**Figure 1b** Diagram of the performed body measurements, lateral view from a calf with the body length (BL), the withers height (WH) and the heart girth (HG)

## Statistics

The data were checked for errors and the records of 8 calves were removed (5 calves were dead at or within hour after birth and 3 of them were not 100% double muscled BB calves) leaving data from 147 calves for further analysis using SPSS 16.0 (SPSS Inc. 233 S. Wacker Drive, Chicago) to explore and check the data for normality by the use of the Kolmogorov-Smirnov test and Q-Q plots. In all the statistical analyses the technician was taken into account.

Simple correlations between the body measurements on the total dataset as well partial correlations correcting for gender, parity and type of calving were calculated per factor. Next, the dataset was divided per factor in a male and female dataset, in a heifer and cow dataset and in a CS and *per vaginam* dataset and individual correlations for the different classes (male - female, heifer - cow and CS - *per vaginam*) were calculated by the Pearson correlation coefficient.

To look for associations between the body measures and some environmental factors (gender of the calf, parity of the dam [heifer versus multiparous cow], type of calving [CS versus *per vaginam*], season of calving [autumn, winter, spring], and time of measurement after birth [D1, D2, D3]) a multivariate mixed ANOVA was used with herd as random effect (SAS 9_2). The body measures were inserted as dependent variable whether the environmental factors as independent variables and a type III model was used.

An assessment was made to see which body part was the limiting factor for calving, so which was the most critical to pass the birth canal. Biologically seen, the shoulder- and hip width are both candidates for being the most critical. A t-test was used to look whether the "HW - SW" difference was significantly different from zero and therefore statistically prove which of the two is the most limiting. Also, it was examined whether this difference (from zero) differed between male and female calves, between calves born from heifers or cows and between CS or naturally delivered calves Whenever the CI spans 1 this difference was significant. In both analyses herd was included as random effect.

A model to predict the size of the two most detrimental body parts for calving ease (SH and HW) was constructed by the use of a generalized linear mixed assessment (herd was included as random effect). This model contained parameters which are easily measurable at parturition, i.e. CF (CFF, CFH) and LH. The only two environmental factors that can be known at the moment of parturition are the gender of the calf (assessed by pregnancy diagnoses after 60 days) and the parity of the dam. Due to specific management characteristics (i.e. using a breeding bull), there was no information available in the present study concerning the moment of mating and hence concerning the length of gestation. The latter resembles practice as this is the case in most of the current BB herds in Belgium. The dependent variables SW or HW, the covariances LH and CFF/CFH and the fixed variables gender and parity were inserted all together in the model to see which of the parameters had an influence on SW or HW. Parameters with a $P > 0.05$ were eliminated from the model. This was repeated until all the parameters left over had significant influence on the dependent variables (SW and HW).

Finally, generalized estimating equation methods of SPSS 16.0 for Windows (SPSS Inc. 233 S. Wacker Drive, Chicago) were used to estimate the likelihood of natural calving by the use of CFF and CFH. A binary logistic model was chosen within the generalized linear models with herd as a subject and type of calving as response. The predictor within this model was the CFF or the CFH. Afterwards a scatter plot was made with the predicted value of mean, the lower and upper bound of confidence interval for mean of CFF or CFH to visualize the probability of natural calving.

# RESULTS

More than 20% of the calves (34) were born in autumn, almost 50% (72) in winter and the rest (41) of the calves in spring. The measurements were made within 25.6 ± 17.7 hours of birth. Table 1 shows the descriptive statistics for all the body measures.

**Table 1** The mean values, the standard deviation (StD), the minimum (min) and the maximum (max) values of body measurements and birth weight of 147 BB newborn purebred calves

| Body measurements | | N | Mean | StD | Min | Max |
|---|---|---|---|---|---|---|
| Body weight at birth | kg | 45 | 49.2 | 7.1 | 35.0 | 65.0 |
| Body length | cm | 147 | 56.4 | 4.5 | 44.3 | 67.8 |
| Length of the head | cm | 147 | 24.4 | 2.3 | 18.7 | 33.3 |
| Shoulder width | cm | 147 | 22.4 | 2.2 | 16.0 | 28.8 |
| Hip width | cm | 147 | 22.9 | 2.1 | 17.0 | 28.7 |
| Circumference of the front fetlock | cm | 147 | 17.9 | 1.1 | 14.5 | 20.3 |
| Circumference of the hind fetlock | cm | 147 | 18.0 | 1.0 | 15.5 | 20.5 |
| Heart girth | cm | 147 | 78.0 | 5.4 | 57.0 | 94.3 |
| Withers height | cm | 146 | 71.0 | 4.7 | 58.7 | 81.8 |

Most simple correlations, partial correlations and correlations per class between the nine body dimensions were significant and moderate to high (Tables 2, 3 and 4 for gender, parity and type of calving, respectively). Male calves demonstrated higher correlation between BW and other body measures, whereas female calves it was lower. For the other body dimensions, the individual male and female correlation showed a variation (different directions for the different measurements) in comparison with the simple correlations of the total dataset (Table 2). Higher correlations between the body dimensions (excluding birth weight) were also seen in heifers and multiparous cows, in contrast with the simple correlations (Table 3). Body measurements of calves delivered *per vaginam* showed a much higher correlation compared to the simple correlations, but this was not the case for body dimensions of calves born after CS (Table 4).

**Table 2** Simple correlations (r; diagonally above), partial correlations adjusted for gender (r; diagonally below) and correlations per class (r; male - female; diagonally below) between the nine body measurements (the body weight at birth [BW], the body length [BL], the length of the head [LH]), the shoulder width [SW], the hip width [HW], the circumference of the fetlock of both the right front [CFF] and hind leg [CFH], the heart girth [HG] and the withers height [WH])

| **Gender** | | BW | BL | LH | SW | HW | CFF | CFH | HG | WH |
|---|---|---|---|---|---|---|---|---|---|---|
| BW | *Partial* | 1.000 | 0.456** | 0.286 | 0.560** | 0.561** | 0.323** | 0.491** | 0.312* | 0.457** |
| | *Male* | | | | | | | | | |
| | *Female* | | | | | | | | | |
| BL | *Partial* | 0.458** | 1.000 | -0.017 | 0.313** | 0.005 | 0.467** | 0.490** | 0.364** | 0.618** |
| | *Male* | 0.520* | | | | | | | | |
| | *Female* | 0.337 | | | | | | | | |
| LH | *Partial* | 0.284** | -0.032 | 1.000 | 0.410** | 0.554** | 0.268** | 0.314** | 0.181* | -0.116 |
| | *Male* | 0.345 | 0.007 | | | | | | | |
| | *Female* | 0.203 | -0.087 | | | | | | | |
| SW | *Partial* | 0.564** | 0.291** | 0.402** | 1.000 | 0.731** | 0.615** | 0.616** | 0.604** | 0.301** |
| | *Male* | 0.709** | 0.399** | 0.357** | | | | | | |
| | *Female* | 0.355 | 0.140 | 0.462** | | | | | | |
| HW | *Partial* | 0.561** | -0.005 | 0.552** | 0.734** | 1.000 | 0.414** | 0.484** | 0.533** | 0.085 |
| | *Male* | 0.683** | 0.013 | 0.490** | 0.693** | | | | | |
| | *Female* | 0.481* | -0.025 | 0.625** | 0.784** | | | | | |
| CFF | *Partial* | 0.356* | 0.448** | 0.262** | 0.618** | 0.445** | 1.000 | 0.414** | 0.484** | 0.533** |
| | *Male* | 0.439** | 0.457** | 0.229* | 0.644** | 0.377** | | | | |
| | *Female* | 0.286 | 0.430** | 0.297* | 0.605** | 0.519** | | | | |
| CFH | *Partial* | 0.531** | 0.469** | 0.310** | 0.608** | 0.510** | 0.849** | 1.000 | 0.541** | 0.498** |
| | *Male* | 0.577** | 0.462** | 0.255* | 0.598** | 0.458** | 0.819** | | | |
| | *Female* | 0.485* | 0.469** | 0.373** | 0.630** | 0.573** | 0.882** | | | |
| HG | *Partial* | 0.311* | 0.349** | 0.171* | 0.595** | 0.530** | 0.533** | 0.541** | 1.000 | 0.428** |
| | *Male* | 0.455** | 0.398** | 0.054 | 0.656** | 0.544** | 0.515** | 0.583** | | |
| | *Female* | 0.106 | 0.283* | 0.324** | 0.516** | 0.519** | 0.563** | 0.496** | | |
| WH | *Partial* | 0.457** | 0.610** | -0.128 | 0.285** | 0.078 | 0.513** | 0.495** | 0.417** | 1.000 |
| | *Male* | 0.505** | 0.598** | -0.154 | 0.358** | 0.094 | 0.529** | 0.541** | 0.411** | |
| | *Female* | 0.380 | 0.628** | -0.092 | 0.178 | 0.061 | 0.511** | 0.444** | 0.427** | |

* Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

**Table 3** Simple correlations (r; diagonally above), partial correlations adjusted for parity (r; diagonally below) and correlations per class (r; heifer - cow; diagonally below) between the nine body measurements (the body weight at birth [BW], the body length [BL], the length of the head [LH]), the shoulder width [SW], the hip width [HW], the circumference of the fetlock of both the right front [CFF] and hind leg [CFH], the heart girth [HG] and the withers height [WH])

| **Parity of cow** | | BW | BL | LH | SW | HW | CFF | CFH | HG | WH |
|---|---|---|---|---|---|---|---|---|---|---|
| BW | *Partial* | 1.000 | 0.456** | 0.286 | 0.560** | 0.561** | 0.323** | 0.491** | 0.312* | 0.457** |
| | *Heifer* | | | | | | | | | |
| | *Cow* | | | | | | | | | |
| BL | *Partial* | 0.301 | 1.000 | -0.017 | 0.313** | 0.005 | 0.467** | 0.490** | 0.364** | 0.618** |
| | *Heifer* | a | | | | | | | | |
| | *Cow* | 0.149 | | | | | | | | |
| LH | *Partial* | -0.265 | 0.437 | 1.000 | 0.410** | 0.554** | 0.268** | 0.314** | 0.181* | -0.116 |
| | *Heifer* | | 0.324 | | | | | | | |
| | *Cow* | -0.316 | 0.499** | | | | | | | |
| SW | *Partial* | -0.087 | 0.482* | 0.350 | 1.000 | 0.731** | 0.615** | 0.616** | 0.604** | 0.301** |
| | *Heifer* | | 0.576** | 0.302 | | | | | | |
| | *Cow* | -0.083 | 0.468** | 0.367** | | | | | | |
| HW | *Partial* | 0.201 | 0.454* | 0.296 | 0.714** | 1.000 | 0.414** | 0.484** | 0.533** | 0.085 |
| | *Heifer* | | 0.429* | 0.282 | 0.716** | | | | | |
| | *Cow* | 0.261 | 0.486** | 0.346** | 0.711** | | | | | |
| CFF | *Partial* | -0.087 | 0.453** | 0.457* | 0.604** | 0.666* | 1.000 | 0.414** | 0.484** | 0.533** |
| | *Heifer* | | 0.568** | 0.507** | 0.619** | 0.657** | | | | |
| | *Cow* | -0.087 | 0.602** | 0.454** | 0.676** | 0.641** | | | | |
| CFH | *Partial* | -0.139 | 0.654** | 0.422* | 0.605** | 0.658** | 0.916** | 1.000 | 0.541** | 0.498** |
| | *Heifer* | | 0.677** | 0.438* | 0.632** | 0.638** | 0.933** | | | |
| | *Cow* | -0.139 | 0.633** | 0.417** | 0.644** | 0.664** | 0.910** | | | |
| HG | *Partial* | 0.281 | 0.633* | 0.324 | 0.746** | 0.802** | 0.624** | 0.606** | 1.000 | 0.428** |
| | *Heifer* | | 0.626** | 0.265 | 0.759** | 0.834** | 0.557** | 0.606** | | |
| | *Cow* | 0.210 | 0.672** | 0.529** | 0.703** | 0.785** | 0.642** | 0.607** | | |
| WH | *Partial* | 0.217 | 0.471 | 0.355 | 0.555** | 0.721* | 0.658* | 0.601** | 0.697** | 1.000 |
| | *Heifer* | | 0.463* | 0.262 | 0.414* | 0.711** | 0.644** | 0.589** | 0.624** | |
| | *Cow* | 0.277 | 0.586** | 0.473** | 0.603** | 0.759** | 0.686** | 0.661** | 0.746** | |

a Cannot be computed because at least one of the variables is constant; * Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

**Table 4** Simple correlations (r; diagonally above), partial correlations adjusted for type of calving (r; diagonally below) and correlations per class (r; CS - *per vaginam [PV]*; diagonally below) between the nine body measurements (the body weight at birth [BW], the body length [BL], the length of the head [LH]), the shoulder width [SW], the hip width [HW], the circumference of the fetlock of both the right front [CFF] and hind leg [CFH], the heart girth [HG] and the withers height [WH])

| **Type of calving** | | BW | BL | LH | SW | HW | CFF | CFH | HG | WH |
|---|---|---|---|---|---|---|---|---|---|---|
| BW | *Partial* | 1.000 | 0.456** | 0.286 | 0.560** | 0.561** | 0.323** | 0.491** | 0.312* | 0.457** |
| | *CS* | | | | | | | | | |
| | *PV* | | | | | | | | | |
| BL | *Partial* | 0.456** | 1.000 | -0.017 | 0.313** | 0.005 | 0.467** | 0.490** | 0.364** | 0.618** |
| | *CS* | 0.462** | | | | | | | | |
| | *PV* | a | | | | | | | | |
| LH | *Partial* | 0.299* | -0.012 | 1.000 | 0.410** | 0.554** | 0.268** | 0.314** | 0.181* | -0.116 |
| | *CS* | 0.313* | -0.071 | | | | | | | |
| | *PV* | | 0.522** | | | | | | | |
| SW | *Partial* | 0.594** | 0.334** | 0.372** | 1.000 | 0.731** | 0.615** | 0.616** | 0.604** | 0.301** |
| | *CS* | 0.623** | 0.315** | 0.366** | | | | | | |
| | *PV* | | 0.461* | 0.477* | | | | | | |
| HW | *Partial* | 0.595** | 0.013 | 0.527** | 0.707** | 1.000 | 0.414** | 0.484** | 0.533** | 0.085 |
| | *CS* | 0.627** | -0.072 | 0.530** | 0.699** | | | | | |
| | *PV* | | 0.669** | 0.495* | 0.788** | | | | | |
| CFF | *Partial* | 0.336* | 0.482** | 0.236** | 0.594** | 0.380** | 1.000 | 0.414** | 0.484** | 0.533** |
| | *CS* | 0.397* | 0.423** | 0.194* | 0.585** | 0.326** | | | | |
| | *PV* | | 0.751** | 0.653** | 0.677** | 0.799** | | | | |
| CFH | *Partial* | 0.505** | 0.503** | 0.287** | 0.598** | 0.458** | 0.876** | 1.000 | 0.541** | 0.498** |
| | *CS* | 0.564** | 0.438** | 0.249** | 0.579** | 0.408** | 0.863** | | | |
| | *PV* | | 0.806** | 0.676** | 0.741** | 0.853** | 0.935** | | | |
| HG | *Partial* | 0.321* | 0.372** | 0.154 | 0.592** | 0.516** | 0.510** | 0.528** | 1.000 | 0.428** |
| | *CS* | 0.323* | 0.327** | 0.166 | 0.584** | 0.483** | 0.470** | 0.482** | | |
| | *PV* | | 0.709** | 0.643** | 0.657** | 0.855** | 0.808** | 0.864** | | |
| WH | *Partial* | 0.456** | 0.618** | -0.106 | 0.333** | 0.106 | 0.528** | 0.518** | 0.443** | 1.000 |
| | *CS* | 0.472** | 0.609** | -0.165 | 0.302** | 0.029 | 0.482** | 0.470** | 0.401** | |
| | *PV* | | 0.680** | 0.554** | 0.567** | 0.802** | 0.809** | 0.807** | 0.789** | |

a Cannot be computed because at least one of the variables is constant; * Correlation is significant at the 0.05 level

**Table 5** Body measurements divided in gender, parity of cow and type of calving (mean ± standard deviation) and the significant differences between these body measurements within these classes (by multivariate mixed ANOVA)

| Measurement | | Gender | | Parity | | Type of Calving | |
|---|---|---|---|---|---|---|---|
| | | Male (n = 80) | Female (n = 67) | Heifer (n = 27) | Cow (n = 120) | CS (n = 120) | *Per vaginam* (n = 27) |
| Body weight at birth | (kg) | 49.4 ± 89 | 49.0 ± 6 | 48.0 ± 5 | 49.2 ± 7 | 49.2 ± 7 | 47.8 ± 4 |
| Body length | (cm) | 57.1 ± 5 | 55.5 ± 4**a | 57.0 ± 4 | 58.2 ± 4 | 56.3 ± 5 | 56.6 ± 4 |
| Length of the head | (cm) | 23.6 ± 2 | 23.2 ± 2 | 22.1 ± 1 | 22.4 ± 2 | 23.6 ± 2 | 22.3 ± 1 |
| Shoulder width | (cm) | 22.7 ± 2 | 21.9 ± 2 | 21.5 ± 2 | 22.1 ± 2** | 22.6 ± 2 | 21.0 ± 2*** |
| Hip width | (cm) | 23.0 ± 2 | 22.7 ± 2 | 21.4 ± 1 | 22.0 ± 1** | 23.1 ± 2* | 21.5 ± 2* |
| Circumference of the front fetlock | (cm) | 18.4 ± 1 | 17.3 ± 1*** | 17.5 ± 1 | 18.0 ± 1 | 18.0 ± 1 | 17.4 ± 1 |
| Circumference of the hind fetlock | (cm) | 18.4 ± 1 | 17.5 ± 1*** | 17.6 ± 1 | 18.1 ± 1 | 18.1 ± 1 | 17.6 ± 1 |
| Heart girth | (cm) | 78.6 ± 5 | 77.2 ± 5 | 75.6 ± 4 | 78.1 ± 4 | 78.3 ± 6 | 76.1 ± 4*** |
| Withers height | (cm) | 71.6 ± 5 | 70.4 ± 4 | 71.6 ± 3 | 73.3 ± 4 | 71.0 ± 5 | 71.7 ± 4 |

a Results of the multivariate mixed ANOVA, the significance is within row within class; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Body measurements and BW presented by gender, parity of the cow and type of calving are shown in Table 5. From all the assessed environmental factors, the multivariate mixed ANOVA confirmed a significant association between the calf's gender and its BL ($P < 0.01$) and the CF of both its front and hind leg ($P < 0.001$; Table 5). All the above mentioned body parts demonstrated to be larger in bull calves in comparison to heifer calves (Table 5). Both SW and HW showed a significant association with the type of calving and with parity. Calves born via CS had broader shoulders ($P < 0.01$) and hips ($P < 0.01$) compared to calves born after natural delivery (Table 5). Measures from calves born out of multiparous cows were larger than from calves born out of heifers (SW: $P < 0.001$; HW: $P < 0.05$; Table 5). None of the nine body measurements were significantly associated with the season of birth or with the moment the measurement was done relative to birth (data not shown).

As SW and HW are the broadest points of a BB calf, they are both candidates for being the limiting measures for calving ease. Based on the dataset of the present study, the difference between HW and SW for the total dataset was not different from zero ($P > 0.05$), thus the body part being the most detrimental factor concerning calving ease could not be assessed for the total dataset. The difference between HW and SW was significantly different between male and female calves, whereas this difference between HW and SW was not significantly different between heifers and cows and between naturally calving animals and animals that were delivered by CS, respectively (Table 6). Within classes, in female calves the statistical analysis demonstrated that the difference between the HW and SW was significantly different from zero (Table 6; 95% CI [0.157 - 1.283]), suggesting the HW being the limiting factor at least in the female calves. In male calves this difference was not significant (Table 6; 95% CI [-0.392 - 0.697]). For calves that were born naturally the difference between HW and SW was also significantly different from zero, in contrast with calves born via CS (Table 6; 95% CI [0.120 - 1.559] and [-0.303 - 0.820] for naturally and CS respectively).

**Table 6** Estimated marginal means, standard errors and 95% confidence intervals of the difference between hip width (HW) and shoulder width (SW) between the different classes of gender, parity and type of calving as well as the difference between HW and SW within one class.

| Parameter | Estimate | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| *Gender*[a] | 0.567 | 0.228 | 0.117 | 1.017 |
| Male[b] | 0.152 | 0.263 | -0.392 | 0.697 |
| Female[b] | 0.720 | 0.273 | 0.157 | 1.283 |
| *Parity*[a] | -0.065 | 0.285 | -0.632 | 0.502 |
| Heifer[b] | -0.074 | 0.249 | -0.590 | 0.442 |
| Cow[b] | -0.009 | 0.166 | -0.467 | 0.450 |
| *Type of calving*[a] | 0.581 | 0.339 | -0.088 | 1.250 |
| CS[b] | 0.259 | 0.268 | -0.303 | 0.820 |
| *Per vaginam*[b] | 0.839 | 0.359 | 0.120 | 1.559 |

a Assessment of the differences between the classes for the difference between HW and SW; b Assessment to see whether the difference between HW and SW is different from zero within a class

Models to predict these limiting measure for calving, HW for female calves and SW and HW for male calves, at the time of parturition are described by the equations demonstrated in Table 7. Both for SW as for HW these models are assessed for posterior and anterior position of the calf taking the CFF and the CFH respectively into account.

**Table 7** Equations to predict shoulder width (SW) and hip width (HW) at the time of parturition for posterior and anterior position

| Limiting factor | Position of the calf | Parameter | Estimate | Std. Error | df | t | *P* |
|---|---|---|---|---|---|---|---|
| SW (cm) | *Anterior* | Intercept | -5.89 | 2.72 | 139.37 | -2.17 | <0.05 |
| | | Gender | 0.79 | 0.31 | 137.78 | 2.57 | <0.05 |
| | | LH (cm) | 0.22 | 0.07 | 22.42 | 3.22 | <0.01 |
| | | CFF (cm) | 1.27 | 0.15 | 140.35 | 8.67 | <0.001 |
| | | Intercept | -0.51 | 2.46 | 142.61 | -0.21 | NS[a] |
| | *Posterior* | CFH (cm) | 1.26 | 0.14 | 142.67 | 9.27 | <0.001 |
| HW (cm) | *Anterior* | Intercept | 3.92 | 2.21 | 139.09 | 1.77 | NS |
| | | Gender | 1.05 | 0.26 | 135.43 | 1.07 | <0.001 |
| | | CFF (cm) | 1.00 | 0.12 | 136.38 | 8.37 | <0.001 |
| | *Posterior* | Intercept | 3.36 | 2.26 | 139.29 | 1.49 | NS |
| | | Gender | 0.85 | 0.25 | 134.94 | 3.43 | <0.01 |
| | | CFH (cm) | 1.03 | 0.12 | 136.88 | 8.43 | <0.001 |

a Not Significant

Figure 2 and 3 show the probability of natural calving by the use of the CFF and CFH. With the minimum circumference of 14.5 cm for CFF in the present dataset, the probability for natural calving was estimated to be 47% (95% CI: 23 - 74%), whereas with the maximum measured CFF (20.3 cm) the probability for natural calving was reduced to 5% (2 - 13%). The mean CFF of this dataset (17.9 cm) corresponded with a chance of natural calving of 14.5% (7 - 27%). For the CFH, the minimum (15.5 cm) and maximum (20.5 cm) measured circumference gave a probability of natural calving of 38 (16 - 66%) respectively 5% (1 - 14%). With the mean CFH (18.1 cm) of this dataset the probability of natural calving was 14.2% (6 - 25%).

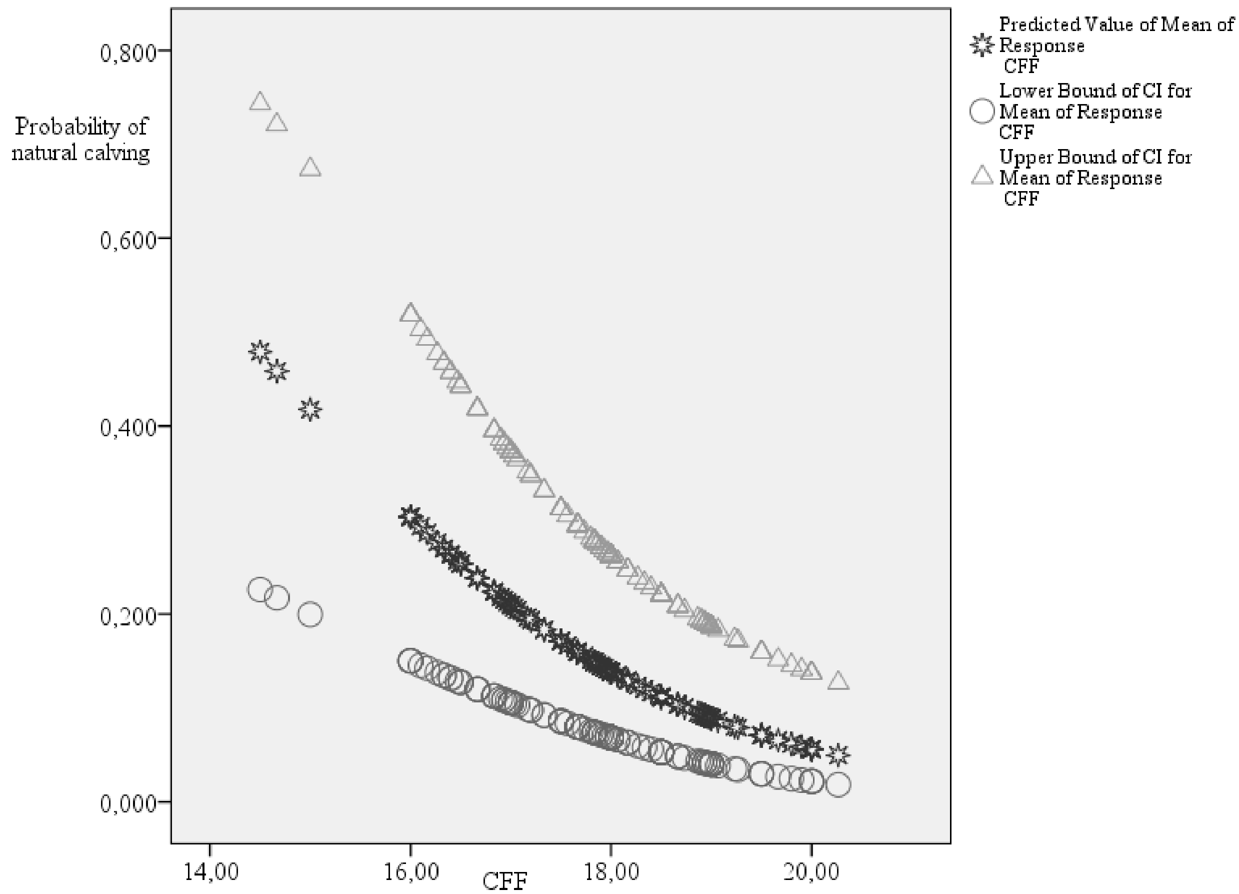


**Figure 2** Probability of natural calving based on the circumference of the front fetlock (CFF in cm; bounds of 95% CI) assessed by a generalized estimating equation method

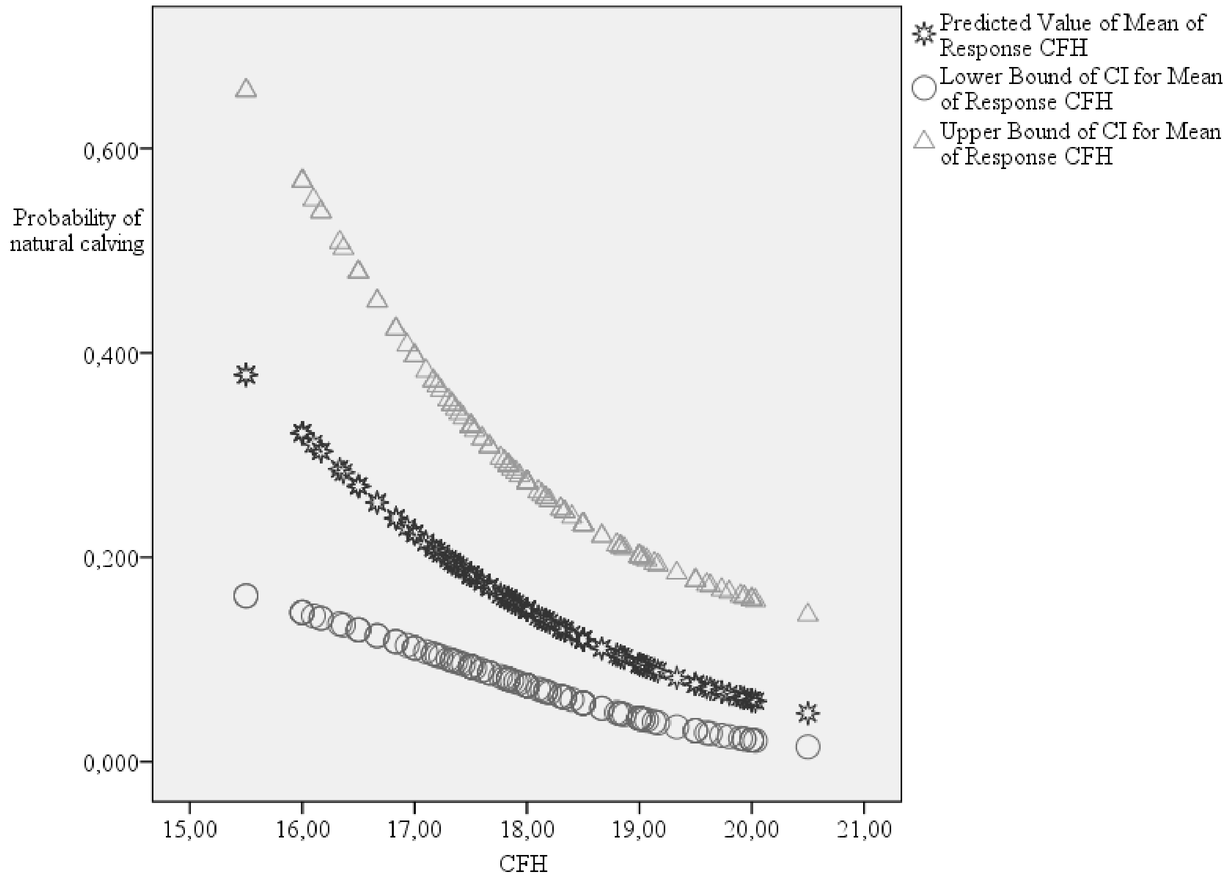


**Figure 3** Probability of natural calving based on the circumference of the hind fetlock (CFH in cm; bounds of 95% CI) assessed by a generalized estimating equation method

# DISCUSSION

In this study the mean +/- StD of the BW and eight other body dimensions of newborn double muscled BB calves were obtained. BW data were similar to those reported by Fiems et al. (2001), but lower for male and higher for female calves when compared to the data of West (1997) and Coopman et al. (2004). Comparison of our measurements with those obtained by Coopman et al. (2004), also revealed a decrease of SW, HW, HG and WH. The inclusion of (smaller) calves born *per vaginam* in our study – whereas Coopman et al. (2004) only measured calves born by CS – is probably not responsible for this difference, as the calves born by CS in our study were also smaller than the ones measured by

Coopman et al. (2004). Another explanation might be the apparent decrease in WH of the DM-BB animals over the last decade(s), which has been stated to be the result of the high selection for conformation (muscularity) (Hanset, 2004, 2005). As dam size is correlated with calf size (Laster, 1974), it is possible that DM-BB calves are smaller in 2006 - 2007, than in 1995 till 2001 when the studies of Coopman et al. (2004) were performed. Furthermore, within the DM-BB breed a trend for selection in favour of smaller, and hence more viable, calves has been noticeable over the last years, as heavy calves in the BB generally have greater difficulties in suckling. The publication of bull genetic indices for calf viability at birth and willingness to suckle has indirectly accelerated selection for calves with lighter birth weight (Berger et al., 1992; HBBBB, 2008).

The limiting dimension for ease of calving of BB female calves seems to be the HW. This is in agreement with the reports of veterinarians in the field attempting *per vaginam* deliver of the calf, in that so called ‘hip lock’ is a common occurrence with female calves. Difficulties during per vaginam delivery of bull calves often occurs early in the expulsive phase of calving, as male calves have relatively wide shoulders. Equations to calculate SW and HW were evaluated in this study, to enable the farmer and the veterinarian to predict the size of the calf at the beginning of the expulsive stage of parturition. This together with the knowledge of the pelvic size of the dam and should enable a more accurate prediction of the possibility of natural calving being possible. However, the generalized estimating equations are most likely an underestimation as CS is performed on a routine basis without attempts to deliver the calf naturally. With evaluating selection towards natural calving, these generalized estimating equations should be adjusted as the likelihood for natural calving increases.

It is generally known that at birth, bull calves are heavier than heifer calves (Thomson and Wiltbank, 1983; Houghton and Corah, 1989; Echternkamp, 1993; Zollinger and Hansen, 2003), so in non-DM breeds of cattle they probably also have larger body dimensions. This can partly be explained by the fact that bull calves generally have a one- to two- day longer gestation length, during which time they continue to grow. Houghton and Corah (1989) and McGuirk et al. (1998) showed that the frequency of seriously difficult calvings was greater in male calves, which were larger, and had a better conformation (for subsequent rearing) than heifer calves. In a study of Burfening et al. (1978a), bull calves of the Simmental breed had gestation lengths of about 1 day longer, were 3.0 kg heavier at birth; their birth was associated with a 0.23 unit lesser calving ease score, and required 12.7% more assistance. The effect of the calf's gender on the incidence of assisted births and on calving ease was greater in young than in older cows (Laster et al., 1973; Burfening et al., 1978a,b). Our results correspond well with the data on other breeds in the fact that bull calves were heavier compared to female calves.

Parity and age of the dam are also known to significantly influence BW (Nelson and Beavers, 1982). Dawson et al. (1947) showed that BW of calves tended to increase per month parallel with the increase in age of the dam until six years of age, and that the weight of the dam was related to BW to the same extent as the age of the dam. However, in our study involving DM-BB cows, there was no association between the parity of the dam and the BW of the calf, although some body dimensions of calves born from multiparous cows were larger than those of calves born from heifers.

The season of birth appeared to have no influence on the BW, or the eight other body dimensions. In contrast, Wilson and Rossi (2006) found that calves born in the fall weighed less than calves born in the winter and spring months, which is most likely caused by a higher nutrient intake due to supplementary feeding of the cow. Deutscher et al. (1999) concluded that calf BW increased 1 lb, and calving difficulty increased by 2.6 percent for each degree Fahrenheit the average winter temperature is reduced. Colburn et al. (1996) also showed an influence of temperature on BW, resulting in larger BWs and more calving difficulties following winter temperatures which were below average. Compared to the extensively managed breeds described in these latter studies (all on cattle without double muscling), the BB is managed very intensively with minor variations in nutrition during winter and summer. Besides this, the DM-BB breed is also known for its excellent feed conversion, which enables the dams to maintain adequate body reserves at all times. Hence, this may be a reason for absence of any influence of the season of the year on BW and body dimensions in the DM-BB breed.

The data presented in the present study show significant differences between body sizes (only SW and HW) of calves born by CS and calves delivered *per vaginam*.

Unfortunately, it is very difficult to correctly assess the validity of this observation in relation to the incidence of dystocia as in DM-BB cows, since CSs are performed electively in Belgium. As mentioned above, this will probably underestimate the predictive value for a natural calving by the use of the CFF and CFH. Nevertheless, the results of our study demonstrate that the few BB calves that are not born by elective CS, but *per vaginam*, have smaller SW, HW and HG measurements, which suggests an influence of the calf's body conformation on the incidence of dystocia. Although DM-BB calves born by CS are heavier, the difference in BW between DM-BB calves born *per vaginam* and by CS was not significant, and BW does not correlate with type of calving. Casas et al. (1999) indicated that in double muscled animals the BW of the calf has a significant effect on calving difficulty, as their results showed an increase of 0.7% in calving difficulty per kilogram increase in BW, however only the homozygous double muscled calves had a greater calving difficulty. Coopman et al. (2004) measured WH, SW, HW and HG in double muscled BB calves, and found that all four dimensions were positively and significantly correlated with BW, which was confirmed in our study. Consequently, the smaller SW and HW in DM-BB calves born *per vaginam*, as encountered in our study, might be responsible for the lower BW in these calves, which may further contribute to the fact that they were born *per vaginam*.

Although the correlation of body dimensions with the risk of dystocia is much lower than birth weight with dystocia (West, 1997), birth weight has been shown to be highly correlated with calf conformation and body measurements; the correlations ranging from 0.60-0.85 (Freking, 2000). Although these correlations are lower in the DM-BB breed (shown in this study; Coopman et al., 2004), these correlations are still significant, and hence influence birth weight and possibly but indirectly also dystocia. However, selection for smaller dimensions and lower birth weight should not be too great, as the viability of the calf decreases with excessive decrease of the birth weight. Furthermore, light calves need to have the potential to grow into large cows, so that on turn, they are able to calve naturally. The latter suggests that in attempting to reduce frequency of elective CSs, the selection for lower birth weight and shorter gestation length (Norman et al., 2009) should be performed simultaneously with selection for an increase in pelvic dimensions of the adult cows.

## ACKNOWLEDGEMENTS

We greatly acknowledge Professor Noakes for reviewing the manuscript carefully and giving his comments.

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# FACTORS INFLUENCING DYSTOCIA IN THE PHENOTYPICALLY DOUBLE MUSCLED BELGIAN BLUE BREED (CHAPTER 5.4)

Modified from:

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Factors influencing dystocia in the phenotypically double muscled Belgian Blue breed.

Reproduction of Domestic Animals (to be submitted).

# ABSTRACT

The Belgian Blue (BB) breed is a double muscled (DM) beef breed in which dystocia occurs frequently resulting in the elective application of Caesarean Section (CS). In the present paper, an evaluation was made of the fetal-dam disparity within DM-BB cattle (on average and based on individual cow-calf combinations), and of the influence of parturition (both by CS and calving *per vaginam*) on the pelvic width (PW), pelvic height (PH) and pelvic area (PA) in DM-BB cows. Measurements in 507 DM-BB animals of which 56 animals calved *per vaginam* showed a mean PH of 18.8 ± 1.9 cm with a minimum and maximum of 11.0 and 23.0 cm respectively, compared to a mean shoulder width (SW) and hip width (HW) of 147 newborn DM-BB calves of 22.4 ± 2.2 cm and 22.9 ± 2.1 cm respectively. Thus purely mathematically spoken, the average DM-BB calf is too large to pass the birth canal of the average DM-BB dam. However, the largest cows (with a PH of 23.0 cm) are still able to deliver the average DM-BB calf. Comparison of individual cow-calf combinations originating from a herd with a high frequency of calving *per vaginam*, showed that more animals (multiparous animals as well as heifers) calved *per vaginam* than mathematically considered (to be) possible. The latter is both very intriguing and hopeful for selection against dystocia in the future, but also suggests other factors contributing to calving ability, including the influence of parturition itself on the pelvic dimensions. Results of measurements performed to test this hypothesis demonstrate that animals which calved by CS had a significantly larger PH within 24 hours after parturition compared to their PH one month before parturition (0.45 cm, $P < 0.05$). No significant influence was however seen on PW and PA. All three pelvic measures of animals that delivered their calf *per vaginam* increased around calving in comparison with measurements one month before parturition (PH: 1.42 cm [$P < 0.001$], PW: 0.53 cm [$P < 0.05$] and PA: 35.64 $cm^2$ [$P < 0.001$]). These findings indicate that besides the pelvic dimensions of the dam and the body sizes of the calf, parturition itself significantly influences the size of the pelvic canal and thus contributes to the calving ability in the DM-BB breed.

# INTRODUCTION

Dystocia is generally defined as a difficult or delayed birth at any stage of labour (Mee, 2008). The most common cause of dystocia is fetal-dam disparity (Mee, 2008) with calf birth weight (BW) and maternal pelvic size as the two primary determinants. These two factors account for 50% and 5 - 10% of the phenotypic variance in dystocia, respectively (Meijering, 1984). A three-dimensional relationship exists between calf BW and body conformation, pelvic area (PA) and dystocia (Thomson and Wiltbank, 1983). Within each size of PA, dystocia increases with the increase of BW and the body conformation of the calf (Thomson and Wiltbank, 1983). Understanding the relationship between calf BW, calf body conformation and pelvic dimensions of the dam is of paramount importance to decrease the occurrence of dystocia, but applying this information to cattle production is complicated (Andersen et al., 1993).

The Belgian Blue (BB) breed is a double muscled (DM) beef breed in which dystocia occurs frequently resulting in the elective application of Caesarean Section (CS). In agreement with literature in other breeds, the high frequency of dystocia in DM-BB cattle is suggested to be caused by a combination of two factors: a direct influence of the calf (Arthur, 1995; Casas et al., 1999) and a maternal influence of the dam (Arthur, 1995). Selection for growth rate and muscularity in the DM-BB breed has influenced these two factors and thus calving ability (Hanset, 1981).

Previous research in the DM-BB breed on these two determining factors showed associations between the body conformation of the DM-BB calf and the pelvic dimensions of the DM-BB dam on the one hand and type of calving and age on the other hand. The calf's shoulder and hip width (SW and HW) showed a significant association with the type of calving. Calves born by CS had significantly broader shoulders and hips compared to calves born *per vaginam* ($P < 0.01$; Chapter 5.3). In female calves, the HW was suggested to be the limiting factor for calving whereas in male calves the difference between HW and SW was not significantly different from zero (Chapter 5.3). Furthermore, a study on pelvic dimensions and body size in DM-BB dams also revealed a significant association between types of calving on the one hand and withers height, the heart girth, the distance between the *tubera coxae*, the distance between the *tubera ischiadica*, the pelvic height (PH), the pelvic width (PW) and the PA on the other hand. DM-BB cows that delivered *per vaginam* had larger body and pelvic measurements compared to animals that had delivered by CS (Chapter 5.2). By illustrating a significant association between the type of calving and the pelvic dimension of the DM-BB dam, the question arose whether parturition itself (by relaxation of the ligaments through hormonal influence or by mechanical force caused by the calf passing through the birth canal or by both) could have an influence on the pelvic dimension in the DM-BB breed. In other breeds, Henson et al. (1989) demonstrated an increase of PA around parturition caused by an increase of estrogens. Other groups investigated the influence of estrogen implants at 2 and 6 months of age on the PA (Deutscher et al., 1986; Hancock et al., 1994) and noticed an increase in PA. However, these implants did not have any influence on BW or the incidence of dystocia (Deutscher et al., 1986).

This present study aims to explore the fetal-dam disparity present in DM-BB cattle, by comparing the mean SW and/or HW of DM-BB calves and the mean PH of DM-BB dams, as well as by comparing individual cow-calf dimensions. Besides that, the influence of the type of parturition (delivery by either CS or *per vaginam*) on the PW, PH and PA in DM-BB animals was investigated.

## MATERIAL AND METHODS

### Datasets for the evaluation of the general fetal-dam disparity (comparison of shoulder and hip width of DM-BB calves and the pelvic height of DM-BB dams)

For this comparison two different datasets were used containing only animals of the DM-BB breed. From literature (West, 1997; Coopman et al., 2004) and our previous studies (Chapter 5.3) it is known that the width of the shoulder and hip (SW and HW) are the broadest points of a DM-BB calf, whereas the determinant factor of the dam is the PH as it is bigger than the PW and thus the largest measure of the pelvic inlet (Morrison et al., 1986; Murray et al., 1999).

The data of the internal PHs of the DM-BB dams were taken from a dataset collected over a period of 2 years (2005 - 2007) at 27 herds in Flanders (Chapter 5.2), with a total of 507 animals measured. The age of the animals ranged from 2 to 12 years with a mean of 5 years. Fifty-six of them calved *per vaginam* at least once.

The specific body parts contributing to the ease of calving, namely the SW and HW of newborn purebred DM-BB calves were selected out of the dataset described by Chapter 5.3, recorded during the autumn, winter and spring of 2006 - 2007. The body dimensions of 147 BB calves (120 born by CS and 27 born *per vaginam*), were obtained on 15 commercial farms, one experimental farm and at the Department of Reproduction, Obstetrics and Herd Health of the Faculty of Veterinary Medicine of Ghent University (Belgium).

The dams and calves used for the individual comparison belonged to one herd (Herd 2, see below). This DM-BB herd consisted of ~80 purebred animals of which more than 30% calved *per vaginam*. A herd with such a high frequency of natural calvings is very unique in Belgium.

## Dataset for the individual cow-calf combinations and for the study of the influence of parturition on pelvic dimension

### Animals

Data from two different herds were obtained. The first herd (Herd 1) was a ~150 DM-BB experimental beef herd, where parturition was managed by CS routinely. The animals were kept in straw boxes before calving and were moved to a tie stall three days before expected calving for better observation. At parturition a CS was performed in a CS box without preceding trial traction. The calves were weaned directly after birth and were moved to an individual calf pen. Subsequently, the cows were moved to another tie stall were they remained till they went onto pasture. Throughout the entire data collection period, the animals received the same feeding regime, consisting of a mixture of maize and grass silage supplemented with concentrates, until the summer period.

The second participating DM-BB herd (Herd 2) consisted of ~80 animals of which more than 30% calved naturally. For Belgium standards, this is an exceptionally high frequency of calving *per vaginam*. A thorough gynaecological examination including trial traction was performed on every animal in labour and if positive, the cows were assisted to deliver *per vaginam*. CSs were only performed in case the trial traction revealed that giving birth to a live calf would not be possible *per vaginam*. The animals were kept in tie stalls and the calves were housed in small boxes in the same stall behind the cows. Each compartment of the tie stall contained four calves and four cows, allowing the calves to suckle all four cows until the age of three months. The feeding regime, consisting of maize silage mixed with concentrates in the morning and hay in the evening, was identical for all participating cows until the summer period.

In total 38 animals between 3 and 12 years old (20 animals delivered by CS at the first farm, 18 animals which calved *per vaginam* at the second farm) were examined before, at and after parturition. Of the 38 calves, 18 were female (8 delivered by CS, 10 *per vaginam*), and 20 were male (12 delivered by CS, 8 *per vaginam*).

## Measurements

Internal pelvic measurements (PH and PW) were conducted at one month (day 27 – day 32) before the expected calving date (measurement 1 = M1), within 24 hours after parturition (measurement 2 = M2) and at one month after parturition (measurement 3 = M3) using a Rice pelvimeter (Lane Manufacturing, 2075 So. Balentia St., Unit C, Denver, Colorado, USA) on the standing animal. Before measuring, 2 ml of a 4% procaine hydrochloride (VMD®, Belgium) was injected into the epidural space at the level of the sacro-coccygeal or first inter coccygeal articulation. As a result, the internal measurements could be performed during rectal manipulation in cattle adapting a normal stance. The pelvimeter was introduced after removal of the faeces and localization of the pelvic inlet. The PH and PW were measured as described in Chapter 5.1 and the PA by the product of these values.

## Statistics

All cows were identified and their measurements recorded in an Excel spread sheet (Microsoft Office Excel 2007), cleaned and explored and checked by SPSS 16.0 for Windows (SPSS Inc. 233 S. Wacker Drive, Chicago). Normality was tested by the Kolmogorov-Smirnov test and by visual analysis of the Q-Q plots. A repeated measure ANOVA was used to analyse the differences between the pelvimetric measurements (PH, PW and PA) with the moment of measuring (M1, M2 and M3) as a fixed and the animals as random factor. An independent t-test was used to analyse the differences in pelvic dimension between animals based on the age and the type of calving (CS and calving *per vaginam*). The significance level for the analyses was set at $P < 0.05$.

# RESULTS

### Fetal-dam disparity (comparison of the mean and individual shoulder and hip width of the DM-BB calves and the mean and individual pelvic height of the DM-BB dams)

The mean PH of the DM-BB dams per age category and type of calving as well as the mean SW and HW of the DM-BB calves per gender and type of calving are presented in Tables 1 and 2. On average, the total cow dataset showed a mean PH of 18.8 ± 1.9 cm with a minimum and maximum of 11.0 and 23.0 cm respectively. Overall, a significantly higher PH was noticed in cows that calved *per vaginam* compared to those that calved by CS ($P < 0.001$; Table 1). However within each age category, this difference was only significantly higher in natural calvers at 5 ($P < 0.05$), 6 ($P < 0.01$) and 7 ($P < 0.05$) years of age (Table 1). The mean SW and HW of the 147 newborn BB calves were 22.4 ± 2.2 cm and 22.9 ± 2.1 cm, respectively (Table 2). Thus mathematically speaking, the average DM-BB calf is too large to pass the birth canal of the average DM-BB dam. However, the largest cows (with a PH of 23.0 cm) are still able to deliver the average DM-BB calf. Bull calves had a significantly larger SW in comparison with heifer calves ($P < 0.05$), but this could not be demonstrated for the HW ($P > 0.05$; Table 2). In addition, calves born by CS had a larger SW and HW when compared to calves born *per vaginam* ($P < 0.001$; Table 2).

**Table 1** The mean value, the standard deviation (StD), the minimum (Min) and maximum (Max) value of the pelvic height (PH) of 507 double muscled Belgian Blue (DM-BB) female animals per age category and type of calving (CS = Caesarean Section; *PV* = *Per Vaginam*)

| | | | **Pelvic height** | | | |
|---|---|---|---|---|---|---|
| **Age** | **Type of calving** | **N** | **Mean (cm)** | **StD (cm)** | **Min (cm)** | **Max (cm)** |
| *2* | *CS* | 12 | 15.0 | 2.3 | 12.0 | 20.0 |
| | *PV* | | | | | |
| | *Total* | 12 | 14.5 | 2.4 | 11.0 | 20.0 |
| *3* | *CS* | 90 | 17.0 | 1.7 | 11.0 | 19.7 |
| | *PV* | | | | | |
| | *Total* | 90 | 16.8 | 1.7 | 11.0 | 19.7 |
| *4* | *CS* | 88 | 18.6 | 1.4 | 14.0 | 21.5 |
| | *PV* | 7 | 19.6 | 0.9 | 18.0 | 20.5 |
| | *Total* | 95 | 18.6 | 1.4 | 14.0 | 21.5 |
| *5* | *CS* | 90 | 19.2* | 1.2 | 16.0 | 21.5 |
| | *PV* | 5 | 20.3 | 0.8 | 19.5 | 21.5 |
| | *Total* | 95 | 19.2 | 1.2 | 16.0 | 21.5 |
| *6* | *CS* | 69 | 19.3** | 1.2 | 17.0 | 21.7 |
| | *PV* | 10 | 20.5 | 0.9 | 19.0 | 22.5 |
| | *Total* | 79 | 19.5 | 1.2 | 17.0 | 22.5 |
| *7* | *CS* | 53 | 19.9* | 1.1 | 17.0 | 22.0 |
| | *PV* | 14 | 20.6 | 1.2 | 19.0 | 23.0 |
| | *Total* | 67 | 20.0 | 1.2 | 17.0 | 23.0 |
| *8+* | *CS* | 49 | 20.0 | 1.1 | 18.0 | 22.0 |
| | *PV* | 20 | 21.0 | 1.0 | 19.0 | 22.5 |
| | *Total* | 69 | 20.2 | 1.1 | 18.0 | 22.5 |
| | *Total CS* | 451 | 18.6*** | 1.8 | 11.0 | 22.5 |
| | *Total PV* | 56 | 20.6 | 1.0 | 18.0 | 23.0 |
| | *End total* | 507 | 18.8 | 1.9 | 11.0 | 23.0 |

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; difference in PH between CS and *PV* animals

**Table 2** The mean value, the standard deviation (StD), the minimum (Min) and maximum (Max) value of shoulder width (SW) and hip width (HW) of 147 double muscled Belgian Blue (DM-BB) calves per type of calving (CS = Caesarean Section; *PV = Per Vaginam*), per gender and in total

| | Type of calving | Gender | N | Mean (cm) | StD (cm) | Min (cm) | Max (cm) |
|---|---|---|---|---|---|---|---|
| **SW** | *CS* | | 123 | 22.6 | 2.1 | 16.0 | 28.8$^{***a}$ |
| | *PV* | | 24 | 21.0 | 1.8 | 18.2 | 23.5 |
| | | *Male* | 80 | 22.7 | 2.2 | 16.0 | 28.8$^{*b}$ |
| | | *Female* | 67 | 21.9 | 2.1 | 18.2 | 26.8 |
| **Total** | **SW** | | 147 | 22.4 | 2.2 | 16.0 | 28.8 |
| **HW** | *CS* | | 123 | 23.1 | 2.1 | 17.0 | 28.7$^{***a}$ |
| | *PV* | | 24 | 21.5 | 1.5 | 18.3 | 23.3 |
| | | *Male* | 80 | 23.0 | 2.0 | 17.0 | 28.7 |
| | | *Female* | 67 | 22.7 | 2.3 | 18.3 | 27.5 |
| **Total** | **HW** | | 147 | 22.9 | 2.1 | 17.0 | 28.7 |

* $P < 0.05$; *** $P < 0.001$; a Significant difference between calves born per CS or *PV*; b Significant difference between male and female calves

Looking at the individual cow-calf combinations (Table 3a,b) assessed on Herd 2 where parturition took place both by CS and by calving *per vaginam*, a mathematical discrepancy between the PH of the dam and the HW of the calf was present in both groups of animals. In animals that had calved by CS, the mathematical difference between the PH of the dam and the HW of the calf was -4.34 cm (-3.81 cm for multiparous animals and -5.04 cm for heifers; Table 3a). On the other hand in cows that had calved *per vaginam*, the mean difference between the PH and the HW was -3.50 cm (-3.20 cm for multiparous animals and -5.30 cm for heifers; Table 3b). Based on these measurements and purely mathematically spoken, only 2 cows would have been able to calve *per vaginam* while in reality 23 did.

**Table 3a** Individual comparison of pelvic height (PH) of double muscled Belgian Blue (DM-BB) dams with the hip width (HW) of DM-BB calves of Herd 2[a]. All calvings were done by CS (n = 14). The influence of parturition itself on this comparison is also illustrated

| Cow | Parity[b] | Type of Calving[c] | PH dam (cm) | PH dam + influence parturition[d] | HW calf (cm) | Difference (cm)[e] | Difference + influence parturition (cm)[f] |
|---|---|---|---|---|---|---|---|
| 1 | H | CS | 16.00 | 16.45 | 22.20 | - 6.20 | -5.75 |
| 2 | H | CS | 16.00 | 16.45 | 20.33 | - 4.33 | -3.88 |
| 3 | H | CS | 17.50 | 17.95 | 21.20 | - 3.70 | -3.25 |
| 4 | C | CS | 21.00 | 21.45 | 24.33 | - 3.33 | -2.88 |
| 5 | C | CS | 19.50 | 19.95 | 21.50 | - 2.00 | -1.55 |
| 6 | H | CS | 17.50 | 17.95 | 23.00 | - 5.50 | -5.05 |
| 7 | C | CS | 19.00 | 19.45 | 24.20 | - 5.20 | -4.75 |
| 8 | H | CS | 16.00 | 16.45 | 22.00 | -6.00 | -5.55 |
| 9 | H | CS | 16.00 | 16.45 | 20.50 | -4.50 | -4.05 |
| 10 | C | CS | 17.50 | 17.95 | 21.50 | -4.00 | -3.55 |
| 11 | C | CS | 21.00 | 21.45 | 24.50 | -3.50 | -3.05 |
| 12 | C | CS | 19.50 | 19.95 | 21.50 | -2.00 | -1.55 |
| 13 | C | CS | 19.00 | 19.45 | 23.00 | -4.00 | -3.55 |
| 14 | C | CS | 17.50 | 17.95 | 24.00 | -6.50 | -6.05 |

a Herd 2 is a DM-BB herd consisted of ~80 animals of which more than 30 % calved *per vaginam*, which is very exceptional for Belgium standards; b H = heifer, C = multiparious animal; c CS = Caesarean Section; d 0.45cm for CS animals; e Difference = PH dam - HW calf; f Difference = PH dam + influence parturition - HW calf

**Table 3b** Individual comparison of pelvic height (PH) of double muscled Belgian Blue (DM-BB) dams with the hip width (HW) of DM-BB calves of Herd 2[a]. All calvings took place *per vaginam* (n = 23). The influence of parturition itself on this comparison is also illustrated

| Cow | Parity[b] | Type of Calving[c] | PH dam (cm) | PH dam + influence parturition[d] | HW calf (cm) | Difference (cm)[e] | Difference + influence parturition (cm)[f] |
|---|---|---|---|---|---|---|---|
| 15 | C | *PV* | 21.50 | 22.92 | 22.50 | - 1.00 | **0.42** |
| 16 | C | *PV* | 21.50 | 22.92 | 22.33 | - 0.83 | **0.59** |
| 17 | C | *PV* | 19.50 | 20.92 | 23.33 | - 3.83 | -2.41 |
| 18 | C | *PV* | 20.00 | 21.42 | 18.33 | **1.67** | **3.09** |
| 19 | H | *PV* | 15.50 | 16.92 | 20.80 | - 5.30 | -3.88 |
| 20 | C | *PV* | 20.50 | 21.92 | 22.00 | - 1.50 | -0.08 |
| 21 | C | *PV* | 21.00 | 22.42 | 23.00 | - 2.00 | -0.58 |
| 22 | C | *PV* | 21.50 | 22.92 | 22.70 | - 1.20 | **0.22** |
| 23 | H | *PV* | 19.00 | 20.42 | 22.70 | - 3.70 | -2.28 |
| 24 | C | *PV* | 21.50 | 22.92 | 20.50 | **1.00** | **2.42** |
| 25 | H | *PV* | 19.00 | 20.42 | 25.00 | -6.00 | -4.58 |
| 26 | C | *PV* | 20.50 | 21.92 | 27.00 | -6.50 | -5.08 |
| 27 | C | *PV* | 22.50 | 23.92 | 26.00 | -3.50 | -2.08 |
| 28 | H | *PV* | 20.00 | 21.42 | 26.00 | -6.00 | -4.58 |
| 29 | C | *PV* | 21.50 | 22.92 | 26.50 | -5.00 | -3.58 |
| 30 | C | *PV* | 22.50 | 23.92 | 26.00 | -3.50 | -2.08 |
| 31 | C | *PV* | 21.00 | 22.42 | 29.00 | -8.00 | -6.58 |
| 32 | C | *PV* | 21.00 | 22.42 | 22.00 | -1.00 | **0.42** |
| 33 | C | *PV* | 22.50 | 23.92 | 25.00 | -2.50 | -1.08 |
| 34 | C | *PV* | 21.00 | 22.42 | 28.00 | -7.00 | -5.58 |
| 35 | C | *PV* | 20.50 | 21.92 | 27.00 | -6.50 | -5.08 |
| 36 | C | *PV* | 21.00 | 22.42 | 25.00 | -4.00 | -2.58 |
| 37 | C | *PV* | 22.50 | 23.92 | 28.00 | -5.50 | -4.08 |

a Herd 2 is a DM-BB herd consisted of ~80 animals of which more than 30 % calved *per vaginam*, which is very exceptional for Belgium standards; b H = heifer, C = multiparious animal; c *PV* = *Per vaginam*; d 1.42 cm for naturally calving animals; e Difference = PH dam – HW calf; f Difference = PH dam + influence parturition - HW calf

## Influence of parturition on pelvic dimension

The mean pelvic dimensions (PH, PW, and PA) measured at three different time points (M1, M2, and M3) relative to calving and categorized per age and type of calving, are shown in Table 4.

All three pelvic measures of animals that had delivered their calf *per vaginam* increased around calving in comparison with measurements before parturition (significant difference between M1 and M2 for PH: -1.42 cm [$P < 0.001$], PW: -0.53 cm [$P < 0.05$] and PA: 35.64 $cm^2$ [$P < 0.001$]; Table 5). For PH and PA the results showed a significant difference between M1 and M3 as well (PH: -1.06 cm; PA: -26.29 $cm^2$; $P < 0.001$; Table 5).

For animals in the CS herd, the mean PH was significantly larger at M2 compared to the mean pelvic height on M1 (0.45 cm, $P < 0.05$; Table 5). No significant difference was found between the mean PH taken before (M1) and one month after parturition (M3) and between measurement at one month after parturition (M2 and M3). The mean PW and the mean PA of animals delivering by CS did not significantly differ between the three different time points.

**Table 4** The mean value and standard deviation of the pelvic height (PH), the pelvic width (PW) and the pelvic area (PA) on the three measure moments categorized per age and type of calving

| **Type of calving**[a] | **Age** | **N** | **Measurements**[b] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M1 | | | M2 | | | M3 | | |
| | | | PH(cm) | PW (cm) | PA ($cm^2$) | PH (cm) | PW (cm) | PA ($cm^2$) | PH (cm) | PW (cm) | PA ($cm^2$) |
| CS | 3 | 7 | 18.9 ± 1.4 | 15.6 ± 1.1 | 295.9 ± 38.4 | 19.3 ± 1.4 | 15.5 ± 1.2 | 300.0 ± 40.9 | 19.1 ± 1.0 | 15.4 ± 1.1 | 294.3 ± 32.1 |
| | 4 | 8 | 18.7 ± 1.1 | 15.9 ± 1.1 | 300.9 ± 36.1 | 19.6 ± 0.6 | 16.3 ± 0.9 | 320.7 ± 26.8 | 19.3 ± 1.0 | 16.1 ± 0.9 | 311.8 ± 32.5 |
| | 5 | 3 | 19.5 ± 0.6 | 17.2 ± 0.5 | 334.9 ± 18.9 | 19.9 ± 0.8 | 17.4 ± 0.5 | 347.1 ± 21.3 | 19.9 ± 0.2 | 17.5 ± 0.8 | 349.0 ± 14.3 |
| | 7 | 2 | 20.2 ± 0.4 | 17.5 ± 0.4 | 352.9 ± 15.5 | 20.1 ± 0.5 | 16.8 ± 0.1 | 337.9 ± 8.1 | 19.4 ± 0.1 | 17.3 ± 0.3 | 334.9 ± 2.5 |
| | Total | **20** | **19.1 ± 1.1** | **16.1 ± 1.1** | **309.5 ± 37.4** | **19.6 ± 1.0** | **16.3 ± 1.1** | **319.1 ± 33.8** | **19.3 ± 0.9** | **16.2 ± 1.1** | **313.6 ± 33.5** |
| *PV* | 3 | 3 | 17.8 ± 1.5 | 16.3 ± 1.0 | 292.2 ± 42.7 | 19.8 ± 0.8 | 17.0 ± 0.5 | 337.3 ± 20.7 | 19.5 ± 0.5 | 16.3 ± 0.3 | 318.4 ± 4.3 |
| | 4 | 4 | 19.6 ± 0.9 | 17.0 ± 0.9 | 334.2 ± 33.2 | 21.4 ± 0.9 | 18.1 ± 0.6 | 387.7 ± 26.8 | 20.9 ± 1.1 | 18.0 ± 0.8 | 376.4 ± 36.7 |
| | 5 | 2 | 21.0 | 17.5 | 367.5 | 21.0 | 18.3 ± 1.1 | 383.3 ± 22.3 | 21.0 | 18.0 ± 1.4 | 378.0 ± 29.7 |
| | 6 | 2 | 20.8 ± 0.4 | 18.8 ± 0.4 | 389.1 ± 14.0 | 22.3 ± 0.4 | 19.0 ± 0.7 | 422.6 ± 9.0 | 21.5 ± 0.7 | 18.8 ± 0.4 | 403.0 ± 5.7 |
| | 7 | 2 | 20.3 ± 0.4 | 18.3 ± 0.4 | 369.5 ± 0.7 | 21.8 ± 1.1 | 18.0 | 391.5 ± 19.1 | 21.0 | 18.0 | 378.0 |
| | ≥8 | 5 | 20.4 ± .6 | 17.8 ± 0.9 | 363.4 ± 26.0 | 21.7 ± 0.8 | 18.1 ± 1.0 | 393.3 ± 33.8 | 21.6 ± 0.7 | 18.3 ± 0.6 | 395.4 ± 18.9 |
| | Total | **18** | **19.9 ± 1.3** | **17.5 ± 1.0** | **349.0 ± 39.3** | **21.3 ± 1.0** | **18.0 ± 0.9** | **384.7 ± 33.1** | **20.9 ± 0.9** | **17.9 ± 0.9** | **375.3 ± 34.1** |
| | End total | **38** | **19.5 ± 1.2** | **16.8 ± 1.3** | **328.2 ± 42.7** | **20.4 ± 1.3** | **17.1 ± 1.4** | **350.2 ± 46.8** | **20.1 ± 1.2** | **17.0 ± 1.4** | **342.8 ± 45.7** |

a CS = Caesarean Section; *PV* = *Per vaginam*; b M1: One month before; M2: Within 24 h after parturition; M3: One month after parturition

**Table 5** Results of a repeated measure ANOVA for the pelvimetric measurements (pelvic height [PH], pelvic width [PW] and pelvic area [PA]) between different moments of measuring for animals calved by CS and animals calved *per vaginam* (*PV*) to explore the influence of parturition on the pelvic dimension

| **Type of calving**[a] | **Measures** | **Moment of measurement**[b] 1 | 2 | **Mean difference (1-2; cm)** | **Standard error** | ***P*** |
|---|---|---|---|---|---|---|
| CS | *PH* | M1 | M2 | -0.45* | 0.17 | <0.05 |
| | | M1 | M3 | -0.21 | 0.17 | NS |
| | | M2 | M3 | 0.24 | 0.17 | NS |
| | *PW* | M1 | M2 | -0.06 | 0.14 | NS |
| | | M1 | M3 | 0.01 | 0.14 | NS |
| | | M2 | M3 | 0.07 | 0.14 | NS |
| | *PA* | M1 | M2 | -8.24 | 4.89 | NS |
| | | M1 | M3 | -2.89 | 4.89 | NS |
| | | M2 | M3 | 5.35 | 4.89 | NS |
| *PV* | *PH* | M1 | M2 | -1.42*** | 0.19 | <0.001 |
| | | M1 | M3 | -1.06*** | 0.19 | <0.001 |
| | | M2 | M3 | 0.36 | 0.19 | NS |
| | *PW* | M1 | M2 | -0.53* | 0.19 | <0.05 |
| | | M1 | M3 | -0.39 | 0.19 | NS |
| | | M2 | M3 | 0.14 | 0.19 | NS |
| | *PA* | M1 | M2 | -35.64*** | 4.93 | <0.001 |
| | | M1 | M3 | -26.29*** | 4.93 | <0.001 |
| | | M2 | M3 | 9.34 | 4.93 | NS |

a CS = Caesarean Section; *PV* = *Per vaginam*; b M1: One month before; M2: Within 24 h after parturition; M3: One month after parturition; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; c NS = Not Significant

## Fetal-dam disparity, after taking the influence of parturition into account.

When adding the mean difference in PH measured before parturition and within 24 hours of parturition (M1 – M2 = -0.45 cm for CS animals and -1.42 cm for animals calving *per vaginam*) to the individual PH of the DM-BB heifers and cows, the mean difference between the PH of the dam and the HW of the calf for the CS animals becomes -3.89 cm, (-3.36 cm for multiparous animals, -4.59 cm for heifers; Table 3a). The mean mathematical discrepancy for animals that had calved *per vaginam* remained -2.14 cm (-1.77 cm for multiparous animals, -3.83 cm for heifers; Table 3b). Through this addition 19% more cows (6 instead of 2 out of 23 cows that calved *per vaginam*; Table 3b) could have mathematically calved, while in the CS group still none of the animals could.

# DISCUSSION

In the DM-BB, the fetal-dam disparity has its origin in the thorough selection for the DM phenotype. The latter causes a DM-BB calf to become too broad to be born alive *per vaginam*. On the DM dam side, the selection resulted in a decrease in body height and length and a significant decreased PA (Hanset, 2004, 2005). Regarding the pelvic inlet, the PH is the most decisive factor for calving ease as it is larger than the PW (Morrison et al., 1986; Murray et al., 1999). In DM-BB calves, we clearly demonstrated that the largest measure at birth is the HW. Comparison of the PH of DM-BB dams with the HW of the calves, showed that mathematically spoken on average a delivery *per vaginam* not possible in the present DM-BB population, as on average the HW of the calves is 4.3 cm larger than the PH of the cows. Nevertheless, the smaller calves still can theoretically pass the birth canal of the biggest cows (HW of 17.0 cm versus a PH of 23.0 cm). Indeed, data of individual DM-BB cow-calf combinations showed some animals calving *per vaginam* that had a PH larger than the HW of the calf they delivered (Table 3).

On the other hand, these individual data (Table 3) also showed that more animals (multiparous animals as well as heifers) calved *per vaginam* than mathematically considered possible based on our measurements. The fact that calves with hips broader than the PH of their respective dams were born naturally is very hopeful for selection against dystocia in the future. Furthermore, these results show that the difference between the PH of the dam and the HW of the calf within animals calving *per vaginam* is only a little less negative in comparison with animals that had calved by CS (with the exception of the heifers which rarely calve *per vaginam*). These findings suggest that possibly more animals would have been able to calve *per vaginam* when they had been given the opportunity to do so and that the difference between calving *per vaginam* or by CS is just a matter of millimetres to centimetres from the cows' point of view. From the results of the present and former studies in the DM-BB breed, it is clear that the fact whether a cow calves *per vaginam* or by CS is influenced by a lot of other different factors besides the size of the pelvic inlet.

A plausible hypothesis is the occurrence of specific adaptations in pelvic dimensions taking place at calving time. The latter has also been investigated in the present study, and the results show a significant increase in PH when pelvises were measured within 24h after calving in comparison with a measurement carried out one month before calving. In cows that had delivered by CS, this PH increase was on average 0.45 cm, while it was 1.42 cm in cows that had calved *per vaginam*. In the latter animals, the natural calving process also caused a significant increase in PW (0.53 cm) and PA (35.64 $cm^2$). The possibility that these small increases are caused by an inaccuracy of the pelvimetric measurements is not very likely as the repeatability and reliability within the technician and between technicians has been proven to be very good (Kolkman et al., 2007; Chapter 5.1). Some authors have shown that at calving, the effective PA could increase up to 15% in first calving animals due to an increased mobility of the iliosacral joints, relaxation of the pelvic ligaments, abdominal straining and changes in posture (Rüsse et al., 1978; Smeaton et al., 2004). Schebitz (1980) observed a 5 cm increase in PH from 5 days before up to the day of calving followed by a decrease of 5-7 cm after calving. The difference between the increase in PA around parturition between animals that had been delivered by CS (this study: 8.3 $cm^2$) and those that had calved *per vaginam* (this study: 35.6 $cm^2$; Henson et al., 1989: 13 $cm^2$) indicates that the mechanical force of the calf passing the pelvic canal maybe of greater importance. In contrast, some authors showed that hormonal actions during the preparative stage of the calving process brings about the motility in the iliosacral joints, allowing the effective PH to be larger than measured (Belic and Ménissier, 1968; Schuijt, 1977). To know whether the increase in PH in the natural calving DM-BB is caused by the passage of the calf (mechanical force) or rather is itself the reason why the calf is able to pass (better relaxation of the soft tissue and 'opening' of the birth canal), research should be done, measuring PW and PH one month before parturition and compare these data with similar measurements carried out just before and just after calving. An increase of the pelvic measures just *before* calving in comparison with one month earlier, is probably due to a better hormonal relaxation of the birth canal, whereas when the difference is mainly situated between measurements done just before versus just *after* calving, the increase in pelvic dimensions is mainly of mechanical origin and caused by the passage of the calf (beside the hormonal influence). This research was not performed by our group because it was not possible to organize this as for the unpredictability of the calvings and the distance to the farm.

Other factors that can be proposed to explain the fact that some 'mathematically impossible' natural calvings have indeed taken place, are the body size (conformation, pelvic slope, shape of the pelvic inlet) and differences in calving ability between individual cows (e.g. preparation for calving, hormonal relaxation of the soft tissues, the will and power to strain during parturition; Meijering, 1984; Gaines et al., 1993), and the compressibility of the calf. These factors have to be studied in the future.

## CONCLUSION

To conclude, as criticism against the elective application of CS in the DM-BB breed is rising, it is relevant trying to increase the incidence of calvings *per vaginam* in this breed, albeit without losing its supreme carcass characteristics, for which the breed is highly valued by meat processors. The rather small difference of fetal-dam disparity of DM-BB animals calving *per vaginam* versus animals that had calved by CS encourages us to further explore the possibilities for selection towards calving *per vaginam*. Apparently a large fraction of the population is suitable to be used for this goal.

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# Pelvic height compared to pelvic diagonal height in Belgian Blue cattle pelvimetry (Chapter 5.5)

Modified from:

Kolkman I, Hoflack G, Opsomer G and Lips D

Pelvic height compared to pelvic diagonal height in Belgian Blue cattle pelvimetry

(Short communication).

Reproduction of Domestic Animals (to be submitted).

# Abstract

The maternal pelvic size is very important in the prevention of dystocia as it is one of the two principal determinants of feto-pelvic disproportion, besides the birth weight (BW) of the calf. After assessment of the pelvic area (PA; in particular the pelvic height [PH]) and the width of the calf in the double muscled Belgian Blue (DM-BB) breed, it was demonstrated that in some cases, although theoretically impossible as the calf's shoulder and/or hip width measurements were larger than the dam's PH, calves were delivered naturally. To investigate the influence of the shape of the pelvic inlet, a comparison was made between the PH and the pelvic diagonal height (left oblique diameter [ODL] and right oblique diameter [ODR]) in 87 BB cows. Overall, a significant difference could be shown between PH and ODL and ODR respectively ($P < 0.001$; difference PH - ODL: -0.43 cm; difference PH - ODR: -0.45 cm), but no dissimilarity was seen between the ODL and ODR. In individual cows this difference of 0.4 cm can be a world of difference in the decision for a natural delivery. The elliptic shape of the pelvic inlet might have an influence on calving ability and can be a possible explanation for these rare individual cases were the calf is born naturally even though theoretically impossible.


# Introduction

Pelvimetry is a well known technique used in cattle in the selection against dystocia as the maternal pelvic size is one of the two principal determinants of feto-pelvic disproportion, besides the birth weight (BW) of the calf. Particularly in beef breeds it is used to determine the pelvic area (PA; Laster, 1974) in order to predict the calving ability of both cows as well as heifers (Morrison et al., 1985a,b; Van Donkersgoed et al., 1990, 1993; Basarab et al., 1993a,b) and to sort out heifers with a small PA prior to breeding or mating (Colburn et al., 1997).

It is generally acknowledged that a calf can be delivered naturally whenever the pelvic height (PH) of the dam, which is considered the biggest measure within the pelvic inlet and thus the determining factor, is larger compared to the hip width (HW; broadest point of the musculature on the *trochanter major*) of the calf. In order to identify selection parameters towards a natural calving population within the double muscled Belgian Blue (DM-BB) breed, the cow's inner PH and the calf's outer HW were determined and compared (Chapter 5.4). This assessment demonstrated that in some cases, although theoretically impossible as the calf's HW measurements were on average 2.4 cm larger than the dam's PH, calves were delivered naturally (Chapter 5.4). Hypotheses to clarify these rare and illogical cases were sought in specific adaptations in pelvic dimensions around the time of parturition (the PH significantly increased by 1.4 cm during parturition compared to one month before parturition, Chapter 5.4; Henson et al., 1989), the calving ability differences between individual cows (e.g. preparation for calving, relaxation of the soft tissue, abdominal straining; Meijering, 1984; Van Donkersgoed, 1992; Gaines et al., 1993) and/or the compressibility of the calf (on average 10% [unpublished data] which represents up to 2.9 cm). The influence of expansion of the pelvis during parturition (on average 1.4 cm) combined with the compressibility of the calf (on average 2.9 cm) will explain almost all the individual cases (1.4 cm + 2.9 cm > 2.4 cm on average).

However in some individual cases we have seen that the calf's HW is larger than the cow's PH together with the pelvic relaxation during parturition and the calf's compressibility. We therefore hypothesize that the pelvic diagonal height might be larger than the PH which is generally determined during pelvimetry. The aim of this study was to investigate whether a difference between PH and pelvic diagonal height was present in some cows and if so, to quantify the size of this difference.

## MATERIALS AND METHODS

To investigate this assumption, pelvimetric measurements were conducted in 87 purebred DM-BB animals between 2 and 6 years old, all belonging to the same herd. Some of the animals were tethered whereas the others were housed in straw boxes. The feeding regime off all animals consisted of grass and maize silage supplemented with concentrates. Pelvic width and height and oblique diameters were assessed during mid-gestation using a

Rice pelvimeter (Lane Manufacturing, 2075 So. Balentia St., Unit C, Denver, Colorado, USA), with an accuracy of 0.25 cm. Before the measurements, a low epidural analgesia was administered using 2 ml of a 4% procaine hydrochloride solution (Eurovet®, Belgium). As a result, the pelvimetric measurements could be performed in cattle adapting a normal stance during rectal manipulation. The closed pelvimeter was slowly introduced into the empty rectum and the pelvic width (PW; transversal diameter) was measured by opening the device within the pelvic canal between the shafts of the *ilium* at the widest point, placing the ends of the pelvimeter on the *tubercula psoadica* of the *ilium* in the pelvic entrance (Figure 1). The PH (conjugate diameter) was defined as the vertical distance between the *pubic symphysis* and the sacral vertebrae (Figure 1; Rice, 1994; Chapter 5.1). The pelvic diagonal height diameters were measured 5 cm left (oblique diameter left [ODL]) and right (oblique diameter right [ODR]) aside the *symphysis* and from that point, diagonally in a straight line up to the ventral side of the sacral vertebrae (Figure 1). All pelvic measurements were conducted three times consecutively by the same technician and the resulting mean value was used for further analyses. SPSS 16.0 for Windows (SPSS Inc. 233 S. Wacker Drive, Chicago) was used to explore and analyse the data. The database was tested for normality using the Kolmogorov-Smirnov test and by looking at the Q-Q plots. By the use of a paired t-test the differences between the conjugate and oblique diameters were assessed taking the age of the animal into consideration.

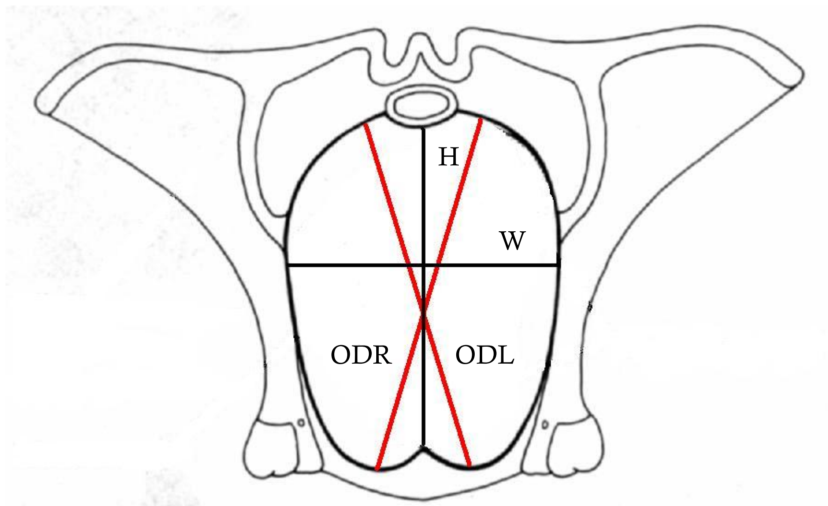


**Figure 1** The maternal pelvic inlet with the pelvic width (W) and height (H; the black lines) and the oblique diameters (ODL and ODR; the red lines)

# RESULTS

The mean PW, PH, ODL and ODR were 15.3 ± 2.0 cm, 18.1 ± 1.9 cm, 18.6 ± 1.9 cm and 18.6 ± 1.8 cm respectively. Pelvic diameters (transverse, conjugate and oblique) of the pelvic inlet categorized by age are shown in Table 1. Overall, a significant difference could be shown between PH and ODL and ODR respectively ($P < 0.001$; difference PH - ODL: -0.43 cm; difference PH - ODR: -0.45 cm). No dissimilarity was seen between the ODL and ODR. Significant differences between PH and the oblique diameters (ODL and ODR) were no longer noticed in animals older than 4 years of age (Table 1).

**Table 1** Pelvic width, pelvic height and oblique diameters of the pelvic inlet categorized by age

| **Age (years)** | **N** | **Pelvic width (cm)** | | | **Pelvic height (cm)** | | | **Oblique diameter (cm)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Left** | | | **Right** | | |
| | | Mean ± StD[a] | Min | Max | Mean ± StD | Min | Max | Mean ± StD | Min | Max | Mean ± StD | Min | Max |
| 2 | 40 | 13.8 ± 1.7 | 10.0 | 16.5 | 16.8 ± 1.7 | 13.0 | 19.0 | $17.2 \pm 1.8^{b**}$ | 14.0 | 19.5 | $17.2 \pm 1.8^{c**}$ | 13.5 | 19.5 |
| 3 | 24 | 16.0 ± 1.2 | 13.5 | 19.0 | 18.9 ± 1.0 | 17.0 | 20.5 | $19.5 \pm 0.7^{b***}$ | 18.5 | 20.5 | $19.7 \pm 0.7^{c***}$ | 18.5 | 21.0 |
| 4 | 10 | 16.7 ± 1.2 | 15.0 | 18.0 | 19.4 ± 0.7 | 18.5 | 20.5 | $19.8 \pm 0.5^{b*}$ | 19.0 | 20.5 | $19.7 \pm 0.3^{c*}$ | 17.0 | 21.0 |
| 5 | 7 | 16.7 ± 0.9 | 15.0 | 17.5 | 19.4 ± 0.9 | 18.0 | 20.5 | 19.7 ± 1.6 | 16.5 | 21.0 | 19.6 ± 1.3 | 17.0 | 21.0 |
| 6 | 3 | 18.5 ± 1.3 | 17.0 | 19.5 | 21.0 ± 1.3 | 19.5 | 22.0 | 20.8 ± 1.3 | 19.5 | 22.0 | 20.8 ± 0.8 | 20.0 | 21.5 |
| 7 | 1 | 18.0 | | | 21.0 | | | 21.0 | | | 21.0 | | |
| 8 | 2 | 17.3 ± 1.2 | 16.5 | 18.3 | 19.8 ± 1.8 | 19.5 | 20.0 | 20.3 ± 1.8 | 20.0 | 20.5 | 20.0 ± 0.7 | 19.5 | 20.5 |

a StD = Standard Deviation; b Significant difference between pelvic height and left oblique diameter; c Significant difference between pelvic height and right oblique diameter; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

# DISCUSSION

This experiment demonstrates that the shape of the pelvic inlet might influence calving ability, as in average, the OD turned out to be 0.4 cm larger compared to the PH. While the shape of the pelvic inlet in cows is generally considered as a square, it turns out to be rather circular up to elliptic. This difference might explain why some calves with a hip width larger than their dam's pelvic height were born naturally and adds to other factors such as pelvic dilatation at calving (Chapter 5.4) and compressibility of the calf. During parturition, in case the cross sectional diameter of the fetal chest or hips is bigger than the maternal pelvic inlet (= width), birth may still be possible by the displacement and realignment of the fetal parts in such a way the hip's of the calf still might pass through the PH instead of the PW at the time of parturition (Figure 2). Nevertheless, it almost never possible to turn the hip's of the calf for the total 90 degrees, so the broadest point of the calf will eventually pass the pelvic inlet through the pelvic diagonal height instead of the PH. In that case the distance of the pelvic diagonal height diameter of the pelvis is the determinant for natural calving.

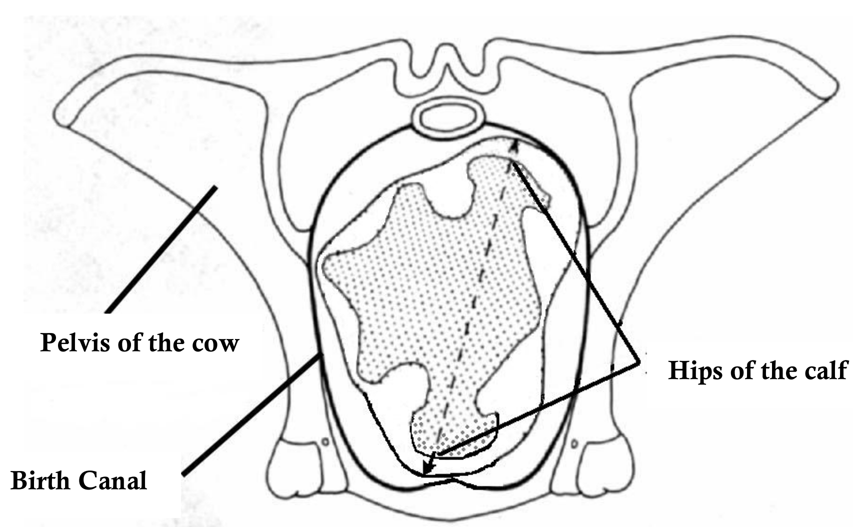


**Figure 2** Displacement and realignment of the fetal hips of the calf in the maternal pelvic inlet at the time of parturition

The purpose of this experiment was to find a possible explanation for the rare individual cases were the calf is born naturally even though theoretically impossible as the calf's HW measurements were larger than the dam's PH. For selection purposes, this finding is probably irrelevant, as Morrison et al. (1986) showed that calculation of PA as an ellipse instead of a square did not influence the heritability estimates as the same PH and PW measurements were used to calculate each PA. The elliptic calculated PA was 21% lower than the square calculated PA but the heritability estimate was unaffected (Morrison et al., 1986). Besides, PW and PH are generally well known, simpler to standardize and to use in practice as the anatomical structures are easy to localize. Hence, these standardized pelvimetric measurements can further be performed in selection programmes in order to prevent dystocia. However, breeding has developed new osseous structures in the contemporary cow making the pelvis more massive and less suitable for delivery compared to the medieval animals (Nakhur et al., 2003). Therefore, in individual cows this difference may be important as 0.4 cm, the mean difference between the OD and the PH, can be a world of difference in individual cases in the decision whether a calf can be extracted or has to be delivered by CS. Other factors that can contribute to this phenomenon can be the calving ability differences such as preparation for calving, relaxation of the soft tissue and straining capability, but these are very hard to investigate.

Age seems to influence the variation in pelvic size, as seen in other studies applying pelvimetry (Murray et al., 2002; Chapter 5.1). The pelvis is late maturing and its growth keeps pace with or exceeds increases in bodyweight between 2 and 6 years, which is one reason why feto-pelvic disproportion is less important in multiparous cows than in heifers (West, 1997). In this case dissimilarity between the latter diameters was only illustrated up till 4 years of age (Table 1), although this finding has to be put in perspective as only small numbers of cows were present in the older age groups.

# Conclusion

In conclusion, these results show that there is a difference between the pelvic diagonal diameters compared to the PH, which can have its influence on individual calving ability. Considering dystocia, the PA and shape have an important contribution and the latter difference may be an explanation for these rare individual cases calves were delivered naturally although theoretically impossible as the calf's HW measurements were on average larger than the dam's PH.

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# Chapter 6

# General Discussion

# TO CALVE OR NOT TO CALVE?

Since the beginning of selection of the Belgian Blue (BB) towards the double muscled (DM) phenotype (the first half of the 20$^{th}$ century), it was a challenge to breed DM cattle with normal calving ability. However, after the development and perfection of the CS technique, other characteristics were favoured to select for or against, and calving ease never was a priority in the DM-BB breed. Selection towards the DM phenotype was unintentionally accompanied by a relative reduction in the comparative size of the viscera and the length of the limb bones (Arthur et al., 1988), resulting in a decrease in inner pelvic dimensions (Coopman et al., 2003). This created a high incidence of dystocia caused by either the small variation in maternal pelvic size or by the impact of large fetal size, high birth weight and conformation or by both. Because in the majority of cases a Caesarean Section (CS) has to be carried out to raise the chance of the birth of a live calf, ethical questions arose limiting the use of this DM-BB breed for beef production on a large scale. In this work the consequences of CS in DM-BB cows concerning its complications and possible animals discomfort are studied, as well as the possibility of selection towards calving *per vaginam* in the DM-BB breed.

# THE CAESAREAN SECTION

## Individual welfare of the cow

The first part of the present thesis considers the individual welfare of the dam in relation with CS and *calving per vaginam*. Difficulties and complications experienced during CS were investigated in DM-BB as well as in non-BB animals. Overall, we can conclude that in the DM-BB breed the CS generally ends up with good results and few complications during the operation when compared to other breeds (Mijten, 1994; Newman, 2008), probably because surgery in these cows is performed at an early stage of parturition. This is a completely different situation compared to other breeds were the CS is a “rescue procedure” to save the calf and/or the cow. In the latter situation, the dam is usually in parturition for a much longer time before the operation is performed. Because of the high economic value of DM-BB calves and the relatively low cost of a CS in Belgium, Belgian farmers are not willing to risk the calf's life and usually expect their veterinarian to perform an elective CS. For that same reason, veterinarians will hardly ever carry out a trial extraction when facing a DM-BB animal in labour. Omitting a trial extraction in case of elective CS has several advantages in this particular situation such as less straining during surgery and subsequently a lower probability of recumbency during the operation. The incision of the abdominal wall is also easier due to less straining, and hence the exteriorization and incision of the uterus are less complicated. Furthermore, there is a reduced contamination risk of the uterine fluid, which is important to avoid complications after surgery such as peritonitis or wound infection (Mijten et al., 1996). Research concerning the complications after CS revealed that the amount of complications in the DM-BB breed is also low (Mijten, 1994) in comparison with other, mainly dairy breeds undergoing CS (Cattell and Dobson, 1990; Barkema et al., 1992; Bouchard et al., 1994).

In general, cows undergoing their second or third surgery experience more complications during surgery. As in Belgium, DM-BB cows generally undergo 2-3 consecutive CSs (or sometimes more) in a life time; one would expect more difficulties in cows with multiple CSs in this breed. But even during subsequent CSs, it is rather rare that difficulties occur in the BB breed. The combination of operating in an early stage during parturition and the operation being performed by very experienced veterinarians probably is the reason for these excellent surgery results. However, it has to be said that the number of operations that can be performed on a cow is not unlimited. Thus, systematically performing CSs limits the economic life span of DM-BB cows. Nevertheless, this restriction of the number of CSs per animal is not a major problem, as DM-BB cows are only growing, gaining weight and thus being profitable until approximately 4 to 5 years of age. Hence, culling after 2-3 CSs is economically considered to be the most profitable option.

Pain in animals is a complex issue and is dependent on several aspects such as the degree of tissue damage and previous pain experiences. Studies on pain or animal welfare are conducted using widely different methods. Practical experience has shown that pain in cattle is linked to typical signs and behavioural changes such as a significant decrease in food intake and grooming. Assessing behavioural responses is also a non invasive method and thus not harmful for the animal in contrast to invasive methods such as measuring plasma cortisol levels. We therefore chose for an observational study to evaluate discomfort and/or pain. Using a methodology comparable to our study, other scientists also studied the behaviour of animals, assessing stereotypes and other forms of abnormal behaviour (Lawrence and Rushen, 1993; Fitzpatrick et al., 2006). The interpretation of welfare using objective indices, such as physiological measures or signs of ill-health has also been described. Cortisol has been measured as an indicator of stress and/or pain in a study of welfare in farm animals (Kent et al., 1993). However, the blood sampling itself causes stress which may significantly affect the results (Queyras and Carosi, 2004). Acute phase proteins have been shown useful to evaluate disease severity, and can also be correlated with welfare and pain (Eckersall and Conner, 1988; Eckersall et al., 2001). Common alterations in physiology that indicate pain are heart rate (Lay et al., 1992), respiratory rate, body temperature (Mellor and Stafford, 1999), an increase in blood pressure and changes in the digestive system or the locomotory system (Morton and Griffiths, 1985). As we only recorded a large amount of behavioural parameters but no physiological parameters, our estimates of pain related to CSs and subsequent animal welfare has its limits. Therefore combining several methods for measuring animal welfare for pain related to CS might be indicated in future studies. Such a multidisciplinary approach was suggested by Sandøe et al. (2003).

Whether a skilfully performed CS with proper aftercare is causing more pain compared to calving *per vaginam* was recently not known. Watts (2001) demonstrated an increase of heart and respiratory rate for 24-36 hours after the CS and cows appeared to be more sensitive to wound pressure until 48 hours after the operation. However, this study did not consider calving *per vaginam* and hence had no 'reference' population. A rather subjective study, carried out to assess how experts score pain related to conditions and procedures in sheep and cattle, revealed that the bovine CS was perceived to be more painful than the same procedure in ewes (Fitzpatrick et al., 2002), but again there was no assessment of the perception of pain during calving *per vaginam*. Our investigation by objective observations done for both calving methods revealed some behavioural differences – specifically regarding the overall activity and the activity budget – primarily on the first day after parturition. Cows that underwent a CS spent less time eating and ruminating and had a longer resting time in comparison with their naturally calving herd mates. These parameters could be interpreted as an attempt to alleviate discomfort due to pain, suggesting that an analgesic treatment on the first day after CS might be indicated. Literature on the use of analgesic treatment for post caesarean pain relief is scarce. Watts (2001) found no significant reduction in parameters indicating pain after the use of meloxicam compared to a placebo after CS, but the number of animals studied was small. More profound research should be done on this subject, by means of increasing the number of animals, comparing pre- and postoperative administration of analgesic drug and comparing meloxicam to other analgesic treatments and a negative control.

However, so far we do not know how complications might increase discomfort or pain in animals. However, it appears plausible that a perfectly performed CS under good local anaesthesia with minimal tissue trauma and complications causes less pain than a CS with complications, manipulations and contamination leading to possible infection. Consequently, pain probably occurs less in the DM-BB breed as the elective nature of the CS minimizes the risk for complications compared to other non-DM breeds. Still, since all our observations were performed both during CSs and *per vaginam* parturitions without complications, we are unable to draw conclusions about the discomfort and pain during and following parturitions accompanied by complications. Complicated CSs are generally accompanied by excessive tissue trauma and/or an increased risk for infections. The consequences of these complications should be further explored. Another comment that has to be made is that our observational study was only conducted in multiparous animals as DM-BB heifers hardly ever calve naturally. For DM-BB heifers one may however hypothesize that a CS will probably be less painful than to calving *per vaginam*, as it is known that the pelvic area of these animals is not yet fully developed and in heifers fewer complications do occur during CS in comparison to multiparous animals. Hence, one could assume that a CS in DM-BB heifers is the method of choice to deliver a live calf.

## Instrumentalisation

Although the amount of complications and discomfort due to CSs seems to be low and maybe acceptable for the individual DM-BB animal, there is also an ethical discussion concerning the DM-BB breed itself. The high incidence of CS is considered to be an indication of the excessive instrumentalisation of these animals (Lips et al., 2001). Because of this reason some consumers might develop a growing aversion against the DM-BB breed. The possible limitation of CSs to be carried out only for medical reasons has been a major issue of debate in some European politics (e.g. Sweden, the UK and the Netherlands) for the last couple of years. The DM-BB breed has been developed commercially using selective breeding processes that exploit a natural mutation which gives rise to the double muscling effect. The DM-BB breed selection follows the same principles as the selection of other animals and plants for food production or hobby. However, the use of CSs and antibiotics in veterinary medicine forces us to take additional conditions into account for the selection of an economically profitable DM-BB breed. The use of technology in animal production can put higher pressure on the animals, possibly worsening the conditions the animal is living in (Christiansen and Sandøe, 2000). Our studies show that, if a CS is performed in an early stage of parturition and in a professional manner, the individual animal welfare is not harmed compared to assisted deliveries. Therefore, professional CS on DM-BB cows is no violation to the animal welfare of the cows. CSs on the DM-BB breed in Belgium are not carried out for biological reasons (20% of the cows is able to calve) but are being used in almost 100% of all deliveries for economic reasons (it is cheaper, takes less time and guarantees almost 100% success). This priority of productivity over animal welfare is an ethical problem in farm animal production as such and is not specific for the DM-BB breed or the use of certain biotechnologies (Roenningen, 1995). Thus, discussion of the use of biotechnologies is part of a wider discussion concerning the ethics of farm animal breeding. The DM-BB breed with its elective CS is only one of the many examples of instrumentalisation of animals within an industrial production system. It is a management choice that has been made to gain as much profits from an individual animal as possible. Similar choices have been made for dairy cattle, for broilers, laying hens, and for the pork industry. The dairy cow now produces 10 times more milk than her calf would suckle

(D'Silva, 1998) and breeding for this level of milk production increases the risk of mastitis (Sandøe et al., 1999). Today, the broiler chicken grows to a weight that is half the time it took 30 years ago. The muscles and gut grow fast but the skeleton and cardiovascular system does not follow, resulting in leg problems and heart failure (Broom, 1998; D'Silva, 1998; Rauw et al., 1998; Sandøe et al., 1999). Pigs, having been selected for high growth rate and lean tissue do have leg problems (D'Silva, 1998; Rauw et al., 1998) and are also more likely to become stressed or die during transport (Broom, 1998). Without entering the argument of elective CS in the DM-BB breed, at least it could be argued that selective breeding of farm animals, results in some net tangible benefit. In the case of pets, it is difficult to find a tangible benefit to either the animal or to society (Spencer et al., 2006). Just as for production animals, the same problems of instrumentalisation in our pet industry can be observed, for example the English bulldog dog breed needs a C-section in about 95% of the deliveries. Issues concerning instrumentalisation in farm production are highly complex and require a multi level approach including concerns of both consumers and producers, which may vary between countries, regions and believes. Giving objective answers to such complex issues is not within the scope of this thesis.

## POSSIBILITIES OF SELECTION TOWARDS A HIGHER PERCENTAGE OF NATURAL CALVING

As the criticism against the elective application of CSs in the DM-BB breed still grows, it is relevant to try to increase the incidence of uncomplicated parturitions *per vaginam* in this breed, albeit without losing its supreme carcass characteristics, for which the breed is highly valued by meat processors. Dystocia or calving difficulty has been studied in other beef and dairy breeds and Calving Ease Estimated Breeding Values (EBV's) are commonly used to improve the ease of calving. By far the most important part of this Calving Ease EBV is the calving difficulty score (Meadows et al., 1994; McGuirk et al., 1998; Luo et al., 1999), but as in Belgium parturition in the DM-BB breed is routinely managed by CS, a calving difficulty score cannot be obtained. The selection towards natural calvings in the DM-BB breed must be focused on reducing the birth weight and the degree of fetal muscular hypertrophy of the shoulders and hindquarters, in combination with increasing the pelvic area of the DM-BB dam, as the disproportion between these two is the most important risk factor for dystocia in cattle (Andersen et al., 1993). Selection towards an increase in pelvic area and a decrease in calf size/birth weight is only feasible if there is substantial variation for these traits among animals of the DM-BB breed in combination with a moderate to high heritability for these specific traits.

Our study indicated that there is substantial variation in pelvic size among DM-BB cattle in Belgium within the S-carcass classified animals besides considerable variations within the body sizes of newborn DM-BB calves, which are necessary to facilitate the selection towards a higher percentage of natural calvings. This fact together with a known high heritability for these traits in other breeds, suggests that selection towards a decrease of the CS frequency in DM-BB animals seems feasible. The results also illustrate that there is still enough margin within the S-carcass classification to increase the pelvic size without loss of conformation. Moreover, the mean differences for these pelvic measurements between animals calving *per vaginam* versus animals delivered by CS were rather small, namely 1.5 and 2.0 cm for pelvic width and pelvic height respectively, illustrating that the gain in pelvic size needed for calving *per vaginam* is surely not unreachable.

The difference between shoulder- and hip width of calves born by CS versus calves delivered *per vaginam* was albeit significantly numerically small. Unfortunately, it is very difficult to correctly assess the relevance of the significant difference in shoulder- and hip width between calves born by CS and those delivered *per vaginam* in relation to the incidence of dystocia, since CSs were performed electively, and consequently some calves born by CS might have been born *per vaginam* if a trial extraction had been performed. Nevertheless, the few DM-BB calves that were not born by elective CS but *per vaginam*, had smaller shoulders and hips and heart girth measurements, which suggests an influence of the calf's body conformation on the incidence of dystocia. Selection for smaller dimensions and lower birth weight is possible due to the sufficiently high heritability in the DM-BB breed for weight, shoulder width and width of the hind quarters at birth as shown by Coopman et al. (2004). However, this selection should not be too stringent, as the viability of the calf diminishes with excessive decrease of its birth weight (Holland and Odde, 1992; Bennett and Gregory, 1996). Furthermore, light calves need to have the potential to grow into large cows, so that on their turn, they are able to calve naturally. The use of sires with a birth weight EBV below the average and an EBV for weight at linear classification of the daughters above the average herein is preferable. Even when inbreeding and genetic abnormalities are also taken into account, there are still suitable DM-BB bulls available but the choice is rather limited.

## TECHNIQUES FOR DATA GATHERING

Gathering information about the pelvic area in the DM-BB breed on a large scale can be done by direct internal measurements or by estimating the internal pelvic dimension from different external measurements. Our studies on both techniques illustrate two important findings:

- The Rice pelvimeter showed good accuracy for both pelvic width and pelvic height. There were only small differences in pelvic width, pelvic height and pelvic area between measurements obtained from living cattle by pelvimetry compared to those obtained after slaughter, with the living measurements being generally smaller.
- The external measurements however proved not reliable enough to predict internal pelvic sizes, as we demonstrated that the association of the external pelvic measurements was too low to use in the models to predict internal pelvic sizes. Also when heart girth and withers height were used in the model, the reliability was only 65% for pelvic width, 65% for pelvic height and 72% for pelvic area. This is too low to use external pelvic measurements in order to ‘predict’ inner pelvic size to prevent dystocia, as still 30% of the variation in pelvic sizes can be explained by other (unknown) factors or even coincidence.

Therefore, we prefer the use of internal measurements by the Rice pelvimeter. Green et al. (1988) came to a similar conclusion that internal pelvic measurements were necessary as there is a large amount of additive genetic variation and one should not rely on estimation of body size alone. In addition, Anderson (1990) claimed that external measurements could not be used to predict the pelvic area as the correlation between the frame size and the pelvic area was not high enough. Consequently, internal measurements by pelvimetry seem to be a better option to use in the selection against dystocia. Furthermore, pelvimetry performed by a skilled person, can be considered completely harmless and without any adverse effect on the animals' welfare. In fact, the impact of the procedure on the animal can be compared with pregnancy diagnosis or artificial insemination. To obtain knowledge about the variation in pelvic size within his herd, the breeder/farmer can ask the assistance of a veterinarian to perform pelvimetry. Applying this technique in the frame of a veterinary herd health program allows data gathering with little extra costs and efforts. An even better procedure would be to implement this procedure in the linear evaluation of pedigree animals to gain knowledge on a quick and easy manner. In this way we would readily be able to calculate EBVs for pelvic dimensions.

When using pelvimetry to estimate the pelvic area, it is relevant to take the age of the animal into account, as a significant association was found between the internal body measurements and age, which is in accordance with the findings of other authors (Brown et al., 1982; Basarab et al., 1993). Furthermore, Basarab et al. (1993) found that heifer age, independent of pelvic area, body weight and hip height, was an important trait in predicting dystocia. In non-DM animals, age adjusted values are advised to be used in order to allow producers to compare the differences in pelvic size between animals (Deutscher, 1988). To adjust the pelvic area of DM-BB heifers for age, knowledge of the pelvic growth pattern within the DM-BB breed should be gathered like in other breeds. Green et al. (1988) found that pelvic size increased up to 5 years of age and that pelvic width is slightly slower in maturation than pelvic height (in Angus, Brangus, Hereford, Red Angus and Simmental breeds). Multiparous cows have a mature skeletal structure and body size and are therefore capable of giving birth to heavier calves (Houghton and Corah, 1989; Zollinger and Hansen, 2003). An ongoing study, in which we are investigating pelvic growth in female DM-BB animals, will provide us data on the rate and the duration of this growth in the DM-BB breed. Hence, estimating at what age a DM-BB animal will be able to calve *per vaginam* is still difficult as the precise age of maturation of the pelvic area in this breed is not yet known. Pelvic sizes in adult cows (> 6 years) in our data gave probabilities of calving *per vaginam* of only 15 - 20%. Consequently, other factors besides the pelvic area of the dam such as the size of the calf contribute to calving ability and thus to the prediction of calving *per vaginam* of the individual animal.

## THE ABILITY TO CALVE *PER VAGINAM* IN THE DOUBLE MUSCLED BELGIAN BLUE BREED

Specifically in the DM-BB breed, the sustained phenotypical selection for double muscling has led to a higher fetal weight and extreme muscular conformation in the DM-BB calf at birth and unintendedly also led to a decrease in body height and length and a significantly decreased pelvic inlet of the DM-BB dam (Hanset, 1998, 2004, 2005). This is causing a fetal-pelvic discrepancy, being the most important indication for CS. Within the pelvic inlet, the pelvic height is the most decisive factor for calving ease as it is larger than the pelvic width (Morrison et al., 1986; Murray et al., 1999). This was also confirmed by our results with a mean pelvic height of 18.8 ± 1.9 cm and a pelvic width of 15.2 ± 2.1 cm. The mean differences for these pelvic measures between animals calving *per vaginam* versus animals delivered by CS were rather small. Furthermore it was noticed that in around 25% of the cases animals that calved by CS had pelvic sizes comparable to those of animals that calved *per vaginam*, which suggests that more DM-BB animals may calve *per vaginam* when they would be given the opportunity. Based only on the PA, probably a part of the present DM-BB population is already suitable to calve *per vaginam*; however other factors also contribute to the ease of parturition.

The determining parts of the body of the DM-BB calf regarding ease of calving turned out to be the hip width for female calves. This finding concerning female calves is in agreement with reports of practitioners attempting to deliver DM-BB calves *per vaginam*, as ‘hip lock’ situations occur most frequently during the birth of female calves. Difficulties during *per vaginam* delivery of bull calves often occurs early in the expulsive phase of calving, as male calves have relatively wide shoulders. However this could not be demonstrated, as there was no significant difference between shoulder- and hip width in bull calves.

Comparison of the average pelvic height of DM-BB dams with the average hip width of the calves showed that mathematically spoken a delivery *per vaginam* is no longer possible in the present DM-BB population, as on average the hip width of the calves is 4.3 cm larger than the pelvic height of the cows. Nevertheless, the smaller calves still can theoretically pass the birth canal of the largest cows (hip width of 17.0 cm versus a pelvic height of 23.0 cm). Logically, data of individual DM-BB cow-calf combinations obtained at a farm with an exceptionally high frequency of calving *per vaginam* showed animals calving *per vaginam* that had a pelvic height larger than the hip width of the calf they delivered. However, these individual data also showed that even more animals (multiparous animals as well as heifers) calved *per vaginam* than considered possible based on these measurements (PH < HW). The fact that at least some calves with hips broader than the pelvic height of their mother were born naturally is very hopeful in order to select for natural deliveries. Furthermore, our results showed that the average difference between the pelvic height of the dam and the hip width of the calf in animals calving *per vaginam* was -3.50 cm whereas this difference was -4.34 cm in animals that calved by CS. The difference between the two groups of animals is small. All these abovementioned findings suggest that possibly more animals would have calved *per vaginam* when they had been given the opportunity to do so and that the difference between calving *per vaginam* versus by CS is just a matter of a few centimetres from the cows' point of view.

Whether a cow calves *per vaginam* or by CS can be due to a lot of other factors than the size of the pelvic inlet and the size of the calf. Specific adaptations in pelvic dimensions at calving were demonstrated by a significant increase in pelvic height was measured within 24 hours after parturition in comparison with measurements carried out one month before calving. In cows that delivered by CS this increase was 0.45 cm, while it was 1.42 cm in cows that had calved *per vaginam*. In the latter animals, we also found a significant increase in pelvic width (0.53 cm) and pelvic area (35.64 $cm^2$). Surprisingly, these results were found in multiparous animals, where the pelvic entrance is considered to be a rigid structure due to the ossification of the symphyse cartilage. Additionally, measurements have proven that if the obstetrician is able to turn the calf during parturition in such a way that the calf's hip width passes through the oblique pelvic axis another 0.43 to 0.45 cm can be 'gained'. These results may be important in the decision of individual cases whether a calf can be extracted or has to be delivered by CS when pelvic measures are known. In that case the distance of the pelvic diagonal height diameter of the pelvis is the determinant for natural calving. In our studies we tried to gain data for the farmer to use to predict the probability of calving *per vaginam* in a more accurate way, but the reliability of our equations to estimate the calf turned out to be too low for this purpose. With the availability of B-mode transrectal ultrasonography, future studies assessing the shoulder- and hip width of the fetus in late gestation should establish a more accurate estimation of these body sizes to minimize the risk for the farmers at the moment of parturition

In order to determine, whether this increase in pelvic height at the moment of parturition in natural calving animal DM-BB is caused by the passage of the calf (mechanical force) or rather is itself the reason why the calf is able to pass (better relaxation of the soft tissue and 'opening' of the birth canal), research should be done, measuring pelvic width and pelvic height one month before parturition and comparing these data with similar measurements carried out just before and after calving. An increase of the pelvic measures just *before* calving in comparison with one month earlier is probably due to a better hormonal relaxation of the birth canal, whereas a difference between measurements done just *before* versus just *after* calving would be caused by the passage of the calf.

For the individual parturition, it was seen that more animals (multiparous animals as well as heifers) calved *per vaginam* than considered possible based on our measurements. The fact we were not able to clarify all the reasons for this by comparing the dam's pelvic height with the calf's hip width or by the influence of the parturition and the shape of the pelvic inlet, suggests that other factors contribute to the ability to calve *per vaginam*. Factors on the dam's side proposed to have an influence are body size, more specific conformation and pelvic slope, and differences in calving ability between individuals. The latter can be divided in the preparation for the parturition, the hormonal relaxation of the soft tissues, and the will and power to strain during parturition (Meijering, 1984; Gaines et al., 1993). From the calf's point of view, the compressibility of its body may also have considerable influence. Whether these factors play a part in the calving ability and to what extent has to be studied more in detail.

Concerning the viability of the calf, research should be done on the amount of stress a DM-BB calf can handle during parturition *per vaginam*. Already in other breeds the number of calves lost from calving difficulty exceeded losses from all other causes (Cappel et al., 1998). Research has shown that calves experiencing calving difficulty are about four (Laster et al., 1973) or five times (Azzam et al., 1993) more likely to be still born or to die within 24 hours after birth than those born without difficulty. Calf mortality rises with the increase of the severity of dystocia (Nix et al., 1997). Dystocia leading to CS was connected with an even higher mortality rate of more than 50% (Hajurka, 2006). A study of Cappel et al. (1998) showed that the degree of calving difficulty has a pronounced effect upon the calf's ability to adapt to its new environment. Calves that require mechanical assistance and/or surgical intervention express depressed cortical and neutrophil values necessary for the immediate adjustment to their new environment. Besides, their survival mechanisms are further compromised by depressed metabolic adaptation capabilities (Cappel et al., 1998). Based on empirical data we know that compared to a Holstein Friesian calf, DM-BB calves are more fragile and cannot cope with the same amount of stress and metabolic acidosis. The DM-BB calf has a lower ventilation and cardiac reserve capacity (Uystepruyst et al., 2002), so consequently it will be more susceptible to stress and metabolic changes during parturition. The force a DM-BB calf can cope with during an extraction without a negative influence needs further investigation in order to prevent that the selection towards natural calving performed to counteract ethical concerns does not result in higher calf mortality which might be an even greater concern to animal welfare as very few DM-BB calves die after CS. Moreover, compared to vaginal deliveries, elective CS has been associated with a higher neonatal survival rate in the DM-BB breed (Baier et al., 1973, Rasschaert, 1980; Michaux and Hanset, 1986; Michaux and Leroy, 1997). In addition, Mijten (1994) saw that the perinatal mortality rate increased in cases the allantoic sac had been ruptured for more than 2 hours at the time of the obstetric intervention compared to an intact allantoic sac. A comparison of calves born by CS and natural delivery in the BB breed demonstrated that metabolic acidosis and hence anorexia related to parturition was lower in the calves born by CS (Dardenne et al., 1997). Performing a CS at a very early stage as it is electively done in this breed in Belgium, was demonstrated to have a positive influence on the respiratory and metabolic adaptation in full-term DM-BB calves (Ustepruyst et al., 2002).

## GENERAL CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

Our studies demonstrate that, taking the existing variation in the DM-BB pelvic dimensions (in animals within the S carcass classification), the DM-BB calf body sizes, and the high heritability estimates for these traits in account, selection towards calving *per vaginam* is possible without loss of conformation. The rather small discrepancy of fetal-dam disparity of DM-BB animals calving *per vaginam* compared to animals that had calved by CS encourages the selection towards calving *per vaginam* in the DM-BB breed. These findings also suggest that possibly more animals are able to calve *per vaginam* when they get the opportunity to do so. To select in a way that diminishes the CS rate and improves the image of the DM-BB breed, there should be cooperation between farmers/breeders, the BB herd book (Herd book Blanc-Bleu Belge [HBBBB]), the Belgian cattle association (Coöperatie Rundvee Verbetering/Vlaamse Rundveeteelt Vereniging [CRV-VRV]) and the Belgian government. In order to start a selection program, EBVs for pelvic measurements are necessary and those should hence be determined. Gathering information to determine these EBVs can be done with minimal effort as pedigree animals are already registered and linearly classified and pelvimetry data can relatively easy be added to the linear classification procedure. Furthermore, DM-BB breeders should be encouraged to register these data as soon as possible as the pelvic area already decreased 37 $cm^2$ (difference between pelvic area measurements of Murray's Belgian group [325.7 ± 45.0 $cm^2$] versus ours [288.5 ± 60.9 $cm^2$]; Murray et al., 2002) in 6 years through the selection towards better muscled animals. Simultaneously, the focus within the selection program for decreasing dystocia should also be on lower birth weight and decreased muscular conformation at birth of the DM-BB calf, with the remark that both muscular conformation and stature of these calves should fully develop after birth. Taking the already existing EBVs for these traits at birth into account at the same time will help in decreasing the number of CSs in the DM-BB population. A breeding program that was simultaneously started with the present doctoral research has already produced several natural born DM-BB calves of normal size and conformation. However, these existing EBVs are based upon estimates rather than measurements of birth weight and conformation. To more accurately determine EBVs of these calf traits, it should be advised to breeders/farmers to weigh and measure birth weight and/or shoulder- and hip width and register these data in a centrally controlled dataset. These assembled data would allow us to calculate more reliable EBVs for the different traits proven to be important for calving *per vaginam*, such as pelvic height of the dam (corrected for age), and the birth weight and body size of the calf. The Belgian cattle association and the HBBBB are the well-chosen organisations that could coordinate this and publish EBVs for calving ease traits. In addition, the HBBBB might promote calving *per vaginam* in the BB breed towards the Belgian farmers as well as towards the rest of the world.

To start selection towards calving *per vaginam* in a particular herd a breeder/farmer should first have knowledge of the variation in pelvic dimensions in his herd. To get this information, pelvimetry should be applied on all suitable animals (prebreeding and at older age) to enable the farmer to select the 10 or 20% largest cows (at least 20 cm pelvic height at 3 - 4 years) of his herd to start with. These animals can be sired with a DM-BB bull known to give calves with a low birth weight and/or smaller shoulder- and hip width according to his EBVs for these traits. However, selection for smaller dimensions and lower birth weight should not be too intense, as the viability of the calf diminishes with an excessive decrease of birth weight. Furthermore, light calves need to have the potential to grow into large cows, so that on turn, they are able to calve naturally. These selected animals also are the ones that should be given an opportunity to prepare for parturition and the farmer and/or the veterinarian should at least perform a trial extraction on these animals. Recommendations according feeding around parturition are difficult as underfeeding has not proven to lower the incidence of dystocia (Bellows et al., 1971) while overfeeding aiming to stimulate the growth of the dam has led to fat animals and even more complications during parturition (Rutter et al., 1983). In practice, however, in the UK a poor ration is given to the British Blue dams during the last month before parturition although the content of such a ration is not at all well defined and differs between farms. The best ration to prepare cows for calving *per vaginam* without losing growth and carcass quality in the DM-BB breed, has yet to be investigated.

Nevertheless, the CS will still be necessary for those animals with small pelvic areas or abnormalities during parturition, i.e. as a rescue procedure. During a CS in the bovine, mild and/or severe operative difficulties are always possible and consequently farmers and veterinarians should be aware of factors influencing the risk for difficulties, such as multiple CS, as this will help them to minimize the occurrence of problematic situations. Results show that performing a CS at an early stage during parturition significantly reduce the odds of encountering problems before and during surgery. Hence, when a CS is electively performed, the veterinarian should intervene in the early stages of parturition. Having had a prior CS was associated with an increased risk for mild and severe complications, so a decrease in the amount of CS per animal is also a good management tool to reduce difficulties. From the veterinarian's point of view it was demonstrated that highly experienced vets were less frequently confronted with severe complications. So we have to educate and train our veterinary students as efficient as possible and make sure they are aware of the risk factors around the CS. The use of an analgesic treatment just after surgery might increase the comfort of the animal, as it was shown that animals calving via CS had a more discomfort during the first day post partum. This however has to be further investigated.

To conclude, based on the results of the present thesis we can state that there is a relatively wide variation in the size of the pelvic canal in modern phenotypically DM-BB cows as well as in the body sizes of phenotypically DM-BB calves which suggests that selection towards calving *per vaginam* is possible without loss of conformation. I sincerely hope that this work will encourage farmers gathering information to determine EBVs for calving ease traits within the DM-BB breed and stimulating the HBBBB to publish them. The Rice pelvimeter is a suitable 'tool' to measure the pelvic area of pedigree animals with minimal effort. Finally, the CS will still be necessary in the future; however results of this thesis demonstrate that performing a CS correctly at an early stage of parturition significantly reduces the odds of encountering problems before and during surgery and causes only subtle discomfort for the cow.

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# Chapter 7

# Summary

In the double muscled Belgian Blue (DM-BB) breed dystocia is caused by incompatibility between the size of the calf and its mother's pelvis due to the selection towards hypermuscularity. Therefore, in most of the cases a Caesarean Section (CS) has to be carried out, which poses ethical questions limiting the use of this breed for beef production to a large extent. In order to investigate the CS and its complications as well as the possibility of selection towards calving *per vaginam* (= natural calving without or with mild traction) several studies were performed which are described in the present doctoral thesis.

After the general introduction (**Chapter 1**), a literature overview is given in **Chapter 2** considering both calving methods. The history, the indications and the technique of the CS are reviewed together with the complications that may arise before, during or after the operation (**Chapter 2.1**). In **Chapter 2.2** an outline of all the factors influencing the ability to calve is displayed.

The primary aim of this thesis was to gain a clear view of both methods of calving in the DM-BB breed (**Chapter 3**). This was achieved by investigating the difficulties encountered during a CS and the observation of behavioural changes experienced after this operation in comparison with calving *per vaginam* (**Chapter 4**). In the second part of the thesis (**Chapter 5**), some experimental studies are described which were carried out to assess the possibility of selection towards calving *per vaginam* by investigating what specific body measures of the dam and her calf are detrimental for normal parturition and whether there is sufficient variation within these sizes to open possibilities for future genetic selection. Besides this, we searched for other factors influencing the calving process of this breed.

As the CS is still the most common way of calving in this breed, our first aim was to investigate this operation. Complications encountered during this operation in practice on (mainly) DM-BB cows are described in **Chapter 4.1** together with the identification of associated risk factors (breed, number of CSs and veterinarian). This was done by a questionnaire completed by 18 veterinarians immediately after the CS. Results of this study including 1275 CSs revealed that the DM-BB breed had fewer severe operative problems in comparison with animals of other breeds, most likely due to the fact that CSs in the BB breed are performed in a very early stage of parturition. Mild as well as severe difficulties were more likely to happen during surgery in cows that had undergone a CS before. Cows at their second or third surgery, had a significantly higher proportion of larger calves and more scar tissue was present, both increasing the risk of abdominal wall muscular and uterine bleeding. These factors can all lead to problems with exteriorizating and suturing of the uterus, which implies that careful attention is needed when performing a CS on a cow which has experienced the procedure before. Besides the breed and the CS number a significant influence was seen of the veterinarian. Experienced veterinarians reported fewer complications during the operation.

As the elective use of the CS poses ethical questions limiting the exploitation of this breed for beef production to a large extent, we explored the behavioural differences to estimate and discomfort and possibly pain experienced by DM-BB animals following CS versus natural calving (**Chapter 4.2**). An observational study was carried out during the peripartum period in order to assess the differences in discomfort or pain perception in cows calving *per vaginam* versus cows delivered by CS. In total 30 multiparous animals of the same herd, of which 17 were delivered by CS and 13 had calved *per vaginam*, were closely observed at approximately 1 month before calving and at days 1, 3 and 14 after parturition. Besides overall activity and activity budget, the main behavioural indicators of discomfort or pain included were alertness, transition in posture from standing to lying and vice versa, aggressive behaviour, vocalization, rumination quality, reaction on wound and vulva pressure, and the percentage of visible eye-white. The main significant differences were a lower overall activity and more transition in posture in animals that were delivered by CS in comparison to cows that had calved naturally. In the CS group, animals spent less time eating and ruminating, their total resting time was longer and their total standing time was shorter. These significant differences were only observed during the first day after calving. Furthermore, cows of the CS group reacted significantly more when pressure was put on the left flank on the first, third and fourteenth day after calving, whereas animals that had calved *per vaginam* showed more reaction when pressure was put on the area around the vulva, but again only during the first day. Based on the results of this study, we conclude that there are some significant short-term behavioural differences between DM-BB cows that calve *per vaginam* and those that are delivered by CS, but in general, these differences are subtle and of short duration.

Besides the debate about discomfort or pain caused by CS on the individual animal, the second ethical discussion concerning the DM-BB breed is the high incidence of CSs being an indication of the excessive instrumentalisation of these animals. Selection towards a decrease in the number of CSs without losing conformation and carcass quality would be an answer for these ethical concerns and may open doors to a more widespread distribution of the breed. As in Belgium almost all DM-BB cows calve by CS, there is no possibility to gather information about the calving difficulty score, and the use of a calving ease index in the selection against CS is not an option in our country. It is generally known that the calf's birth weight (BW) and size account for most of the variation in ease of calving. In the DM-BB breed, it had however to be clarified which body parts are of decisive importance to allow natural delivery. On the maternal side, the size of the pelvic area (PA) is the major contributor towards the variability in calving ease. Information about the pelvic size of the dam and the size of the decisive body parts of the calf may probably allow the obstetrician to more accurately predict the probability of natural calving. Furthermore, to decrease the number of CSs within the DM-BB breed, a simultaneous selection for a bigger PA in the dam and a smaller body size of the calf will be necessary.

As it is known from literature that there is a moderate to high hereditability for the size of the PA and other decisive parts in other beef breeds, we first investigated the variability among these sizes within the DM-BB breed. This was performed in the second part of this thesis (**Chapter 5**). In order to select towards a larger PA, we should be able to accurately measure this on living animals. Pelvimetry may offer an accurate method for this purpose. The pelvimeter had already been used in this breed once in a study in 1998, but no observations were made on the suitability of measuring the PA to predict and reduce the dystocia rate in calving heifers. It was known that the pelvis of DM-BB animals had a somewhat different shape in comparison with other beef breeds, associated with the decrease in overall body size, including pelvic height (PH), through years of selection for hypermuscularity. Therefore, pelvic measurements (pelvic width [PW], PH, PA) from 466 DM-BB cows aged 2 - 10 years old and of an excellent carcass qualification (S and E in the

SEUROP classification) were done with the pelvimeter approximately 12 hours prior to, and by a graduated ruler within 2 hours after slaughter (**Chapter 5.1**). The mean difference of measurements between living and dead animals were -0.2 cm for PW (95% limits of agreement -2.5 - 2.1 cm), and 1.2 cm for PH (95% limits of agreement -1.8 - 4.1 cm). The correlation coefficient between all pelvic measurements was between 0.46 - 0.59 ($P < 0.001$). PH was only influenced by the age of the animals, whilst carcass weight had an association with all the components of the pelvic dimension (PW, PH and PA). There was a significant correlation between the pelvimetric measurements of the birth canal in living cows obtained using a Rice pelvimeter compared to actual measurements obtained from the carcass. Therefore it was concluded that the Rice pelvimeter is a suitable tool for assessing accurate pelvic skeletal conformation and to select animals in this breed with a larger birth canal and hence less dystocia problems.

In **Chapter 5.2** the Rice pelvimeter was used, besides other measuring equipments, to explore the mean and variation of pelvic sizes (both measured internally as well as externally) and body dimensions of DM-BB cattle in Belgium that calved either by CS or *per vaginam*. The withers height (WH), heart girth (HG), the distance between the two *tubera coxae* (TcTc) and the distance between the two *tubera ischiadica* (TiTi) were compared to the internal pelvic measurements of width, height and area. Herds in Flanders presented 507 cows and heifers for measuring. Mean values were 58.9 ± 6.2 cm for TcTc, 14.6 ± 2.3 cm for TiTi, 15.2 ± 2.1 cm for pelvic width (PW), 18.8 ± 1.9 cm for pelvic height (PH) and 288.5 ± 60.9 $cm^2$ for pelvic area (PA). There was a significant correlation between type of calving (CS or calving *per vaginam*) and WH ($P < 0.05$), TcTc ($P < 0.05$), TiTi ($P < 0.001$), PH and PA ($P < 0.001$). Cows that had calved *per vaginam* had larger body and pelvic measurements compared to animals that were delivered by CS. The external pelvic value TcTc had a higher correlation ($r = 0.58 - 0.63$) with the internal pelvic measurements than the TiTi ($r = 0.22 - 0.28$). The correlation between other external body measures such as HG and WH was even higher ($r = 0.69 - 0.74$ for HG and $r = 0.67 - 0.74$ for WH). Measuring internal pelvic parameters and to a lesser extent external body parameters for cows of this breed may assist selecting cows that can calve *per vaginam* and reduce the dependence on elective CS for developing its conformational characteristics.

On the calf's point of view it is generally known that most of the variation in calving difficulty is determined by BW and size. As the DM-BB is a beef breed characterized by its extreme muscularity, calving ability is probably more dependent on the specific conformation instead of 'the overall size' of the calf. To clarify which body parts of the calf are of decisive importance allowing natural delivery and to investigate both the mean value as well as the variation among these body sizes within this breed (variation being an important condition for selection), measurements of nine body parts (BW, body length [BL], length of the head [LH], shoulder width [SW], hip width [HW], heart girth [HG], withers height [WH] and the circumference of the fetlock of both the front [CFF] and the hind leg [CFH]) were assessed in 147 newborn DM-BB calves on 17 farms (**Chapter 5.3**). The mean BW was 49.2 ± 7.1 kg. The average BL was 56.4 ± 4.5 cm and the mean LH 24.4 ± 2.3 cm. Measurements obtained for SW and HW were 22.4 ± 2.2 cm and 22.9 ± 2.1 cm respectively, while the mean WH was 71.1 ± 4.7 cm. Measurements of circumferences revealed a CFF of 17.9 ± 1.1 cm, a CFH of 18.0 ± 1.0 cm and a mean HG of 78.0 ± 5.4 cm. Partial correlations of the BW with eight body measurements were significant ($P < 0.01$) and ranged between 0.17 - 0.85, 0.42 - 0.88 and 0.24 - 0.88 when corrected for gender, parity and type of calving, respectively. Body length ($P < 0.01$) and the CFF and CFH ($P < 0.001$) were significantly larger in bull calves than in heifer calves. Calves born via CS had a broader SW ($P < 0.01$) and HW ($P < 0.01$) when compared with calves delivered *per vaginam*. Sizes of calves born out of multiparous animals were generally larger than of calves born out of heifers (SW: $P < 0.001$; HW: $P < 0.05$). As SW and HW are the broadest points of a BB calf, they are both candidates for being the limiting factors for calving ease, but the difference between HW and SW for the total dataset was not different from zero ($P > 0.05$). In contrast to male calves where no significant difference between HW and SW could be found, in female calves the HW was significantly different from the SW ($P < 0.001$), thus in female calves the HW is the most limiting factor of the calf's body. The significant variation in some body measures and the strong correlation within these sizes makes selection towards smaller calves possible. Furthermore, based on our results we were able to build equations for the farmer to use at the moment of calving containing the LH, the CF and the calf's gender to accurately estimate SW and HW. Together with the knowledge of the pelvic size of the dam, this information gives the obstetrician or the farmer a more accurate prediction of the probability of a natural calving.

In **Chapter 5.4** an evaluation was made of the fetal-dam disparity present in DM-BB cattle, by comparing the mean SW and/or HW of DM-BB calves and the mean PH of DM-BB dams, as well as by comparing individual cow-calf dimensions. Measurements in 507 DM-BB animals of which 56 animals calved *per vaginam* showed a mean PH of 18.8 ± 1.9 cm with a minimum and maximum of 11.0 and 23.0 cm respectively, compared to a mean shoulder width (SW) and hip width (HW) of 147 newborn DM-BB calves of 22.4 ± 2.2 cm and 22.9 ± 2.1 cm, respectively. Thus purely mathematically speaking, the average DM-BB calf is too large to pass the birth canal of the average DM-BB dam. However, the largest cows (with a PH of 23.0 cm) are still able to deliver the average DM-BB calf *per vaginam*. Comparison of individual cows and their calves of a herd with a high frequency of calving *per vaginam* showed that more animals (multiparous animals as well as heifers) calved *per vaginam* than mathematically possible when the individual cow-calf measures were compared, which is both very intriguing and hopeful for selection against dystocia in the future. The latter however also suggests other factors to contribute to calving ability, including the influence of the parturition process itself on the pelvic dimensions. Therefore, the influence of the type of parturition itself being either CS or a delivery *per vaginam* on the PW, PH and PA in DM-BB cows was examined. The results of these measurements demonstrated that cows which calved by CS had a significantly larger PH within 24 hours after parturition compared to their PH one month before parturition (0.45 cm, $P < 0.05$). No significant influence was seen on PW and PA. In cows that gave birth *per vaginam*, all three pelvic measures increased around calving in comparison with the measurements one month before parturition (PH: 1.42 cm [$P < 0.001$], PW: 0.53 cm [$P < 0.05$] and PA: 35.64 $cm^2$ [$P < 0.001$]). These findings indicate that parturition itself influences the pelvic canal size and thus contributes to calving ability in the DM-BB breed, besides the pelvic dimensions of the dam and the body sizes of the calf.

By trying to find an answer on these rare cases where the calf was delivered naturally, although theoretically impossible as the calf's SW and/or HW measurements were larger than the dam's PH, another possible factor influencing dystocia – the influence of the shape of the pelvic inlet – was investigated in **Chapter 5.5**. To do so, a comparison was made between the PH and the pelvic diagonal height (left oblique diameter [ODL] and right oblique diameter [ODR]) in 87 DM-BB cows. Overall, a significant difference was found between PH and ODL and ODR respectively ($P < 0.001$; difference PH - ODL: -0.43 cm; difference PH - ODR: -0.45 cm), but no dissimilarity was seen between the ODL and ODR. In individual cows this difference of 0.4 cm may make up a difference in the decision for a natural delivery. The elliptic shape of the pelvic inlet might have an influence on calving ability and can be a possible explanation for these rare individual cases where the calf is born naturally even though theoretically impossible.

Finally, in **Chapter 6**, the main results are summarized and discussed. From the results, the following conclusions can be drawn:

1. Double muscled BB cows have significantly less complications during CS in comparison with non-BB cows. Having had a prior CS is associated with an increased risk for difficulties. Highly experienced vets encounter fewer complications.

2. Some behavioural differences could be observed in cows that underwent a correctly performed CS under local anaesthesia compared to naturally calving cows, indicating discomfort or pain. This change in behaviour was subtle and of short duration.

3. Pelvimetry is a useful tool for veterinarians and farmers to select animals in the DM-BB breed with a larger birth canal and hence less dystocia as a moderate to good agreement between measurements on the living animal and the carcass measurements was found.

4. Considering the existing variation in the DM-BB pelvic dimension and the HW and SW of DM-BB calves, and the high heritability estimates of pelvic sizes, selection towards less CSs is possible.

5. The rather small discrepancy between the PH of the dam and the HW of the calf in DM-BB animals calving *per vaginam* in comparison with animals that had calved by CS encourages selection towards calving *per vaginam* in the DM-BB breed. Apparently some part of the population is already able to calve *per vaginam*.

6. For individual calvings, the shape of the PA and the influence of the calving itself are important factors in the calving process. These factors may explain why in some cases calves are delivered per vaginam although theoretically impossible as the calf's HW exceeds the dam's PH.

# Chapter 8

# Samenvatting

Bij het Belgisch Wit Blauw (BWB) ras is door de selectie naar hyperbespierdheid een wanverhouding ontstaan tussen de grootte van het kalf en het bekken van de koe. Het kalf is met andere woorden te groot en te zwaar in verhouding tot het bekkenkanaal van de koe. Bij de partus moet daarom in zeer veel gevallen een keizersnede (KS) worden verricht. Als gevolg van deze geboorteproblematiek worden er in Europa en voornamelijk in de Scandinavische landen vragen gesteld bij de fokkerij van het BWB ras. Indien door selectie op kleinere kalveren en bredere bekkens bij de koeien, het ras zodanig veranderd kan worden dat het aantal keizersneden sterkt daalt terwijl de conformatie kan worden behouden, dan zou dit het bestaan van het BWB ras veilig kunnen stellen. Om na te gaan in welke mate de KS – met zijn eventuele complicaties – het welzijn schaadt, en om te zien wat de mogelijkheden zijn voor selectie op kleinere kalveren en bredere bekkens bij de koeien, zijn verschillende onderzoeken uitgevoerd die in dit doctoraat worden beschreven.

Na de algemene introductie (**Hoofdstuk 1**) wordt er in **Hoofdstuk 2** een overzicht gegeven van de bestaande literatuur. De geschiedenis, de indicaties, de techniek en mogelijke complicaties van de KS worden besproken in **Paragraaf 2.1**. In **Paragraaf 2.2** wordt een overzicht van alle factoren die invloed kunnen hebben op het verloop van de kalving bij BWB dikbilkoeien besproken. De precieze doelstellingen van het onderzoek zijn beschreven in **Hoofdstuk 3**.

Omdat in België bij het BWB ras de KS veelvuldig wordt uitgevoerd, wordt in **Hoofdstuk 4** de nadruk gelegd op deze operatie. Ondanks het feit dat Belgische dierenartsen de keizersnedetechniek zeer goed beheersen, blijft het een open buikoperatie met risico op complicaties. Onder praktijkomstandigheden wordt de KS immers vrijwel altijd uitgevoerd in een gecontamineerde omgeving. De operatie kan dus niet worden beschouwd als een 'steriele' procedure. Ook kunnen de dieren niet in alle omstandigheden op een optimale manier worden gefixeerd. Bovendien zijn er vaak nog andere gevaren aanwezig die aanleiding kunnen geven tot complicaties. In **Paragraaf 4.1** wordt het onderzoek beschreven naar de moeilijkheden die tijdens de operatie kunnen optreden en naar de uitlokkende factoren. Dit onderzoek is uitgevoerd op basis van een enquête die werd afgenomen bij 18 dierenartsen met vragen over de techniek van de operatie en de eventuele complicaties die waren opgetreden bij in totaal 1275 KS. Naar voren kwam dat dieren van het BWB ras minder ernstige complicaties ondervonden in vergelijking met dieren van andere rassen (niet-BWB). Dit is waarschijnlijk gerelateerd aan het feit dat BWB dieren meestal in een vroeg stadium van de partus worden geopereerd. Dieren die vaker met een KS zijn verlost, hebben meer kans op complicaties tijdens de volgende KS. Deze dieren hebben ook vaker een groter kalf waardoor de kans op een bloeding in de baarmoeder wordt vergroot. Ook zijn er bij deze dieren meer problemen met het in de wond halen en het hechten van de baarmoeder. Daarnaast hebben dieren die vaker met een KS zijn verlost meer littekenweefsel wat leidt tot meer bloedingen in de wond. Dit alles geeft aan dat er vooral bij dieren die vaker via een KS moeten worden verlost extra aandacht moet besteed worden aan het voorkomen van complicaties. Ook bleek dat een dierenarts met veel ervaring (> 10 jaar), minder last had van complicaties dan een minder ervaren collega.

Het systematisch toepassen van de KS met zijn eventuele complicaties roept bij een aantal personen ethische vragen op aangezien niemand goed weet in welke mate dieren die deze operatie ondergaan pijn of ongemak ondervinden. Omdat de vragen die er rond het routinematig uitvoeren van de KS aanwezig zijn, het voortbestaan van het BWB ras in het gedrang kunnen brengen, wordt in P**aragraaf 4.2** getracht in te schatten in welke mate BWB dieren gedragsveranderingen of ongemak ervaren na een KS in vergelijking tot natuurlijk kalvende dieren van hetzelfde ras. Daartoe is een observationele studie uitgevoerd bij in totaal 30 BWB koeien waarvan er 17 afkalfden via een KS en 13 op natuurlijke wijze. De observaties zijn uitgevoerd 1 maand vóór en 1, 3 en 14 dagen na de partus, waarbij er onder andere onderzoek is gedaan naar algemene activiteit, tijdsbesteding en verschillende pijnindicatoren. De belangrijkste gedragsveranderingen die werden waargenomen, waren een verminderde algemene activiteit en minder veranderingen van liggen naar staan (en visa versa) bij dieren die een KS hadden gehad. De KS koeien besteedden ook minder tijd aan eten en herkauwen. Ze lagen langer en stonden minder. Al deze verschillen werden enkel waargenomen op de eerste dag na de KS en niet op dag 3 en dag 14. Daarnaast reageerden dieren die een KS hadden ondergaan op alle drie de observatiedagen na de partus significant meer op druk uitgeoefend op de linker flank, terwijl dieren die natuurlijk gekalfd hadden enkel op de eerste dag na de partus meer reageerden op druk op de vulva. Aan de hand van deze resultaten, kan geconcludeerd worden dat bij BWB koeien die met een keizersnede zijn verlost enkele gedragsveranderingen waar te nemen zijn, die niet optreden bij BWB dieren die normaal hebben afgekalfd. Deze gedragsveranderingen zijn echter subtiel en van korte duur zijn.

Naast de discussie die gevoerd wordt over het eventuele ongemak waaraan het individuele dier wordt blootgesteld, is er ook veel discussie over de hoge mate van instrumentalisatie (= het gebruik van dieren als een machine). Niettegenstaande het feit dat er in België weinig bezwaren zijn tegen het routinematig uitvoeren van de KS bij BWB dieren, is het niet ondenkbaar dat er op een zeker moment een Europees verbod komt op het routinematig uitvoeren van de KS. Selectie van dieren die met behoud van conformatie wel normaal kunnen kalven, kan mogelijk een oplossing bieden. Omdat in België bijna alle BWB dieren door middel van een KS kalven, zijn er in dit ras geen afkalfscores beschikbaar die toelaten te selecteren op minder afkalfproblemen. Het is al lang bekend dat het geboortegewicht en de lichaamsmaten van het kalf de grootste invloed hebben op de variatie in geboorteproblematiek. Hierbij is het belangrijk te weten welke lichaamsmaten er specifiek bij het BWB ras van determinerend belang zijn met betrekking tot het afkalfgemak. Wat de moeder betreft, is de oppervlakte van de bekkeningang het meest doorslaggevende kenmerk en tevens het kenmerk met de grootste variatie. Informatie over deze oppervlakte en de specifieke lichaamsmaten van het kalf moeten de dierenarts kunnen helpen om een inschatting te maken van de kans op een natuurlijke kalving. Om te kunnen selecteren op een vermindering van het aantal keizersneden binnen het BWB ras, is het daarnaast noodzakelijk om op termijn de bekkeningang van de vrouwelijke dieren te vergroten en het geboortegewicht (de grootte) van het kalf te verminderen.

Om vast te stellen of selectie naar een vermindering van het aantal KSs mogelijk is, moet onderzocht worden of er variatie bestaat in enerzijds de bekkenmaten van BWB koeien en anderzijds de lichaamsmaten van BWB kalveren. Selectie is namelijk alleen mogelijk indien er genoeg variatie voor een bepaalde parameter binnen een populatie aanwezig is samen met een gemiddelde tot hoge erfelijkheidsgraad voor dat bepaalde kenmerk. Het onderzoek naar deze variaties wordt beschreven in **Hoofdstuk 5**, evenals het onderzoek naar de specifieke bekkenmaten bij de moeder en de lichaamsmaten bij het kalf welke van belang zijn voor de individuele natuurlijke kalving. Om te kunnen selecteren naar een grotere bekkeningang om zodoende een reductie te verkrijgen van de geboorteproblematiek, dient een accurate manier gevonden te worden om de grootte van de bekkeningang te meten bij levende dieren. Pelvimetrie is een dergelijke manier, maar deze techniek werd bij het BWB ras nog niet voldoende uitgetest. Er wordt namelijk gesuggereerd dat door de selectie naar hyperbespierdheid er tegelijkertijd een verkleining van het skelet is opgetreden, waardoor het bekken van een BWB dier vermoedelijk ook een andere vorm heeft gekregen in vergelijking tot dat van andere vleesrassen. Om de geschiktheid van de Rice pelvimeter na te gaan zijn bekkenmetingen (bekkenbreedte, -hoogte en -oppervlak) uitgevoerd bij 466 BWB koeien tussen 2 en 10 jaar oud met een excellente karkas classificatie (S en E in het SEUROP classificatie systeem; **Paragraaf 5.1**). Deze metingen zijn eerst verricht op het levende dier door middel van de Rice pelvimeter 12 uur voordat de dieren werden geslacht, en vervolgens op het karkas door middel van een meetlat 2 uur na het slachten. Het gemiddelde verschil tussen de levende en de karkas metingen was -0,2 cm voor de bekkenbreedte (95% limits of agreement -2,5 - 2,1 cm) en 1,2 cm voor de bekkenhoogte (95% limits of agreement -1,8 - 4,1 cm). De pelvimetrisch gemeten bekkenbreedte was groter dan deze gemeten op het karkas, terwijl voor bekkenhoogte de pelvimetrisch gemeten maten kleiner waren. De leeftijd van de dieren bleek alleen significant geassocieerd te zijn met de bekkenhoogte, terwijl het karkas gewicht invloed had op alle drie bekkenmetingen. Er bestond een significante correlatie tussen de metingen verkregen met de Rice pelvimeter en de metingen op het karkas (0,46 - 0,59; $P < 0{,}001$). Hieruit blijkt dat de Rice pelvimeter geschikt is om een accurate meting te doen van het inwendige bekken van een BWB dier en dus gebruikt kan worden voor de selectie naar grotere bekkens.

In **Paragraaf 5.2** wordt beschreven hoe de Rice pelvimeter gebruikt kan worden, naast andere meettoestellen, om de gemiddelde waarden en de variatie te bepalen van de bekken- (zowel in- als uitwendig) en lichaamsmaten van BWB dieren in België. Deze gegevens zijn verzameld bij dieren die zowel via een KS als op een natuurlijke manier verlost waren. Bij 507 BWB dieren is de schofthoogte, de borstomtrek, de afstand tussen beide *tubera coxae* (heupbeenderen), de afstand tussen beide *tubera ischiadica* (zitbeenknobbel) en inwendige bekkenmaten (bekkenbreedte, bekkenhoogte, bekkenoppervlak) gemeten en zijn de leeftijd en het partus type geregistreerd. De afstand tussen beide *tubera coxae* bedroeg

58,9 ± 6,2 cm, de afstand tussen beide *tubera ischiadica* was 14,6 ± 2,3 cm en de bekkenbreedte, -hoogte en -oppervlakte bedroegen respectievelijk 15,2 ± 2,1 cm, 18,8 ± 1,9 cm en 288,5 ± 60,9 $cm^2$. Er werd een significante positieve associatie aangetoond tussen het type kalving en de schofthoogte ($P < 0{,}05$), de afstand tussen de beide *tubera coxae* ($P < 0{,}05$), de bekkenhoogte en het bekkenoppervlak ($P < 0{,}001$). Natuurlijk kalvende BWB dieren hadden grotere lichaams- en bekkenmaten in vergelijking tot BWB dieren die met een KS hadden afgekalfd. De afstand tussen beide *tubera coxae* bleek een hogere correlatie te hebben met de inwendige bekkenmaten (r =0,58 - 0,63) dan de afstand tussen beide *tubera ischiadica* (r = 0,22 - 0,28). Verrassend genoeg blijken de correlaties tussen de andere lichaamsmaten (de schofthoogte en de borstomtrek) en het inwendige bekken groter te zijn (r =0,69 - 0,74; voor borstomtrek en r = 0,67 - 0,74; voor schofthoogte). De resultaten tonen aan dat er variatie aanwezig is in de bekkenmaten van BWB dieren en dat er dus ruimte is voor selectie naar een grotere bekkeningang. Inwendige bekken- en in mindere mate uitwendige lichaamsmaten kunnen gebruikt worden in een selectieprogramma.

Sinds lang is bekend dat het geboortegewicht en de grootte van het kalf de belangrijkste parameters zijn die de geboorteproblematiek beïnvloeden. Omdat het BWB ras een vleesras is dat gekenmerkt wordt door een extreme bespiering, is het denkbaar dat de potentie voor een natuurlijke geboorte eerder afhangt van de specifieke conformatie van BWB kalveren, dan van het geboortegewicht. Om dit te onderzoeken en om aan te tonen welke lichaamsmaten bepalend zijn voor een het al dan niet optreden van een natuurlijke geboorte, zijn er verschillende lichaamsmaten (geboortegewicht, lichaamslengte, lengte van het hoofd, schouderbreedte, achterhandbreedte, borstomtrek, schofthoogte en de omtrek van de kogel van voor- en achterpoot) genomen van 147 BWB kalveren vlak na de geboorte (**Paragraaf 5.3**). Daarnaast zijn in deze studie de gemiddelden en de variaties van deze lichaamsmaten bepaald om te zien of selectie mogelijk was. Het gemiddelde geboortegewicht bedroeg 49,2 ± 7,1 kg, de lengte van het lichaam was 56,4 ± 4,5 cm en de lengte van het hoofd 24,4 ± 2,3 cm. De schouder- en achterhandbreedte waren respectievelijk 22,4 ± 2,2 cm en 22,9 ± 2,1 cm, terwijl de gemiddelde schofthoogte 71,1 ± 4,7 cm bedroeg. De kogelomtrek van de voorpoot was 17,9 ± 1,1 cm, de kogelomtrek van de achterpoot was 18,0 ± 1,0 cm en de borstomtrek bedroeg 78,0 ± 5,4 cm. Partiële correlaties tussen het geboortegewicht en de acht lichaamsmaten waren significant ($P$ < 0,01) en bevonden zich tussen 0,17 - 0,85, 0,42 - 0,88 en de 0,24 - 0,88 gecorrigeerd voor respectievelijk geslacht, pariteit en het partus type. De lengte van het lichaam ($P$ < 0,01) en de beide kogelomtrekken ($P$ < 0,001) bleken groter te zijn bij stierkalveren dan bij vaarskalveren. Daarnaast bleek dat kalveren geboren met een KS bredere schouders ($P$ < 0,01) en een bredere achterhand ($P$ < 0,01) hadden dan kalveren die natuurlijk geboren waren. Ook waren de schouder- en de achterhandbreedte groter bij kalveren geboren uit koeien dan bij kalveren geboren uit vaarzen. Omdat deze laatste twee lichaamsmaten de breedste maten zijn bij een BWB kalf, worden ze beiden geacht limiterende factoren te zijn voor een normale kalving. Alleen bij vaarskalveren kon worden aangetoond dat de achterhandbreedte het meest limiterend is, terwijl er op de totale dataset en bij de stierkalveren geen significant verschil tussen schouder- en achterhandbreedte aanwezig bleek te zijn ($P$ > 0,05). De significante variaties aanwezig binnen een aantal lichaamsmaten en de sterke correlatie tussen deze maten doet vermoeden dat het mogelijk is te selecteren naar kleinere kalveren om zo de geboorteproblematiek te verminderen. Daarnaast is er met de verkregen resultaten een model opgesteld waarmee de schouder- en de achterhandbreedte geschat kunnen worden op het moment van de partus aan de hand van de lengte van het hoofd en de omtrek van de kogel. Samen met informatie over enerzijds de grootte van de bekkeningang van het individuele moederdier en anderzijds het geslacht van het kalf, moet een veehouder of dierenarts in staat zijn om de kans op een natuurlijke kalving meer accuraat te voorspellen.

In het vierde deel van dit hoofdstuk (**Paragraaf 5.4**) is onderzocht hoe groot de wanverhouding is tussen de koe en haar kalf door de gemiddelde schouder- en achterhandbreedte van BWB kalveren te vergelijken met de gemiddelde bekkenhoogte van BWB koeien. Daarnaast zijn ook individuele koe-kalf combinaties op meetkundig vlak met elkaar vergeleken. De gemiddelde bekkenhoogte bedraagt 18,8 ± 1,9 cm met een minimum en maximum van respectievelijk 11,0 en 23,0 cm. Vergeleken met een gemiddelde schouderbreedte van 22,4 ± 2,2 cm en een achterhandbreedte van 22,9 ± 2,1 cm, blijkt dat meetkundig gesproken een gemiddeld BWB kalf te groot is om de bekkeningang van een gemiddelde BWB koe te passeren. Echter, deze resultaten tonen ook aan dat de grootste koeien (met een BH van 23,0 cm) wel degelijk in staat zijn een gemiddeld BWB kalf natuurlijk ter wereld te brengen. Bij een vergelijking van de individuele koe-kalf combinaties, blijkt dat meer dieren (koeien zowel als vaarzen) natuurlijk hadden afgekalfd dan meetkundig kon worden uitgerekend, wat niet alleen intrigerend is maar ook hoopvol voor de selectie naar een vermindering van de afkalfproblematiek. Daarnaast suggereert dit feit ook dat er zeer waarschijnlijk naast het bekken van de moeder en de breedte van het kalf, nog andere factoren een rol spelen bij de afkalfproblematiek, bijvoorbeeld de invloed die de partus zelf uitoefent op de bekkeningang. Om dit te onderzoeken is de invloed van zowel een KS als een natuurlijk kalving onderzocht op de bekkenbreedte, de bekkenhoogte en het bekkenoppervlak door deze metingen uit te voeren 1 maand vóór, binnen 24 uur na en 1 maand na de partus. De resultaten hiervan tonen aan dat BWB dieren die met een KS hadden afgekalfd, in vergelijking tot 1 maand vóór de partus een significant grotere bekkenhoogte hadden binnen 24 uur na de partus (0,45 cm; $P < 0,05$), en dat dit effect niet aantoonbaar was voor de bekkenbreedte en het bekkenoppervlak. BWB dieren die natuurlijk hadden gekalfd, vertoonden echter een significant verschil in alle drie de bekkenmaten gemeten op 24 uur na de partus in vergelijking tot 1 maand vóór de partus (bekkenhoogte: 1,42 cm; [$P < 0,001$)]; bekkenbreedte: 0,53 cm [$P < 0,05$] en bekkenoppervlak: 35,64 $cm^2$ [$P < 0.001$]). Dus naast de grootte van het bekken van de moeder en de schouder- en achterhandbreedte van het kalf, speelt bij het BWB ras ook de partus zelf een rol in het geboortegemak.

Om de zeldzame gevallen te verklaren waarbij het kalf natuurlijk is geboren niettegenstaande dit theoretisch onmogelijk werd geacht, aangezien de schouder- en/of achterhandbreedte van het kalf groter was dan de bekkenhoogte van de moeder, is een andere factor – namelijk de vorm van de bekkeningang – onderzocht die mogelijk ook een rol speelt bij de individuele partus (**Paragraaf 5.5)**. Daartoe is de bekkenhoogte (BH) vergeleken met de diagonale bekkenhoogte (linker diagonale bekkenhoogte [LDBH] en rechter diagonale bekkenhoogte [RDBH]) van 87 BWB koeien. Hieruit bleek dat er een significant verschil bestaat tussen de bekkenhoogte en zowel de linker als de rechter diagonale bekkenhoogte ($P < 0,001$; verschil BH - LDBH: -0,43 cm; verschil BH - RDBH: -0,45 cm). Er bestond geen significant verschil tussen beiden diagonale bekkenhoogten. Voor individuele dieren kan deze 0,4 cm een klein verschil uitmaken bij de beslissing of een natuurlijke kalving al dan niet mogelijk is. De elliptische vorm van de bekkeningang kan dus een mogelijke verklaring zijn voor die zeldzame gevallen waarbij het kalf toch natuurlijk wordt geboren niettegenstaande dit theoretisch onmogelijk was geacht.

In **Hoofdstuk 6** worden de resultaten bediscussieerd. Uit de resultaten van het onderzoek beschreven in dit proefschrift kunnen de volgende conclusies getrokken worden:

1. BWB dieren ervaren significant minder zware complicaties tijdens een KS in vergelijking met niet BWB dieren. Bij dieren die al een KS gehad hebben, bestaat er een verhoogd risico op complicaties. Ervaren dierenartsen hebben minder last van complicaties tijdens het uitvoeren van de operatie.

2. BWB koeien die een routine KS ondergaan hebben, vertonen een enigszins ander gedrag dan koeien die op een natuurlijk manier hebben afgekalfd. Dit andere gedrag wijst op pijn of ongemak maar is subtiel en van korte duur.

3. Pelvimetrie is een geschikt hulpmiddel bij de selectie naar grotere bekkens bij koeien van het BWB ras en dus naar minder geboorteproblemen. Er bestaat een goede overeenkomst tussen de metingen met de Rice pelvimeter en die rechtstreeks gemeten op het karkas.

4. De variatie in zowel de bekkenmaten van de koe als in de lichaamsmaten van het kalf, samen met de bestaande hoge erfelijkheidsgraden voor deze kenmerken, toont aan dat selectie naar een vermindering van het aantal KS binnen het BWB ras mogelijk is.

5. Het verschil in de bekkenhoogte van de koe en de breedte van haar kalf bij BWB dieren die natuurlijk hadden afgekalfd in is vergelijking tot BWB dieren die een KS hadden ondergaan slechts gering. Dit is bemoedigend voor de selectie naar natuurlijke geboorten binnen het BWB ras, aangezien een deel van de populatie qua bekkenmaten (BWB koe) en lichaamsmaten (BWB kalf) al min of meer geschikt blijkt te zijn om normaal te kalven.

6. Wat de individuele partus betreft, blijkt dat naast de grootte van bekkeningang en de breedte van het kalf, zowel de elliptische vorm van de bekkeningang als de partus zelf een belangrijke rol spelen bij het geboorteproces. Deze laatste 2 factoren kunnen een mogelijke

verklaring vormen voor die zeldzame gevallen waarbij het kalf toch op een natuurlijke wijze wordt geboren terwijl de schouders en/of de heupen breder zijn dan de bekkenhoogte van de moeder en de partus dus theoretisch niet had kunnen plaatsvinden.

# DANKWOORD

Een dankwoord, pfff een hele opgave. Niet wetenschappelijk te onderbouwen en meteen het meest gelezen deel van mijn doctoraat. Het meest gevreesde van dit onderdeel vind ik het vergeten mensen te bedanken, dus wil ik me meteen al verontschuldigen moest het onvermijdelijke gebeuren. Ik dacht altijd een doctoraat maken, dat is niets voor mij, maar toch ben ook ik ten onder gegaan. Ik moet bij deze bekennen: ik heb er van genoten!!! Ik ben heel blij met de vele kansen en vrijheid die ik gekregen heb aan deze vakgroep, de contacten en vrienden die ik heb gemaakt en de hilarische momenten die ik heb mogen meemaken tijdens de diensten op de buitenpraktijk en tijdens de vele feestjes. Aan al deze momenten hebben de meeste van de onderstaande mensen bijgedragen, dus daar gaan we…..

Allereerst mijn twee promotoren, Geert en Dirk, allebei onvergetelijke maar totaal verschillende personen. In onwillekeurige volgorde zal ik dan beginnen met Geert. Nadat ik al een half jaar als intern rond huppelde op de buitenpraktijk was jij het (samen met Sarne) die mij bij je riep om eens te praten over de toekomst. Ik was blij dat je toch toekomst in me zag en ik vertelde je dat de keizersnede en onderzoek op dat gebied mij wel aansprak. Jij kwam met het super idee te solliciteren op een 50% PWO project van de KaHo Sint Niklaas over de afkalfproblematiek in het Belgisch Witblauw en je zorgde voor de andere 50%. In de tijd die daarop volgde heb ik je heel wat grijze haren bezorgd – denk ik – aangezien ik vaak te onverzorgd en te snel wilde gaan, vooral bij het schrijven van mijn artikelen. Toch stond je in deze periode voor me klaar en heb je me veel geholpen met mijn artikelen. Nog extra bedankt om mij door het 'doctoraats walhalla' te loodsen aan het eind en voor het snelle lezen en de altijd opbeurende commentaren, zonder jou had ik het niet gered. Maar ook aan het naar congressen gaan met jou heb ik nog veel goede herinneringen: het dansen en de "naakt" sauna (???) in Slovenië en de etentjes in Nice.

Dirk, ook jou wil ik bedanken voor de super mogelijkheid die je me gegeven hebt aan de KaHo Sint Lieven. Ik kan me de sollicitatie nog herinneren. Je vroeg of ik gelovig was. Met het schaamrood op mijn kaken moest ik bekennen dat ik wel Rooms Katholiek opgevoed was, maar al lang niet meer naar de kerk ging. Ondanks dat heb je me een kans gegeven. Ik hoop dat ik je project naar behoren heb uitgevoerd. Hoe irritant ik het vond dat je me in het begin plat belde, zo erg heb ik dat de laatste twee jaar gemist. Tijdens de trip naar Engeland heb ik ook je zorgzame en vaderlijke kant mogen leren kennen en hebben we zelfs nog samen gefilosofeerd (ik wist niet dat ik het in me had ☺!). Ik hoop dat we, ondanks dat ik niet bij de KaHo kom werken, toch nog een hele fijne samenwerking mogen hebben in de toekomst.

Als derde mijn copromotor, Geert Hoflack, de echte BWB/vleesvee man van de faculteit!!! Die mocht natuurlijk niet ontbreken in de begeleidings/examencommissie van mijn doctoraat. Geert, ik ben heel blij dat ik je heb leren kennen en heb heel veel van je geleerd tijdens de bedrijfsbezoeken en de vele uren die we samen hebben gevaccineerd. Die vaccinatie uren, waren voor mij ideale momenten om je te bestoken met moeilijke vragen betreffende mijn artikelen, patiënten en bedrijven die ik had gezien en natuurlijk voor jou om weer een beetje mee te zijn met de laatste roddels van de vakgroep. Buiten één van de meeste verstandige ben je ook een van de meeste chaotische mensen die ik ken en qua organisatie kun je nog iets van mij leren, hahaha! De vaccinatie uren zullen zich nog voortzetten neem ik aan, dus zullen we elkaar nog veel gaan zien.

Dan voor mij de allerbelangrijkste mensen die ik wil bedanken – sorry promotoren en copromotor – maar dat zijn toch wel de veehouders die hebben willen meewerken aan mijn doctoraat. In het bijzonder de familie Lips, de familie Watté, Ludo Jamaer en de "mannen van het ILVO". Vanaf het moment dat ik met mijn proeven begon, heb ik de deur plat gelopen bij de familie Lips en zij hebben me altijd met open armen ontvangen. Hoe druk ook met het werk, zij hadden altijd tijd voor een kopje koffie!! Met de maandelijkse vaccinaties en als het meten eens uit liep, stond Agnes altijd klaar met haar maaltijd niet alleen voor mij maar ook voor de studenten. Door de jaren heen ben ik me echt thuis gaan voelen bij jullie en zijn jullie zelfs een beetje 'familie' geworden. Bedankt voor alles!!!!!! Jolien, ik ben blij dat ik je heb leren kennen en ondanks de 10 jaar leeftijdsverschil klikte het vanaf het begin. Ik hoop dat we elkaar niet uit het oog zullen verliezen en wens je heel veel succes met je rundvee/boomkweek carrière. De familie Watté moet ik ook bedanken voor alle hulp met het vangen van de dieren en de lekkere soep en boterhammen. Ik zal de maandelijkse uitstappen in de zomer niet gauw vergeten waar Luc samen met Eric met zijn beestenkar van Lotenhulle naar Zwalm kwam gereden, waar we dan samen met Johan en Paul de weiden afgingen, 'alleen maar' voor mijn proeven. Ook Eric wil ik daarvoor bedanken. Dan Ludo Jamaer, een heel bijzondere persoon, ik ben blij dat ik jou heb mogen leren kennen. Jij bent degene die de helft van mijn doctoraat heeft mogelijk gemaakt, aangezien 30-40% van jouw BWB natuurlijk kalft. Hierdoor hebben we veel proeven op jouw bedrijf kunnen doen en heb ik met de observaties heel wat uurtjes tussen jouw koeien door gemaakt. In het begin was je wat nukkig en wat tegendraads, maar ik denk dat ook jij Ludo heel blij bent dat we er waren en je het toch stiekem best gezellig vond. Ik hoop dat je hebt genoten van de trip naar Engeland. Bedankt Ludo, en ga vooral door met je eigen visie!!! De mannen van het ILVO: Piet, Eric, Luc, Geert DP, Geert D, Robert, Bart S, Renaat, Martin en Paul mag ik natuurlijk ook niet vergeten. Ook daar ben ik vanaf 2006 maandelijks geweest om metingen te doen. Elke eerste maandag van de maand, zomer en winter, stonden de mannen weer voor me klaar met hetzelfde enthousiasme. Tijdens deze uren werd dan natuurlijk het weekend besproken en mijn BCS en gewicht bijgehouden ☺! Familie Gillis bedankt dat ik jullie dieren mocht gebruiken voor mijn laatste proef en voor de gastvrijheid. Tenslotte wil ik de rest van alle veehouders bedanken waar ik altijd met open armen ben ontvangen zowel in België als in Nederland. Ik heb veel van deze bezoeken geleerd en de mogelijkheid gehad om de vele mooie plekjes van Vlaanderen en Nederland te mogen ontdekken.

Professor de Kruif, dankzij u heb ik de kans gekregen om te werken aan de vakgroep. Na mijn sollicitatie op de plaats van Steven (waarvan ik nog altijd blij ben dat die naar Mirjan is gegaan), heeft u me als intern aangenomen op uw dienst. U hebt altijd van de zijlijn toegekeken, maar was er wel als het nodig was. Ook bedankt voor de steun aan het eind en het zeer kritisch nalezen van mijn artikelen en mijn doctoraat. Sarne, jou wil ik bedanken voor het begeleiden van het keizersnede gedeelte van dit doctoraat, door jouw precisie en inzet zijn mijn eerste artikelen goed van de band gerold (ondanks mijn 'steenkolen' Engels).

Professor Richard Murray I want to thank you for critically reading the articles about pelvimetry and of course evaluating my whole PhD. And thanks for the invitation on your University last year. Prof. Bert Van der Weyden en Prof. Eddy Decuypere verdienen een dankjewel voor hun motiverende opmerkingen en het lezen van mijn doctoraat en ook Dr. Ignace Moyaert en Ing. Pierre Mallieu bedankt voor de kritische noot tijdens de vergaderingen. Rest mij nog de andere leden van mijn examencommissie te danken: Dr. Peter Mijten, Prof. Piet Deprez, Prof. Lieven Vlaminck, Prof. Sarne De Vliegher hartelijk dank voor jullie nuttige opmerkingen in de eindfase van mijn onderzoek.

Ook zijn er verschillende andere mensen die naast de begeleidingscommissie waardevolle of praktische hulp voor mijn onderzoek boden. Kristof Van Damme wil ik bedanken voor de vele uren die we samen hebben doorgebracht in het slachthuis. Op de donderdagavond in het donker en de kou toch de moed vinden om met me mee te gaan en te schrijven, wat soms voor aangename verassingen zorgde (koeien die ergens in slachthuis neerliggen in het donker …..). Natuurlijk dan ook Lieven Boone, de directeur van het slachthuis, die het heeft mogelijk gemaakt dat we mochten komen in zijn slachthuis in Velzeke om überhaupt de metingen te doen. En dat we nog altijd welkom zijn met de studenten om rectaal onderzoek te oefenen. Leo Fiems, dankzij jou kreeg ik de kans op het ILVO mijn maandelijkse metingen te doen en ook later als ik met vragen of proeven aankwam, heb je me altijd geholpen. Ook zijn er verschillende thesisstudenten die ik moet bedanken voor het uitwerken van onderdelen van dit proefschrift. Boudewijn heeft samen met mij de enquêtes van de complicaties doorgeworsteld, Jeroen heeft uren maar dan ook uren geobserveerd, Mayo en Gunther zijn het hele land doorgeweest om kalveren te gaan meten en Kristof heeft mij bewezen dat pelvimetrie heel gemakkelijk aan te leren is. Bedankt allemaal voor jullie inzet! Ook Leen Moerman en Karen Van der Sypt bedankt voor het meegaan op maandelijkse meetmaandagen.

Dan de Buitenpraktijk, een onvergetelijke groep mensen bij elkaar. Om te beginnen mijn twee surrogaat papa's Jef en Marcel. Jef, jouw rust en kalmte en vertrouwen hebben mij heel veel geholpen in de eerste jaren dat ik mee draaide in de buitenpraktijk. Onze band was volgens mij al ontstaan toen ik nog student was en jij, na vakkundig uitgelegd te hebben hoe gevaarlijk een klauwkapkar is, toch de hendel in je gezicht kreeg. Resultaat een

vloekende Jef (op zich al een unicum) en een gat in de wang waaraan ik de eerste hulp heb toegediend. Later heb ik altijd op jou kunnen vertrouwen als ik in moeilijkheden zat en vond/vind ik onze operatietripjes altijd een plezier. Marcel, jij en ik zijn samen onze ‘loopbaan’ aan de faculteit begonnen en ook al ging het niet zo soepel in het begin, toch heb je vrij snel mijn ‘hart’ gestolen en ik denk ik ook het jouwe….. Ik ben heel blij veel van je geleerd te hebben en nog altijd mag leren en ook stiekem een beetje trots dat ik jou toch ook nog iets heb kunnen bijbrengen. Ook Claire bedankt voor de leuke trip naar Budapest samen en de hartelijke ontvangsten en ik hoop nog lang jullie ‘surrogaat dochter’ te mogen zijn. Stefaan wil ik persoonlijk bedanken voor de vele uren die hij mij geholpen heeft met mijn thesis voor het vakdierenarts diploma en mijn doctoraat, voor de menige diensten die hij van me heeft overgenomen en al de literatuur die altijd binnen de dag op mijn email kwam binnen rollen. Natuurlijk ook het feit dat je er altijd voor me was voor een raad, een etentje en een praatje.

In de eerste jaren van de buitenpraktijk zijn er jammer genoeg al vele collega’s zijn vertrokken waaronder Dirk B, Bart, Geert H., Steven V., Leen VD., Hans, Boudewijn, Tom V., Jo L., Nele G., Leen M. en Tim C., allemaal stuk voor stuk hele fijne collega’s die ik nog af en toe een beetje mis. Maar gelukkig zijn er toen die tijd veel nieuwe voor in de plaats gekomen: Steven C (die buurtkroegentocht zal er niet meer inzitten nu je vertrekt, snik, snik), Philippe (zeer gewaardeerde loopcollega en slachthuis maatje, veel succes volgende week ☺, en succes in je carrière), Emily DB, Sofie en Karlien (de supermeiden van het M-team, hoop nog veel met jullie te mogen samenwerken!). De “jonge” nieuwe spruiten in de buitenpraktijk, Wendy en Cyriel, heel erg bedankt voor het overnemen van de diensten aan het einde van mijn doctoraat en ik wens jullie heel veel succes. Ik hoop dat we een toffe tijd te gemoed gaan (met veel lebmagen, hè, Wendy). En Cyriel, ik eis natuurlijk een revance.

Miel en Sebastiaan, mijn twee stapmaatjes, altijd bereid voor een goed gesprek en een raad en daad onder het genot van een pint (en een wijntje voor mij). Sebi, ik hoop stiekem dat je hier nog een beetje blijft hangen (Buitenpraktijk varken, misschien?). Miel, merci voor alle ondersteuning, en hoop nog veel van je te mogen leren!

Ria & Els bedankt voor de goede ondersteuning in de Buitenpraktijk en voor de vele gesprekjes tussendoor! Hetzelfde geldt voor de stalknechten Willy, Dirk & Wilfried, leuk jullie tegen te komen als ik naar mijn patiënten ging kijken. Bedankt ook Nadine (voor alle praktische regelingen), Marnik, Veronique, Steven B (voor de layout), Petra & Isabelle, Leïla, maar ook Nicole (de vrolijke noot in onze propere gangen). Marc C. bedankt voor alles op het laatste nippertje nog te willen lezen.

De hardwerkende kliniek paard collega's mag ik uiteraard ook niet vergeten: Jan, Maarten, Catharina, Katrien S. & Kim. En natuurlijk, mijn (nu ex) huisgenootje van het aflopen jaar Emilie VH. Ik vond het super om met je te mogen samen wonen en heb echt genoten van de overheerlijke kookkunsten (en de rest natuurlijk). Ik wens je het allerbeste in je nieuwe "avontuur" en ben er zeker van dat je dat heel goed gaat doen!!!!

Al mijn andere collega's wil ik ook bedanken voor hun bijdrage aan de super 5 jaar aan de vakgroep. Josine, Jo B, Muriel en Mirjan mijn paardrij maatjes, het heerlijke wekelijkse tussendoortje van het afgelopen jaar. Sarah, Davy (nog super bedankt voor de verhuis), Tom R., Caroline, Iris V., voor de gesprekken tussendoor; de ex-collega's: Nele E. (jammer van vlekje), Bianca (Finland was de max!), Nathalie (je mag nog altijd bellen voor keizersneden bij jullie thuis ☺), Jo V. (een zeergewaarde KaHo collega geweest en heel veel geluk met Rob), Lotte, Inès, Margit, Katrien M., , …. waarschijnlijk ben ik er hier en daar nog vergeten!

Ook mijn collega's aan de KaHo Sint Lieven mag ik niet vergeten. In het bijzonder wil ik Stef, Jo en Hilde bedanken voor de fijne samenwerking in al die jaren en dat jullie altijd voor me klaar stonden ondanks het feit dat ik niet vaak in Sint Niklaas te zien was. Tijdens de praktijk weken heb ik genoten van het enthousiasme waarin mijn collega's het onderwijs proberen over brengen naar de studenten. Elk jaar tijdens het kerstfeest was het altijd fijn weerzien met de rest en waren jullie altijd heel geïnteresseerd in de vorderingen van mijn doctoraat. Ook dank aan Leonel en Inge voor de inbreng tijdens de vergaderingen van de begeleidingscommissie van het PWO project. Hugo Verbeke wil ik bedanken voor zijn hulp met alle administratieve rompslomp van het PWO project en de latere IWT aanvragen. Annemieke Van Bocxelaer bedankt voor de personeelsondersteuning en later

Hans Laevens die me zeer goed geholpen heeft bij het statistisch doorworstelen van de laatste drie artikelen.

Geert Verhoeven mag ik in dit rijtje zeker niet vergeten. Bedankt Geert voor de fijne jaren samen en voor al het geduld dat je met me had en de steun die je me hebt gegeven. Ook nog super bedankt voor het plaatje in mijn artikel en de mooie foto die nu op de voorkant staat te pronken ……!

Mijn vriendinnen van mijn studie tijd, maatjes voor het leven, jullie wil ik bedanken voor de fijne tijd tijdens mijn studie en nu nog altijd. Jullie hebben engelen geduld en ik hoop dat ik nu wat meer tijd ga hebben om jullie te komen bezoeken. Thaampje, succes met Menze en je nieuwe baan. Es, succes met je eventuele associatie en ik wacht op het goede nieuws….. Maart, ook succes met je associatie en heel veel geluk in het komende huwelijk. San en Sarah, ook veel geluk aan jullie toegewenst met de 'nieuwe' lovers en het werk.

Loes, bedankt dat je er voor me was.

Papa, bedankt voor de fijne jeugd die ik heb gehad en de steun die je me hebt gegeven. Mama, het was jij die zei dat ik optie Rund moest kiezen omdat het zo goed bij me paste. Je had gelijk, ik heb geen seconde spijt gehad van mijn keuze. Ik hoop dat je nu met een trotse glimlach naar beneden kijkt! Ik mis je nog elke dag!

Finaal wil ik nog een woordje wijden aan een heel belangrijke persoon in mijn leven, mijn broer Marcel. Broertje, vroeger was je altijd al mijn speelkameraadje. Samen hebben we heel wat doorworsteld en ik wil je bedanken voor al je steun die je me gegeven hebt in de afgelopen jaren. Nu met je 'nieuwe' vriendin Marianne zie ik hoe je bent open gebloeid en hoe je van het leven geniet en dat doet me deugd! Ik ben trots op je, grote broer!

**Iris**

# CURRICULUM VITAE

Iris Kolkman werd geboren op 25 januari 1979 te Lichtenvoorde (Nederland). Na het behalen van het diploma hoger secundair onderwijs (HAVO en VWO) aan het Marianum College te Groenlo, begon zij in 1998 met de studie Diergeneeskunde aan de Universiteit Antwerpen. Na 3 kandidatuurjaren begon ze in 2001 aan de proefjaren in Gent. Zij behaalde haar diploma van Dierenarts, Optie herkauwers aan de Ugent in 2004 met onderscheiding.

Op 1 oktober 2004 trad zij, als intern van het European College of Bovine Health Management (ECBHM) in dienst van de Buitenpraktijk van de Vakgroep Voortplanting, Verloskunde en Bedrijfsdiergeneeskunde. Vanaf 1 mei 2005 werd zij voor 50% aangenomen op een PWO project van de KaHo Sint Lieven in Sint Niklaas. De andere 50% was zij werkzaam als assistent in de Buitenpraktijk. In totaal heeft zij gedurende 5 jaar onderzoek verricht naar afkalfmogelijkheden binnen het Belgisch Witblauw ras. Iris participeerde in deze periode ook in de dag-, nacht- en weekenddiensten van de Buitenpraktijk. Daarnaast volgde zij een 3 jaar durend Residentie programma van het ECBHM. Deze opleiding werd succesvol afgerond in augustus 2009 waarbij zij de "Diplomate" titel behaalde. Eveneens heeft ze in 2009 het postgraduaatdiploma „Vakdierenarts Rund" behaald met grote onderscheiding. Haar scriptie met als titel: "Bedrijfsbegeleiding van het Belgisch Witblauw ras" werd beloond met de Boehringer Ingelheim prijs. In 2009 voltooide zij eveneens de Doctoraatsopleiding in de Diergeneeskundige Wetenschappen.

Iris Kolkman is auteur of medeauteur van 16 publicaties in internationale en nationale wetenschappelijke tijdschriften en was spreker op 5 internationale en verscheidene nationale congressen.

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- Aerts S, **Kolkman I**, Vervaecke H, Vicca J and Lips D 2006. Animal welfare differences between Caesarean Section and natural delivery in Belgian Blue cattle. In: M. Kaiser & M. Lien (eds.). Ethics and politics of Food. Preprints of the 6th congress of the European Society for Agricultural and Food Ethics, Oslo, June 22-24, 2006. Wageningen Academic Publishers, Wageningen, 495-499.

# MONDELINGE PRESENTATIES OP NATIONALE EN INTERNATIONALE CONGRESSEN (1E AUTEUR)

2006

- **Kolkman I** 2006. Caesarean Section. Workshop 7th Middle European Buiatrics Congress, Radenci, Slovenia, 15 April 2006.
- **Kolkman I** 2006. Complications during and after Caesarean Sections in daily bovine practice. Workshop 7th Middle European Buiatrics Congress, Radenci, Slovenia, April 2006.
- **Kolkman I** 2006. Caesarean Section: Complications during Caesarean Section in Belgian Blue. World Buiatric Congress, Nice, France, 19 October 2006.

2007

- **Kolkman I** 2007. Pelvic area – possibility for natural parturition within the Belgian Blue Breed. Workshop Natural calving, Vught, The Netherlands, 25 January 2007.

2008

- **Kolkman I** 2008. Caesarean Section: fixation and technique. Workshop World Buiatric Congress, Budapest, Hungary, 5 January 2008.
- **Kolkman I** 2008. Assessment of pain perception in double muscled Belgian Blue cows following delivery per vaginam versus Caesarean Section. WAFL congress, Ghent, Belgium, 11 September 2008.

# POSTER PRESENTATIES OP NATIONALE EN INTERNATIONALE CONGRESSEN (1E EN COAUTEUR)

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- **Kolkman I**, Vicca J, Vercauteren I, Snauwaert E, Hoflack G and Lips D 2006. Comparison of ruminal development in Belgian-blue-beef calves reared on different feeding methods. Congress poster World Buiatrics Congress, Nice, France, 16-20 October 2006.

- Van De Look J, Vervaecke H, Aerts S, **Kolkman I**, Vicca J and Lips D 2006. Behavioural indicators of pain in Belgian White-Blue cattle: base-line observations. Congress ISAE International Society for Applied Ethology, Bristol (UK), 8-12 August 2006.

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- **Kolkman I**, De Vliegher S, Laureyns J, Van Aert M and Opsomer G 2007. Difficulties encountered during elective Caesarean Section in the bovine. 40th British Cattle Veterinary Association Congress, 22-24 November 2007.

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- **Kolkman I**, Hoflack G, Aerts S, Opsomer G and Lips D 2008. Assessment of the efficacy of the Rice pelvimeter by comparing pelvimetric measurements with measurements on the carcass after slaughter of double muscled Belgian Blue cows. WAFL, 10-12 September 2008.

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- **Kolkman I**, Hoflack G, Laevens H, Lips D and Opsomer G 2009. Factors influencing dystocia in the phenotypically double muscled Belgian Blue breed. ESDAR, 10-12 September 2009.

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- **Kolkman I**, De Vliegher S, Hoflack G, Van Aert M, Laureyns J, de Kruif A and Opsomer G 2006. Caesarean Section. Slovenian Veterinary Research, Proceedings of the 7th Middle European Buiatrics Congress, 329 (abstract).

- **Kolkman I**, De Vliegher S, Hoflack G, Van Aert M, Laureyns J, de Kruif A and Opsomer G 2006. Complications during and after Caesarean Sections in daily bovine practice. Slovenian Veterinary Research, Proceedings of the 7th Middle European Buiatrics Congress, 330 (abstract).

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- Vandelook J, Vervacke H, Aerts S, Kolkman I, Vicca J and Lips D 2006. Behavioural indicators of pain in Belgian White-Blue cattle. Proceedings of the 40th International Congress of the ISAE, International Society for Applied Ethology, Bristol (UK), 8-12 August 2006.

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- **Kolkman I,** Aerts S, Vervaecke H, Vicca J, Vandelook J, de Kruif A, Opsomer G and Lips D 2008. Assessment of pain perception in double muscled Belgian Blue cows following delivery *per vaginam* versus Caesarean Section. WAFL, 10-12 September 2008.