Bovine Neonatal Survival – Is Improvement Possible?

John Mee

Teagasc, Animal and Bioscience Research Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland
Email: john.mee@teagasc.ie

Take Home Messages

- Poor bovine neonatal survival rates are an international welfare issue
- This issue is often not recognized at national or at farm-level; recording needs to be improved
- Improving bovine neonatal survival requires re-prioritization of this issue
- Stakeholders need to be made aware of this re-prioritization
- Actions to effect change need to occur at both national and farm-levels
- National-level actions need firstly to address raising awareness of the issue
- Farm-level actions need to focus on identifiable problem farms through targeted surveillance
- Application of existing knowledge to alter modifiable risk factors is the key to improvement

Introduction

Bovine neonatal survival – is improvement possible? The answer to this rhetorical question is - in theory - yes, but the inconvenient truth is - in practice - often, no. This dichotomous answer hints at the enigmatic discord between what is theoretically possible and what actually occurs in practice. Though this view may conflict with perceived thinking, evidence for this divergence can be found in the disparity between bovine neonatal survival rates (in the first two days of life) internationally and between results from research studies and farm-level data. For example, dairy calf neonatal survival rates in some countries, e.g. Norway, are amongst the highest in the world; in contrast to those in many North American Holstein-Friesian-dominated dairy industries. Whereas experimental and observational studies have identified critical risk factors for improved neonatal survival the results from such studies are not always replicated at farm level. In fact the reverse has occurred in recent years, with a decrease in bovine neonatal survival rates reported in the peer-review literature from many countries around the world.

Unfortunately this decline in neonatal survival has not attracted the same degree of interest or research funding as the well documented decline in dairy cow ‘fertility’, of which it is an adjacent problem. The reason for the lack of improvements in neonatal survival stems from de-prioritisation of the issue relative to other animal health and welfare concerns. This has resulted in less funding of research work with consequent downstream atrophy of knowledge metastasis through extension and implementation programmes. There are knowledge gaps constraining progress towards improved neonatal survival requiring more transdisciplinary research including the ‘omic’ technologies. However, re-prioritisation of neonatal survival as an important welfare deficiency signal, often by the retail arm of the food industry, and better communication of existing knowledge are of greater importance in reversing current trends.

Perinatal mortality may be defined as fetal death prior to, during, or within 48 hours of calving, following a gestation period of at least 260 days, irrespective of the cause of death or the circumstances related to calving (Mee, 2008). The perinatal period is the most hazardous in the life of all animals. Approximately 75% of perinatal mortality occurs within one hour of calving with the remainder occurring either pre- (10%) or post-partum (15%). Some 90% of calves, which die in the perinatal period, were alive at the start of calving and so much of this loss is preventable.

▪ Epidemiology of Bovine Perinatal Mortality

Incidence of Perinatal Mortality

Currently, the average incidence of perinatal mortality in cows and heifers varies between 2 and 20% across dairy industries internationally with the majority of countries between 5 and 8% (Table 1). The variation between national agricultural statistical data averages reflects differences in definitions of perinatal mortality but more importantly, emphasises the differences between those countries which have practised a long-term policy of genetic selection against undesirable functional traits and those which have pursued single trait selection policies and associated dairy breed differences. The most worrying incidence data are those from the US, as these genetics are exported around the world and could influence rates in almost all dairy industries worldwide. The data in Table 1 also highlight the lack of conformity in recording of perinatal mortality and the definitions used to describe it; the need to standardise such definitions is self-evident when attempting to make valid international comparisons.

These average national figures obscure the fact that herd-level statistics follow a right skewed distribution where most herds have none or minimal losses but some herds have 20 to 30% perinatal mortality (Mee et al., 2008; Vernooy et al., 2007). Thus, even within countries with a relatively low incidence rate, problem herds exist. Despite the best efforts of farmers and their veterinarians to manage calving and newborn calves successfully, perinatal mortality can be a perennial problem on some farms yet only occur sporadically on others. Currently there is little research on the causes of this wide inter-herd variation in stillbirth rates and why certain herds have persistent problems and others do not; well designed transdisciplinary studies are warranted.

Table 1. Prevalence of perinatal calf mortality in dairy heifers and cows in 20 countries internationally (2000-2011).

Country	Breed of dam	Heifers (%)	Heifers and cows (%)	Definition of calf mortality
Australia	Holstein-Friesian	10.8	5.1	Death within 48 hours of a singleton calving
Austria	Holstein-Friesian	8.7	5.9	Death within 48 hours of calving
Canada	Holstein-Friesian	9.0	9.6 [a]	Dead at birth
Denmark	Holstein-Friesian	9.0	NR [b]	Death within 24 hours of calving
Germany	Holstein-Friesian & HFx Blackpied	NR	9.3	Death within 24 hours of calving
Iceland	Indigenous	16.0	15.0	Stillbirth
India	Jersey	NR	3.8	Foetal death
Israel	Holstein-Friesian	7.2	5.0	Death within 24 hours of calving
Iran	Holstein-Friesian	4.3	3.5	Death within 1 hour of calving
Ireland	Holstein-Friesian	7.7	4.3	Death within 24 hours of calving
France	Holstein-Friesian & Normande	NR	7.4	Death within 24 hours of calving

Hungary	Holstein-Friesian	12.3	9.3	Death within 24 hours of calving
The Netherlands	Holstein-Friesian	11.4	6.9	Death within 24 hours of a singleton calving
New Zealand	Holstein-Friesian, Jersey and their crosses	7.4	7.2	Death within 48 hours of calving excluding inductions.
Norway	Norwegian Red	3.0	2.0	Death within 24 hours of calving
Portugal	Holstein-Friesian, Montbelliarde, Swedish Red	NR	20.0	Death within 48 hours of calving
Sweden	Swedish Red	3.6	2.5[a]	Death within 24 hours of a singleton calving
Switzerland	Dairy, Beef & Crossbreeds	5.9	2.4	Death within 24 hours of calving
UK	Holstein-Friesian	10.9	5.3	Death within 48 hours of a singleton calving
USA	Holstein-Friesian	12.1	8.0	Dead at birth

[a] cows only, [b] not recorded.

Temporal Trends in Perinatal Mortality

Recent published studies in Denmark, The Netherlands, North America and Sweden indicate that the prevalence of perinatal mortality is increasing, particularly in Holstein heifers (Meyer et al., 2001; Steinbock et al., 2003). Much of this increase has been attributed to North American Holstein introgression, or introduction of particular Holstein sires' genes, into indigenous cattle populations. The resultant calves have a longer gestation length, are larger and heavier at birth, suffer more difficult calving and consequently are at greater risk of perinatal mortality (Hansen et al., 2004; Steinbock et al., 2003). Dutch data suggest half of the increase in stillbirth in first calvers is attributable to genetics and the rest to changes in management (Van Pelt and De Jong, 2011). Recently Brickell et al. (2009) reported that stillbirth rates had changed very little on UK dairy farms in the past 10 years, and at 8% now accounted for over twice as much calf mortality as neonatal losses.

Risk Factors for Perinatal Mortality

The majority of perinatal mortality has been attributed directly to difficult calving particularly in heifers which frequently require assistance at calving. Parity has been shown to be the best predictor variable for perinatal mortality followed in heifers by difficult calving and in older cows by difficult calving and gestation length (Meyer et al., 2000). Other significant animal-level factors, also common to difficult calving, include age at first calving, particularly in heifers less than 24 months old (Benjaminsson, 2007), twinning (Silva del Rio et al., 2007), fetal gender (Steinbock et al., 2003), shorter or longer gestation length (Meyer et al., 2000) and sire predicted transmitting ability (PTA) for perinatal mortality (Mee et al., 2008). In recent years, the interplay between genotypic and environmental risk factors has received more scientific attention. Crossbreeding studies have now illustrated the differences in perinatal mortality between different dairy and dual purpose breeds (Heringstad et al., 2007). The increase in perinatal mortality with increasing proportion of Holstein-Friesian genes in both the calf and in the dam has been demonstrated (Hansen et al., 2004). In addition, the role of inbreeding as a significant risk factor for perinatal mortality has only recently been documented, and though the effects are small and mainly confined to heifers, they were consistently unfavorable.

Significant herd-level risk factors for perinatal mortality include herd (Silva del Rio et al., 2007), year (Johanson and Berger, 2003), season of calving (Johanson and Berger, 2003), larger herd size (Gulliksen et al., 2009) and calving management (Vernooy et al., 2007). While deficiencies of micro-nutrients (iodine, selenium, copper and zinc) have been associated with high stillbirth rates (Murray et al., 2008; Enjalbert et al., 2006), results from randomised clinical trials do not necessarily support a causal relationship (McCoy et al., 1997; Mee et al., 1995). Excess body condition prior to calving, particularly in heifers (Chassagne et al., 1999), has been associated with reduced appetite as calving approaches with resultant mobilisation of fat reserves; also it may reduce magnesium availability, and the ensuing sub-clinical hypocalcaemia could produce uterine atony which is observed clinically as ‘slow calving syndrome’ where fetal death occurs in the absence of difficult calving (non-visible difficult calving).

Management of calving plays a critical role in perinatal mortality in dairy or beef herds (Mee, 2008). For example, increased duration of second stage calving beyond two hours, poor abdominal contractions, use of mechanical calf pullers and changes in the calving supervision all increase significantly the risk of perinatal mortality (Hoedemaker et al., 2008).

In addition to these accepted risk factors, there is now evidence that an increasing proportion of perinatal mortality occurs at unassisted calvings where placental dysfunction and low birth weight may be causative factors

(Benjaminsson et al., 2007; Berglund et al., 2003). Idiopathic stillbirth or weak calf syndrome is particularly associated with heifer calvings.

Causes of Perinatal Mortality

The major proximate causes of perinatal mortality are trauma and anoxia as a consequence of difficult calving (traumotocia and bradytocia), and, to a much lesser extent, congenital defects, infections and other causes (Table 2). The variation in the proportions of necropsy-diagnosed causes of death reflects variations in the causative risk factors such as difficult calving (Mee et al., 2011) but also variations in diagnostic definitions and the number and selection criteria for calves and herds examined.

Traumatic lesions found in stillborn calves associated with difficult calving include fractured ribs (13-23%), fractured spine (3-25%), fractured legs (2%), diaphragmatic tears (4%), hepatic rupture, and collapsed trachea (Schuijt, 1990). Anoxic lesions, often found following clinical difficult calving and 'non-clinical difficult calving' (clinically undetectable prolonged or abnormal stage one or two of calving), include pulmonary atelectasis, scleral, epicardial, endocardial and meningeal petechiation, meconium aspiration syndrome (MAS) and meconium staining or passage (Schuijt, 1992). Meconium staining of the coat has been recorded in 16-30% of vaginally and caesarean-derived calves and occurs more often where death is preparturient, gestation is prolonged, birthweight is heavier and the calf is female or of a beef type (Mee, 2012; Schuijt, 1992). Unfortunately, calves dying following acute anoxia often have unremarkable gross pathological findings.

Perinatal mortality following easy or normal calving or 'weak calf syndrome' may be associated with intrauterine growth retardation (IUGR), prematurity with surfactant deficiency, congenital defects, infections, precalving nutrition, dysmaturity, twins, placental dysfunction or sire-specific genetic weakness. Prolonged stage one with premature placental separation, prolonged stage two with uterine atony, nitrate toxicity and accidents also contribute to easy calving stillbirth. Premature placental separation is associated with premature birth and maldisposition (Mee, 1991). Anecdotally, pharmacological induction of calving, excessive selenium supplementation and subclinical hypocalcaemia have also been implicated.

Table 2. Necropsy-diagnosed causes of death (%) for calves dying in the perinatal period internationally (2000-2011).

Country	Calves (No.)	Difficult calving	Anoxia	Congenital defects	Infection	Other	Not determined
Canada*	560	40.2	NR**	4.3	2.9	31	21.6
Finland	148	43	***	10	10	8	29
Germany	87	0	NR	11.5	8	NR	NR
Iceland	129	34	37	NR	12	13	3.9
Ireland	40	35	5	12.5	0	38	10
Netherlands	180	***	41	4.4	6.6	5.6	48
Sweden	76	46.1	NR	5.3	2.6	10.5	35.5
USA	60	25	28.5	3.3	5	6.6	31.6

*Beef calves; all others are dairy calves, **NR=not recorded, *** Anoxic and difficult calving lesions combined

Respiratory distress syndrome (RDS) in calves has conventionally been associated with prematurity. However, recent research indicates that RDS in mature Belgian Blue calves may be associated with trace element deficiency-induced surfactant insufficiency; specifically, deficiencies of selenium, copper, zinc and iodine (Guyot, 2008). Classical deficiency of trace elements, for example selenium, is still associated with high perinatal mortality rates in individual herds, particularly in heifers (Murray et al., 2008).

Despite these findings, recent research indicates that the proportion of perinatal mortality in both dairy and beef breeds attributable to difficult calving and other traditionally diagnosed causes of perinatal mortality may be decreasing (Muskens, 2008; Berglund et al., 2003). A recent pilot study in Dutch dairy herds failed to link high perinatal losses with these traditional causes (Muskens, 2008). Recent Swedish research indicates that increased perinatal mortality in Holstein-Friesian heifers cannot be attributed to increases in difficult calving and that calf vitality may be a critical factor (Gustafsson et al., 2007). A genetic predisposition has been posited due to the large variation in perinatal mortality in the daughters of different sires. Further investigations suggested placental dysfunction may explain such genetic differences (Kornmatitsuk et al., 2004). In addition, the possibility of undetected intra-uterine infection causing chorioamnionitis and fetal mortality cannot be discounted (Stefaniak et al., 2010).

In many cases the cause is undetermined. Diagnostic rates in veterinary laboratories are often less than 25% indicating the need for a new approach to perinatal loss investigation (Mee, 2010). Additionally, as the incidence of idiopathic perinatal mortality appears to be increasing there is a need for renewed research focus on this cohort of calves to determine the modifiable risk factors and cause of this syndrome. A clear case definition, intensive anamnestic, clinical and pathological investigation, generation of plausible hypotheses and testing of such tentative diagnoses in designed, prospective, multisite, population-based field trials will lead to a clearer understanding of the causation of this syndrome. The role of evidence-based veterinary medicine (EBVM) here is self evident.

▪ Is Improvement Possible?

Re-Prioritization Is Needed

Before significant improvements in perinatal mortality can occur the issue needs to be re-prioritised. By this I mean the stakeholders must view it as a problem worth doing something about. In the absence of this clarity of vision drift will continue. The first issue to address is ‘farm blindness’ whereby high perinatal mortality rates are ‘normalised’ and the farmer becomes blind to the issue. For example, a recent Norwegian study showed that farmers underestimated the incidence of calf diseases by 40% (Gulliksen et al., 2009) and a Canadian study has shown that farmers can underestimate loss rates by up to 50% and there is a very poor correlation (r=0.01) between actual and perceived loss rates. In addition, the majority (94%) of farmers did not consider calf mortality to be a problem even though the average loss rate at birth was 8.8% (Vasseur et al., 2010). Social science research is warranted. In addition, there can be significant under-recording of calving problems in national databases (Mork et al., 2009), partly due to reluctance by farmers to report or discuss the issue with their veterinarian (Svensson et al., 2008). In North America, highly variable recording of stillbirth between farms has been attributed to the voluntary recording systems in use (Henderson et al., 2011). So, reliable recording is central to improved calf survival; “*if you can’t measure it you can’t monitor it.”*

Once the industry recognizes the problem they then need to put it in perspective. Recent UK data show that the loss rates in the perinatal period are more than twice as great as those in all other periods of the animal’s life (Brickell et al., 2009). In addition, there has been enormous effort poured into getting cows in calf but very little effort devoted to getting the calf out alive, without which the former work is nullified. It is perhaps unfortunate that calving is a means, not an aim; dairy farmers get paid to produce milk and not live calves…but this is changing…

Good Animal Welfare Pays

Whether the agricultural stakeholders act to reduce perinatal mortality or not by their own volition, action may be forced on them by the retail multiples. Large international retailers, conscious of the attitudes and opinions of their consumers are beginning to act to encourage their farmer suppliers to improve animal welfare, including perinatal mortality. For example, in 2011 a large UK retailer (Tesco) notified its milk suppliers that under its new welfare code of practice it would be requesting them to record calving performance (including difficult calvings and perinatal mortality). Presumably they will then act on this information when purchasing milk thus correcting the vision of suppliers with farm blindness about the link between good animal welfare (for example lower perinatal mortality) and farm profit. Similarly, another UK retailer (Marks & Spencer) does not accept beef from Belgian Blues because of the high Caesarean rate in purebreds and the welfare image that presents to the consumer (O'Kane, 2011). In Sweden a 'welfare deficit' index, which includes stillbirths, has been successfully used to identify dairy herds with poor animal welfare (Sandgren et al., 2009).

Raising Awareness

Without proactive national awareness, action will be incoherent or possibly forced upon the industry. There is a critical role for extension in creating awareness and in knowledge metastasis. Raising awareness is predicated upon a national knowledge infrastructure involving field extension officers, veterinary organizations, and farmer organizations and farming media support. National awareness campaigns have been successfully used to highlight adjacent problems such as poor cow fertility (In-Calf, Australia) and mastitis (CellCheck, Ireland). Recently (2011), national initiatives have been launched in the UK and in Ireland to highlight and to address the issues surrounding calf health. In the UK the National Youngstock Association has been established as a forum to tackle losses in cattle youngstock. A national calf health campaign (CalfCare) has been launched in Ireland through the national animal health organization (Animal Health Ireland). This campaign is operated through an expert technical working group which produces stakeholder needs analysis and current practices surveys, peer-review publications (e.g. Lorenz et al., 2011), technical leaflets, media releases and service provider and farmer conferences and roadshows.

Acting Nationally

At the national level stakeholders can improve neonatal survival by 1) creating awareness, 2) funding relevant research, 3) altering their genetic selection policy and 4) by addressing endemic infectious diseases impacting calf health. Genetic tools to improve neonatal survival nationally include composite genetic selection indices, encouraging crossbreeding, reducing inbreeding depression and developing genomic selection for calving/calf trait-associated QTLs. Internationally examples exist where genetic selection to improve neonatal survival has been occurring successfully for decades, e.g. Norway (1978), or has recently been introduced, e.g. Ireland (2005). Currently calving traits account for 10.3% of the overall emphasis in the Irish Economic Breeding Index (EBI) (www.icbf.com). National control programmes for endemic infectious diseases have recently gained significant momentum internationally. For example, a national BVD eradication programme is launching in Ireland in 2012 (www.ahi.ie) which should significantly impact calf health.

Role of Research

There are a few foci of veterinary scientists active internationally, including in Canada, who will continue to produce advances from breeding to birth contributing to our understanding of bovine neonatology. Likely future breeding developments include the greater use of genomic selection, exploiting the recently mapped bovine genome, to breed for reduced difficult calving and stillbirth using sharper phenotypes. Gestational advances include use of biomarkers to detect placental dysfunction and ultrasonographic monitoring of fetal size and heart rate. Prepartum developments include vitality assessments of the fetus and its annexes and parturient ethograms combined with point-of-care sensor technologies to accurately predict onset of calving. Intrapartum developments include continuous fetal monitoring during calving to detect reduced vitality. Refinement of current perinatal therapeutic protocols will assist resuscitation of compromised neonates and improve periparturient maternal pain management. Development of a more forensic necropsy protocol will increase our understanding of the ‘unexplained stillbirth’ phenomenon. While the development of cloned calves has added application impetus to this research, many of these technologies are currently not directly transferrable to general practice.

Farm-Level Improvements

At the farm level the application of existing knowledge by practicing veterinarians and extension professionals is where most progress can be made. A recent international survey found that veterinary practitioners attributed the incidence of perinatal mortality primarily to the availability, skills and education of farmstaff (Mee, 2009). There was unanimity amongst respondents regarding the action farmers could take to reduce its incidence: better calving management. This included supervision of the late pregnant cow prior to and during calving, use of correct obstetrical techniques, modern calf resuscitation methods and critically, calling the veterinary practitioner at the correct time. When asked how the veterinary practitioner could reduce perinatal mortality rates, respondents agreed that veterinary practitioners needed to focus on client education related to calving management. This is an often neglected area of a stockman's education, particularly on large farms, which has been shown to be successful in improving neonatal survival (Schuenemann et al., 2011). Focus on modifiable risk factors will effect change, e.g. age-at-first freshening, body condition score pre calving, gestational nutrition, dry period length, sire choice, preventing prolonged gestation, disease control, calving management and investigation of perinatal losses. Less progress will be made with less modifiable risk factors, e.g. breed, parity, season of calving, cow:labour unit ratio, fetal gender and twin pregnancies.

It's A Problem Farm Problem

Once the stakeholders decide to act to improve neonatal survival they need to focus effort. The skewed distribution of perinatal loss rates means that inter-herd variation in loss must be identifiable. Once problem herds, for example, those in the top quartile of loss rates, can be identified (through targeted surveillance) they must be investigated through farm-level collection of a herd history and examination of records, examination of the pregnant animals, and assessment of calving management and collation of necropsy and laboratory findings. These are multi-disciplinary tasks involving data recording organizations, practicing and laboratory veterinarians and extension professionals.

■ Conclusions

High perinatal mortality rates remain an international problem though this is often not recognized at national or at farm-level. Improvement in calf survival rates is dependent upon re-prioritization of this problem relative to other animal health and welfare issues and creation of awareness of this prioritization. Once the problem is recognized action needs to be taken at national and at farm levels, specifically on problem farms. Data recording, research, breeding, veterinary, extension and farmer organizations all have a role to play in improving neonatal survival and hence improving animal welfare.

■ References

Benjaminsson, B. H. 2007. Prenatal death in Icelandic cattle. Acta Vet. Scand. 49 (Suppl 1):S16.

Berglund, B., L. Steinbock, and M. Elvander. 2003. Causes of stillbirth and time of death in Swedish Holstein calves examined post mortem. Acta Vet. Scand. 44:111-120.

Brickell, J. S., M. McGowan, D. Pfeiffer, and D. C. Wathes. 2009. Mortality in Holstein-Friesian calves and replacement heifers, in relation to body weight and IGF-I concentration, on 19 farms in England. Animal 3: 1175-1182.

Chassagne, M., J. Barnouin, and J. P. Chacornac. 1999. Risk factors for stillbirth in Holstein heifers under field conditions in France: a prospective survey. Theriogenology 51:1477-1488.

Enjalbert, F., P. Lebreton, and O. Salat. 2006. Effects of copper, zinc and selenium status on performance and health in commercial dairy and beef herds: retrospective study. J. Anim. Physiol. and Anim. Nutr. 90:459-466.

Gulliksen, S.M., K.I. Lie, and O. Osteras. 2009. Calf health monitoring in Norwegian dairy herds. J. Dairy Sci. 92: 1660-1669.

Gustafsson, H., H. Kindahl, and B. Berglund. 2007. Stillbirths in Holstein heifers – some results from Swedish research. Acta Vet Scand. 49 (Suppl. 1):S17.

Guyot, H. 2008. Contribution to diagnosis and correction of iodine and selenium deficiencies in cattle. DSV Dissertation, University of Liege, Belgium, p.1-125.

Hansen, M., M.S. Lund, J. Perersen, and L.G. Christensen. 2004. Genetic parameters for stillbirth in Danish Holstein cows using a Bayesian threshold model. J. Dairy Sci. 87: 706-716.

Henderson, L., F. Miglior, A. Sewalem, D. Kelton, A. Robinson, and K. Leslie. 2011. Estimation of genetic parameters for measures of calf survival in a population of Holstein heifer calves from a heifer-raising facility in New York State. J. Dairy Sci. 94: 461-470.

Heringstad, B., Y. Chang, M. Svendsen, and D. Gianola. 2007. Genetic analysis of calving difficulty and stillbirth in Norwegian Red cows. J. Dairy Sci. 90: 3500-3507.

Hoedemaker, M., Y. Gundelach, and K. Essmeyer. 2008. Increased frequency of stillbirth in a Holstein-Friesian herd: observations on calves. Proc. 25th World Buiatrics Congress, Budapest, Hungary. p.198-199.

Johanson, J.M., and P.J. Berger. 2003. Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. J. Dairy Sci. 86: 3745-3755.

Kornmatitsuk, B., E. Dahl, E. Ropstad, J. F. Beckers, H. Gustafsson, and H. Kindahl. 2004. Endocrine profiles, haematology and pregnancy outcomes of late pregnant Holstein dairy heifers sired by bulls giving a high or low incidence of stillbirth. Acta Vet. Scand. 45: 47-68.

Lorenz, I., J.F. Mee, B. Earley, and S. More. 2011. Calf health from birth to weaning. I. General aspects of disease prevention. Ir. Vet. J. 64:10.

McCoy, M. A., J. A. Smyth, W. A. Ellis, and D. G. Kennedy. 1997. Experimental reproduction of iodine deficiency in cattle. Vet. Rec. 141: 544 - 547.

Mee, J.F. 1991. Premature expulsion of the placenta and bovine perinatal mortality. Vet. Rec. 128: 521-523.

Mee, J.F. 2008. Newborn dairy calf management. Vet. Clin. North Am. Fd. Anim. Pract. 24:1-17

Mee, J.F. 2009. Bovine perinatology: Current understanding and future developments. Chapter 2. In: Dahnof L.T. (editor). Animal Reproduction: New Research Developments, Nova Science Publishers, Inc., New York, p. 67-106.

Mee, J.F. 2010. The current causes of bovine perinatal mortality – a new diagnostic perspective. Proc. 26th World Buiatrics Congress, Santiago, Chile, p.51.

Mee, J.F. 2012. Bovine neonatology – Current understanding and future prospects. Vlaams Dier. Tijd. (in press).

Mee, J.F., D. Berry, and A. R. Cromie. 2008. Prevalance of, and risk factors associated with, perinatal calf mortality in pasture based Holstein-Friesian cows. Animal 2: 613-620.

Mee, J.F., D. Berry, and A. R. Cromie. 2011. Risk factors for calving assistance and difficult calving in pasture-based Holstein-Friesian heifers and cows in Ireland. The Vet. J. 187: 189-194.

Mee, J.F., P. A. M. Rogers, and K. J. O'Farrell. 1995. Effect of precalving feeding of a mineral-vitamin supplement before calving on the calving performance of a trace element-deficient dairy herd. Vet. Rec. 137:508-512.

Meyer, C.L., P. J. Berger, and K. J. Koehler. 2000. Interactions among factors affecting stillbirths in Holstein cattle in the United States. J. Dairy Sci. 83: 2657-2663.

Meyer, C.L., P. J. Berger, K. J. Koehler, J. R. Thompson, and C. G. Sattler. 2001. Phenotypic trends in incidence of stillbirth for Holsteins in the United States. J. Dairy Sci. 84: 515-523.

Mork, M., A. Lindberg, S. Alenius, I. Vagsholm, and A. Egenvall. 2009. Comparison between dairy cow disease incidence in data registered by farmers and in data from a disease-recording system based on veterinary reporting. Anim. Reprod. Sci. 88: 298-307.

Murray, R.D., A. J. Williams, and I. M. Sheldon. 2008. Field investigation of perinatal mortality in Friesian cattle associated with myocardial degeneration and necrosis. Reprod. Dom. Anim. 43: 339-345

Muskens, J. 2008. Stillbirth in heifers: Experiences in the Netherlands. Proc. 25th World Buiatrics Congress, Budapest, Hungary, p.320-321.

O'Kane, B. 2011. The stabiliser cattle breeding system. Proc. Cattle Veterinary Association of Veterinary Ireland, Cork, Ireland.

Sandgren, C., A. Lindberg, and L. Keeling. 2009. Using a national dairy database to identify herds with poor welfare. Anim. Welf. 18: 523-532.

Schuenemann, G.M., S. Bas, E. Gordon, and J. Workman. 2011. Dairy calving management: Assessment of a comprehensive program for dairy personnel. J. Dairy Sci. 89 (E-Suppl. 1): 483.

Schuijt, G. 1990. Iatrogenic fractures of ribs and vertebrae during delivery. Perinatally dying calves: 235 cases (1978-1988). JAVMA. 197: 1196-1202.

Schuijt, G. 1992. Aspects of obstetrical perinatology in cattle. Proefschrift, Universiteit Utrecht, The Netherlands. p. 101-121.

Silva del Rio N., S. Stewart, P. Rapnicki, Y. M. Chang, and P. M. Fricke. 2007. An observational analysis of twin births, calf sex ratio, and calf mortality in Holstein dairy cattle. J. Dairy Sci. 90: 1255-1264.

Stefaniak, T., P. Jawor, M. Bednarski, J. Twardon, J. Bajzert, and O. Sitnik. 2010. Weak calf syndrome caused by chorioamnionitis and fetal inflammatory response syndrome (FIRS). Proc. XXVI World Buiatrics Congress, Santiago, Chile, 248.

Steinbock, L., A. Näsholm, B. Berglund, K. Johansson, and J. Philipsson. 2003. Genetic effects on stillbirth and calving difficulty in Swedish Holsteins at first and second calving. J. Dairy Sci. 86: 2228-2235.

Svensson, C., C. Sandgren, J. Carlsson, T. Svensson, M. Tornquist, and K. de Verdier. 2008. There is a need for veterinary involvement in calf rearing, but how will they gain admission? Sven. Vet. 60: 19-22.

Van Pelt, M. and G. De Jong, 2011. Genetic analysis of calf vitality in Dutch dairy cows. Proc. 62nd EAAP Conference, Stavanger, Norway, 126.

Vasseur, E., J. Rushen, A. M.,de Passille, D. Lefebvre, and D. Pellerin. 2010. An advisory tool to improve management practices affecting calf and heifer welfare on dairy farms. J. Dairy Sci. 93: 4414-4426.

Vernooy, E., K. Leslie, D. Kelton, K. Hand, B. Muir, and T. Duffield. 2007. Management risk factors associated with stillbirth. Proc. AABP. 40: 222.