Perinatal mortality in the pig: environmental or physiological solutions?

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Abstract

The evolutionary strategy adopted by the pig is to produce a large number of relatively undeveloped offspring. Such a strategy demands that relatively little investment is made in each individual piglet pre-natally, and that piglets which are surplus to resources should die at an early stage with least prejudice to their littermates. Thus, inherent variation in neonatal competitiveness is an advantage and survival of the strongest is promoted. Genetic selection strategies resulting in increased litter size and reduced physiological maturity at birth have compounded these effects, making piglet mortality an intractable problem. Records of piglet mortality in commercial units indicate that most deaths of liveborn piglets are attributed to crushing and starvation, but these ultimate causes are often secondary to the effects of perinatal hypothermia. Piglet survival is the outcome of complex interactions between the sow, the piglet and the environment. Commercial strategy has focused on improving the farrowing environment to modify sow behaviour and increase human intervention. However, concerns about the welfare implications of confining sows in farrowing crates may limit the use of such approaches in the future and change the focus towards genetic selection for characteristics in both the dam and offspring which promote survival. Methods of improving the inherent viability of the piglet, for example by increasing birth weight, neonatal vigour and thermoregulatory ability, have been commercially less effective to date, with intra-partum hypoxia exerting an overwhelming influence. A better understanding of neonatal and maternal physiology in relation to placental transfer of nutrients, regulation of the parturition process, colostrum transfer and expression of appropriate maternal behaviour is required for the development of effective future solutions.

Keywords: Pig; Neonate; Mortality

1. Introduction

This paper reviews the background to perinatal mortality in pigs under commercial conditions and explores the solutions which have been, or might be, implemented to improve piglet survival. The evolutionary strategy adopted by the pig is to produce a large number of relatively undeveloped...
offspring. After birth, these offspring compete for maternal resources with the least able failing to survive unless conditions are very favourable. This situation has been compared to that of ‘avian facultative siblicide’ (Fraser et al., 1995), in which several species of birds produce more eggs than the number of chicks normally reared. Later hatching chicks are normally killed by their stronger sibling, and only raised successfully if competition is reduced by exceptional food abundance or the early death of this sibling. Such a strategy allows the mother to modify the degree of peri- and post-natal maternal investment in accordance with the prevailing food supply and to produce the optimal number of viable weaned offspring. Unlike the avian example, where food is gathered and delivered daily to the chicks, the investments in fetal growth, mammary development and milk production by the sow are dependent on a complex, longer-term interaction between the level of maternal body reserves and current feed intake. However, an inadequate food supply in the period prior to farrowing will result in reduced piglet birth weight, reduced mammary cell number and reduced potential for milk production (Pluske et al., 1995), setting up the conditions for increased neonatal mortality. Similarly, whilst milk output in the first week of lactation depends on pre-farrowing nutrition, reduced feed availability during lactation can modify milk output after this time (Mullan and Williams, 1989). However, to be effective, an evolutionary strategy based on differential mortality of excess offspring demands that relatively little investment is made in each individual piglet pre-natally, and that piglets which are surplus to resources should die at an early stage with least prejudice to their littermates. Thus, inherent variation in neonatal competitiveness is an advantage and perinatal mortality of the weakest piglets is promoted. A level of piglet mortality of 10–20% can therefore be considered normal for the reproductive biology of the pig and has been selected for as an optimal evolutionary strategy. Against this background, it is not surprising that relatively recent (in species evolution terms) attempts to reduce mortality under domestic conditions have yielded limited success.

When looking at historical data it can be seen that, over the last 15 years of UK commercial herd recording, little reduction in the total percentage of pre-weaning mortality has been made (Fig. 1). Prior to this time, major improvements in survival of liveborn piglets resulted from improvements in housing and management, but the relatively small improvements in this parameter since the mid-1980s have been offset by a corresponding rise in the proportion of stillbirths. A similar picture can be seen in many other countries.

Thus, continued recent improvements in number weaned per litter have been largely a consequence of increased total born rather than reduction in mortality. This, in turn, has increased the challenges in maintaining piglet survival. It is well established that the probability of survival decreases with increasing

Fig. 1. Trends in pre-weaning piglet mortality in UK commercial herds recording with the MLC Pigplan Scheme (MLC Pig Yearbooks 1985–2001).
litter size (e.g. Dyck and Swierstra, 1987; Roehe and Kalm, 2000), as a result of the associated reduction in individual birth weight and greater degree of competition for teat access. This has been coupled with additional detrimental effects of genetic selection strategy for increased lean tissue growth rate and reduced body lipid content, resulting in piglets with reduced physiological maturity at birth (Herpin et al., 1993). Against this background it is not surprising that piglet mortality has proved to be an intractable problem in commercial production.

2. Causes of perinatal mortality

In seeking to address a problem, the starting point should be to understand its causation. There have been many surveys of the reasons for piglet mortality in commercial herds. Stillbirths generally account for 4–8% of all pigs born (English and Edwards, 1996), or ~30–40% of the total mortality. Amongst deaths of liveborn piglets, typical commercial results, as shown in Fig. 2, suggest that crushing is by far the major cause (Easicare, 1995). However, survey results of this nature must be treated with extreme caution. The first problem lies with the unreliability of farm diagnosis of cause of mortality. In studies where farm attribution has been compared with detailed post mortem analysis, it is apparent that many deaths are misdiagnosed. In data from one outdoor herd, 42% of piglets believed to have been stillborn were subsequently proven to have died from other causes (Edwards et al., 1994). Similar demonstration of the unreliability of producer-recorded causes of death, with incorrect diagnosis of stillbirths and overestimation of crushing, was found in a study of 13 American herds (Vaillancourt et al., 1990).

Fortunately, supporting data derived from a UK study in which all piglets were subject to post mortem analysis (Riart et al., 2000) indicate that the general conclusions derived from the commercial database are valid (Fig. 3).

However, a second problem with true interpretation of such data lies with the chronological understanding of events. What is recorded as the ultimate cause of death may be only the final act in a chain of events, triggered by some other causal factor. This was most clearly demonstrated in the behavioural study of English (1969) who maintained detailed longitudinal records on individual piglets. This clearly showed that although many piglets were finally killed by crushing, they had been predisposed to this by failure to achieve regular and adequate intake of food. Thus starvation was attributed as the primary cause in 43% of deaths, whereas crushing of otherwise healthy piglets accounted for only 18% (En-
english and Smith, 1975). Piglets which are malnourished spend more time in proximity to the sow and are hence more at risk (Weary et al., 1996). Furthermore, these incidences of starvation are often secondary to, and interactive with, the effects of perinatal hypothermia, rendering piglets more lethargic (Stephens, 1971), less competitive at the udder and less likely to achieve good colostrum intake and immune status (Kelley, 1985). These factors in turn are influenced by the extent of hypoxia at birth. Piglets which died before 3 weeks of age were found to have a 25% higher blood lactate level at birth, indicative of pre-natal hypoxia, than those which survived (English and Smith, 1975). In more recent studies, degree of asphyxia was inversely related to piglet viability score, speed of first suckling, rectal temperature at 24 h of life and survival over the first 10 days (Herpin et al., 1996).

Piglet survival is therefore the outcome of complex interactions between the sow, the piglet and the environment (Fig. 4), and single attributions are hard to find.

![Fig. 3. Causes of mortality determined by post mortem analysis of piglets from indoor (N = 121 litters) and outdoor (N = 93 litters) farrowing systems (from Riart et al., 2000).](image)

![Fig. 4. Interactive events occurring in the chilling-starvation-overlying-disease complex (modified from English and Morrison, 1984).](image)
3. Environmental solutions and their limitations

Perception of the major role of crushing in piglet mortality led to development of systems to control sow movement and the widespread introduction of the farrowing crate. Studies have repeatedly shown improved piglet survival in systems providing such sow restraint (Edwards and Fraser, 1997). Whilst this is often attributed to modification of maternal crushing movements, it can be argued that in reality the benefit of a farrowing crate has been that it allows better environmental provision to be made for the newborn piglet. Thus supplementary heat can be provided close to the site of birth to minimise risk of hypothermia, with substantial reduction in mortality (Morrison et al., 1983). Furthermore, the crate facilitates easy and safe human intervention to assist the farrowing process and the establishment of weaker piglets. Such human interventions in the peripartal period have been shown to reduce mortality by as much as 44% (White et al., 1996).

However, these environmental solutions now require reconsideration for both ethical and economic reasons. Sophisticated farrowing accommodation is expensive to provide, but often gives no better piglet survival than seen in relatively cheap and unsophisticated outdoor farrowing systems, which incorporate no sow confinement or supplementary heat input (e.g. total piglet mortality was 19.6% and 16.3% in indoor and outdoor systems respectively amongst herds recording with the UK Pigplan scheme in 1999; MLC, 2000). As public concerns about intensive farming increase, use of the farrowing crate is increasingly being questioned. It has been demonstrated that confinement at the time of strong nest building motivation, immediately prior to parturition, results in physiological stress in the sow (Lawrence et al., 1994). The recent EU requirement that all sows must be loose-housed during the majority of gestation by 1 January 2006 (Directive 2001/88/EC) may exacerbate stress resulting from subsequent confinement in a farrowing crate (Boyle et al., 2000). Furthermore, public pressure to increase weaning age for welfare reasons makes it less economic to invest in such specialised lactation housing, introducing the need to simplify and cheapen systems or to incur additional labour costs in two-phase lactation housing systems. Such trends will be further promoted by evidence that close confinement with the piglets in later lactation may introduce further stress on the sow (Cronin et al., 1991). Thus, ethical considerations have led to a move to replace the farrowing crate by less restrictive systems, and economic considerations may exert similar pressures in the future. At the present time, any move to adopt less sophisticated indoor farrowing environments is restrained by the higher piglet mortality typically observed in such systems (Edwards and Fraser, 1997). Consequently, there is a growing pressure to refocus attention away from environmental control systems to the biology of the animal, and to seek to improve the maternal ability of the sow and the inherent viability of the piglets.

4. Animal focused solutions

There are many good reasons to believe that biological approaches will prove fruitful in reducing piglet mortality. Great variation in survival between litters is seen within a constant environmental background; Fraser (1990) highlighted the fact that deaths are not randomly distributed amongst litters, and this effect appears to be even more pronounced in less restrictive farrowing systems. However, there are limited data on consistency of individuals across parities for this characteristic. It is well-known that different breeds differ in survival characteristics (e.g. Lee and Haley, 1995; Roehe and Kalm, 2000). More formal genetic analyses within breed have yielded variable heritabilities of 0.05–0.10 (Van Arendonk et al., 1996; Rothschild and Bidanel, 1998). This subject is reviewed in more detail elsewhere (Knol et al., 2002), but the presence of a genetic component to survival indicates that variation exists in some key physiological mechanisms which might be amenable to manipulation. An initial attempt to use this approach to identify key physiological parameters was not enlightening. Increased piglet survival associated with increasing estimated breeding values (EBVs) for direct effects on this parameter could not be explained by differences in the progress of farrowing, improved birth weight, early postnatal behaviour or rectal temperature within 24 h after...
birth (Leenhouwers et al., 2001). However, a high genetic correlation of survival and gestation length in one study is of interest (Hanenberg et al., 2001). Further investigation must take account of both direct and indirect (maternal) genetic effects on survival, since both show some degree of heritability (Van Arendonk et al., 1996).

5. Neonatal physiology

Looking first at aspects of neonatal physiology which might influence piglet survival, a useful starting point is to identify the individual risk factors associated with mortality. Many studies have highlighted the role of birth weight, position in the birth order, speed of first suckling and ability to resist hypothermia (e.g. Hoy et al., 1997; Tuchscherer et al., 2000). Clearly, these factors relate to the ability to maintain body temperature for a long enough period to achieve positive energy balance through establishment of regular and adequate nutrient intake. Physiological aspects of thermoregulation in the neonatal piglet have been studied in detail and are reviewed elsewhere (Herpin et al., 2002). However, whilst extent of body reserves and thermoregulatory ability are an insurance against the possibility of delayed colostrum intake, the key factor to address is really the inherent vitality of the piglet immediately after delivery. This encompasses the ability to quickly stand and become active, to locate the udder, compete with littermates for teat access and withdraw plentiful colostrum. Attempts to quantify neonatal vitality have involved measurement of heart rate, respiration rate, muscle tone and rapidity of attempts to stand, and the use of these measures in deriving viability scores (Zaleski and Hacker, 1993a). However, understanding of inherent vitality and the factors which influence it is made difficult by the overwhelming influence on these parameters of intra-partum hypoxia. There are highly significant correlations between viability score and blood pH and \( pO_2 \) (Zaleski and Hacker, 1993a), and degree of hypoxia exerts a major influence on latency to suckle and survival (Herpin et al., 1996).

Targeted interventions at farrowing designed to increase vitality have been relatively scarce. Administration of oestrogen has been shown to increase activity level in the neonatal piglet, reduce latency to first suckling and tend to reduce perinatal mortality (Bate and Hacker, 1982; Hughes et al., 1992). However, the mechanisms involved in this have not been clearly elucidated. Perhaps the most promising intervention has been that designed to combat hypoxia. Oxygen inhalation by the piglet immediately after birth has been shown to decrease perinatal mortality and to yield overall benefit in piglet survival to weaning (Herpin et al., 2001). Large benefits were also seen when a similar treatment was applied in combination with other procedures in a farrowing management protocol (White et al., 1996).

The extent to which inherent vitality varies in the absence of the confounding factor of intra-partum hypoxia has been little studied. However, significant variation in viability score existed amongst piglets delivered by Caesarean section and these scores were highly correlated with piglet weight (Okere et al., 1997). The relationship between other components of neonatal physiology and piglet viability is still relatively poorly understood. It has been noted that certain pre-suckling biochemical traits differ between piglets which subsequently survive or die; surviving piglets had lower levels of plasma inorganic calcium and phosphorus (Tuchscherer et al., 2000), although the significance of this has yet to be established. Another recent approach has been the examination of increasing target nutrients known to be involved in neural development. Long chain essential fatty acids have been shown in many species to be important in the development of brain function (Uauy et al., 2000). Concentration of 22:6 \( n-3 \) in piglet tissues at birth can be enhanced by incorporation of marine oils in the sow gestation diet, and this strategy has been associated with improved survival of piglets of a given birth weight (Rooke et al., 2001). Enhancement of 22:6 \( n-3 \) reduced the proportion of deaths which were attributable to crushing by the sow, suggesting an effect mediated by improved neonatal vigour, and effects occurred despite reduction in mean birth weight. Gestation length, shown in previous studies to be associated with piglet survival (Roche and Kalm, 2000), was increased, but it could not be ascertained whether this was causal or correlational. The occurrence of effects such as these,
suggest that strategies targeted at modifying neonatal physiology might most effectively be applied through maternal routes.

6. Maternal physiology

Since maternal genetic effects on piglet survival exist, and since there appear to be major litter factors, as well as individual piglet factors, associated with risk of mortality (Fraser, 1990), research on maternal physiology requires equal emphasis to that on neonatal physiology. When considering aspects of maternal physiology which might influence piglet survival, it is possible to identify different categories. These include gestational factors which might affect the inherent viability of the piglet, periparturient factors which might influence the duration of parturition and piglet hypoxia, factors which might affect the availability and quality of colostrum (which provides both nutrients and passive immunity) and subsequently milk, and postnatal factors which might affect behavioural predisposition to crush, exhibit infanticide or fail to nurse.

Studies of gestational physiology in relation to piglet survival have focused primarily on the uterine environment and ways in which the mean piglet birth weight, within-litter variance in weight, and extent of neonatal energy reserves might be influenced. Early attempts to improve piglet viability focused on nutritional approaches, for example increases in feed level or in fat supplementation of gestation diets (reviewed by Pluske et al., 1995). Whilst minor improvements in birth weight and fetal energy reserves can be achieved by such strategies, they have generally had little effect in reducing mortality except in situations where initial mortality rates were high. Similarly, attempts to enhance fetal viability by modifying sow endocrinological state have also met with very limited success. Whilst it has been demonstrated that induction of maternal diabetes can increase fetal energy reserves (Ezekwe and Martin, 1978), administration of somatotropin and insulin to the sow failed to improve piglet weight, size or viability scores (Okere et al., 1997) and no relationship was detected in this study between piglet weight and maternal or piglet serum IGF-1 concentration.

These results suggest that the limitation in enhancing fetal reserves lies in the placental transfer of nutrients rather than maternal metabolic state. It has been demonstrated that there is a relationship between uterine blood flow and litter weight, suggesting that blood flow per fetus may limit individual birthweight (Pere and Etienne, 2000). Piglet birthweight is highly correlated with placental weight (Biensen et al., 1999), although significant variation in the ratio of piglet weight:placental weight exists. In this limited study, no significant association was found between placental weight, or weight ratio, and survival to weaning. In late gestation, genotype-specific mechanisms operate to ensure adequate nutrition for the fast growing fetus (Biensen et al., 1998), with increases in placental area or vascular density. The role of placental nutrient delivery in determining piglet viability is clearly an important area for further research (Finch et al., 2000).

When considering periparturient physiological parameters, an understanding of factors controlling the duration of parturition and consequent extent of piglet hypoxia would seem to be critical to enhancing survival (Randall, 1972). It is known that acute stressors, such as extreme disturbance, can prolong parturition in the sow (Lawrence et al., 1992) and this effect may be mediated by opioid inhibition of oxytocin release. Certain chronic stressors known to cause increased cortisol levels in the sow, for example fear of humans, have been associated with increased mortality of piglets (English et al., 1999; Hensworth et al., 1999). However, housing conditions involving restraint in the periparturient period, which also increase plasma cortisol concentrations, are not reliably associated with increased duration of parturition (Lawrence et al., 1997; Fraser et al., 1997). It appears that opioids strongly regulate oxytocin release during undisturbed farrowings (Lawrence et al., 1997), but the extent to which this system might be manipulated to increase parturition rate has not been explored. A range of other factors have been associated with the duration of parturition, including extent of exercise during gestation (Ferket and Hacker, 1985), litter size, sow parity, body condition and environmental temperature (Zaleski and Hacker, 1993b). Endocrine state of the sow (Hacker et al., 1979) has been associated with
differences in the farrowing process, but oestrogen injection prior to parturition failed to enhance piglet survival (Kirkwood and Thacker, 1995). Other pharmacological interventions have reduced the incidence of stillbirths in some experiments (e.g. English and Edwards, 1996; Bilkei, 1993) and this aspect of maternal physiology clearly also merits further investigation.

Factors influencing the quality and quantity of colostrum, and subsequent immune status of the piglet, are reviewed in detail elsewhere (Rooke and Bland, 2002). However, in view of the critical role of early and adequate ingestion of nutrients in the energy balance and vitality of piglets, improved understanding of the milk ejection process in the sow would be beneficial. One very prominent characteristic of high mortality litters is poor piglet liveweight gain in the immediate post farrowing period (Fraser, 1990), suggesting failure in some aspect of the milk transfer process. It can be deduced that the milk ejection reflex limits the transfer of milk from sow to piglets to a level below piglet appetite (Hartmann et al., 1997). Duration of milk ejection has a high coefficient of variation, but the possible role of physiological regulation of milk flow in piglet survival has not been investigated. There are also breed differences in suckling frequency (Sinclair et al., 1998), which will further influence nutrient availability to the piglets.

The physiological regulation of other aspects of maternal behaviour relating to piglet survival are also still poorly studied. The clearest instance of adverse maternal behaviour is infanticide or savaging of newborn piglets. While this is a relatively minor cause of mortality (Fig. 2), it has been shown to be more common in primiparous sows and to have a genetic component (Knap and Merks, 1987; Van der Steen et al., 1988). In other species, a steroid endocrine basis for maternal behaviour has been established, but there is no evidence of this in the pig (McLean et al., 1998). Another detrimental maternal behaviour is restlessness in the peri- and postnatal period. Such behaviour increases the probability of crushing of piglets and impedes early teat seeking and suckling attempts. There is evidence that endogenous opioids act as a neural substrate for passivity in the parturient sow (Jarvis et al., 1999). Maternal restlessness differs between genotypes (Sinclair et al., 1998) and sows also differ in responsiveness to piglet distress calls and other maternal behaviours related to piglet survival (Wechsler and Hegglin, 1997). Once again, whether such differences have manipulable physiological bases remains to be determined.

7. Conclusions

As discussed in the Introduction, perinatal piglet mortality may be underlain by a species reproductive strategy of producing a large number of relatively undeveloped offspring which has had evolutionary advantage, and will therefore be difficult to reduce. Whilst most improvements to date have resulted from modification of the farrowing environment, public concerns regarding animal welfare may limit such options in the longer term. This will place greater emphasis on solutions utilising biological mechanisms of the animals themselves. Methods of improving the inherent viability of the piglet and the maternal characteristics of the sow have so far yielded little commercial benefit and therefore require more fundamental research.

References


