PRENATAL MORTALITY IN FARM ANIMALS

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I. INTRODUCTION

The division of prenatal development in farm animals into three periods, that of the ovum, that of the embryo and that of the foetus is now a widely used convention. However, the difficulties involved in determining accurately the time of death and the difficulties involved in deciding the limits of these periods rob them of their value as a basis for the classification of prenatal mortality. The dividing limits of these periods were defined by Winters, Green & Comstock (1942) as being the time of attachment, which they reported as occurring in the bovine animal at about the eleventh day after fertilization, and the time when the formation of the major tissues and organs is concluded, which they arbitrarily put at 45 days following fertilization. However, there would appear to be some controversy as to when attachment does in fact occur (Melton, Berry & Butler, 1951; Chang, 1952) and there is by no means universal acceptance of the arbitrarily chosen 45-days limit to the embryonic period. As a result of this, there is considerable variation in the application of the terms used in describing prenatal death, although most authors, for convenience, tend to use the term 'embryonic death' to describe prenatal mortality occurring at anytime during the period of the ovum, the period of the embryo and to a varying extent the early part of the period of the foetus as defined by Winters and his co-workers. This convenience will be availed of in this review.

The subject of prenatal mortality has been reviewed previously with reference to farm animals by Laing (1952), Casida (1953, 1956) and Robinson (1957), and in each case the paucity of knowledge of the true nature of embryonic death was emphasized. This survey is intended to do no more than to summarize the position up to date.
II. METHODS OF STUDY

The methods used to demonstrate the existence and extent of prenatal death obviously vary with the animal in question. In the bovine animal, Laing (1949) and Tanabe & Casida (1949) were the first to use the direct method of slaughter at intervals following mating to demonstrate the possible extent of embryonic death in a group of animals. This method entails slaughter at different intervals after mating, the first up to 3 to 4 days and the second at some longer interval, usually in the region of 30 days, thus estimating the fertilization rate and the number of fertilized ova that fail to continue development in the intervening time. Similar investigations have been carried out since then by other workers (Tanabe & Almquist, 1953; Hawk, Wiltbank, Kidder & Casida, 1955; Bearden, Hansel & Bratton, 1956).

These studies demonstrated the fact that death following fertilization can occur either at a time when it does not alter the interval between oestrus beyond the normal range for the unmated animal or at a time when, presumably through persistence of the corpus luteum, the interval is prolonged. Stewart (1952), by repeated clinical examination of animals that had apparently failed to conceive and had returned to oestrus at an interval greater than the average length of the oestrous cycle, concluded that this was most frequently due to the persistence of a corpus luteum that had been associated with a pregnancy. Further, it has been shown that mating with a vasectomized bull had no effect on the length of the subsequent return interval (Marion, Smith, Wiley & Barrett, 1950). The accumulation of evidence such as that mentioned above has given rise to the practice of taking the frequency of occurrence of increased return intervals as reflecting the extent of embryonic death. This method, however, is open to several objections. It does not take into account death that occurs too early to affect the return interval, and it is difficult to make a true allowance for other causes of prolonged intervals.

Information on prenatal death occurring during the late embryonic and foetal period has been obtained by the comparison of the results of pregnancy diagnosis by rectal palpation at 30 to 40 days with subsequent pregnancy diagnoses or with calving rate.

Finally, artificial-insemination records give an indication of the relative extent of prenatal death occurring at different stages. The general pattern shown by these records is a decline, up to the time of parturition, in the percentage of animals not returning for re-insemination from the first month, a figure in the region of 65 to 85%. This decline is greater up to the third month than it is subsequently and it is in keeping with this that the non-return percentage at 3 months is accepted as being the most suitable index of the fertility of artificial insemination under field conditions. This has, of course, been confirmed by pregnancy diagnoses. While there are obviously many factors, such as fertilization failure and faults in technique and management, contributing to the non-return figure at 1 month and to the more rapid decline up to 3 months, it is accepted from experimental and other evidence that prenatal death is one of the major factors. Since an increase in embryonic death causing increased cycle length affects the rate of decline from the first to the third
month, some workers have used a change in this rate, under certain conditions, to evaluate the effect of these conditions on embryonic death.

Recent work by Dawson (1958) suggests that the counting of what he terms miniature corpora albicantia could be an aid in estimating temporary pregnancy of 2 to 5 months duration.

In the pig, since total loss of pregnancy is apparently uncommon, the effect of prenatal death takes the form of a reduction in litter size (Wilson, Nalbandov & Krider, 1949; Robertson, Grummer, Casida & Chapman, 1951) and information is obtained by comparison of the number of corpora lutea with the number of surviving embryos or with litter size, it being generally taken that the fertilization rate is normally close to 100% (Self, Grummer & Casida, 1955; King & Young, 1957, and others).

In the sheep, the methods based on slaughter and on the delay in return interval have been used. The basing of estimates on return-to-service data must, of course, make allowance for the fact that more than one ovum may be shed.

III. EXTENT OF PRENATAL MORTALITY

In the bovine animal, information has been accumulated on the extent of prenatal mortality in animals with histories of infertility and in animals without such histories, including random populations of cows and heifers, such as those served by artificial-insemination organizations.

**Table 1**

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of animal</th>
<th>Stage of pregnancy (days)</th>
<th>Estimated prenatal mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanabe &amp; Casida (1949)</td>
<td>Cow</td>
<td>34</td>
<td>39-2</td>
</tr>
<tr>
<td>Laing (1949)</td>
<td>Heifer</td>
<td>27</td>
<td>44-0</td>
</tr>
<tr>
<td>Casida (1953)</td>
<td>Cow</td>
<td>34</td>
<td>59-4</td>
</tr>
<tr>
<td>Tanabe &amp; Almquist (1953)</td>
<td>Heifer</td>
<td>30</td>
<td>54-1</td>
</tr>
<tr>
<td>Hawk, Wiltbank, Kidder &amp; Casida (1955)</td>
<td>Cow</td>
<td>34</td>
<td>51-7</td>
</tr>
</tbody>
</table>

Table 1 shows the incidence of embryonic death reported in animals with histories of infertility ('repeat breeders'). In all cases, the method of slaughter at intervals was used. With the exception of Laing's work, which included animals without histories of infertility, the criteria for the selection of the experimental animals were similar, the object being to exclude all animals with clinically obvious causes of infertility. In all cases, high-fertility bulls were used and the animals were mated at what was considered to be the optimum time for fertilization. In the experiment carried out by Hawk, Wiltbank, Kidder & Casida (1955), the animals were slaughtered at 16 days and at 34 days. Since the percentage embryonic death reported by them was similar to that found by the other workers for the whole period from fertilization to 34 days, they concluded that in repeat breeders most of the embryonic death occurred between 16 and 34 days.
Prenatal mortality in farm animals

Table 2 shows the estimated prenatal death in animals not selected for infertility. In the last two reports listed, the increased return interval was used to establish the estimated prenatal death rate. Hawk, Tyler & Casida (1955), who were studying the effect of different systems of mating on prenatal death, used pregnancy diagnosis in addition and the figure given is the over-all figure for prenatal death. Both Kidder, Black, Wiltbank, Ulberg & Casida (1954) and Bearden, Hansel & Bratton (1956) were studying the effects of the level of fertility of the bull on embryonic death and again the figures are average over-all estimates.

Table 2
Prenatal mortality in animals without histories of infertility

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of animal</th>
<th>Stage of pregnancy (days)</th>
<th>Estimated prenatal mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laing (1949)</td>
<td>Heifer</td>
<td>27</td>
<td>21.0</td>
</tr>
<tr>
<td>Kidder, Black, Wiltbank, Ulberg &amp; Casida (1954)</td>
<td>Heifer</td>
<td>90</td>
<td>16.0</td>
</tr>
<tr>
<td>Bearden, Hansel &amp; Bratton (1956)</td>
<td>Heifer</td>
<td>33</td>
<td>14.9</td>
</tr>
<tr>
<td>Hawk, Tyler &amp; Casida (1955)</td>
<td>Cow</td>
<td>150</td>
<td>19.9</td>
</tr>
<tr>
<td>Erb &amp; Holtz (1958)</td>
<td>Cow</td>
<td>100</td>
<td>20.6</td>
</tr>
</tbody>
</table>

An indication of true foetal mortality from 34 to 50 days up to parturition was given by Fosgate & Smith (1954), who carried out a monthly pregnancy-diagnosis on cows found pregnant at 34 to 50 days. They report a mean loss of 6.38% in 690 pregnancies over 6 years. The variation of the loss at each monthly examination was not significant.

Table 3
Prenatal mortality in the pig

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of animal</th>
<th>Stage of pregnancy (days)</th>
<th>Estimated prenatal mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casida (1953)</td>
<td>Sow</td>
<td>birth</td>
<td>44</td>
</tr>
<tr>
<td>Perry (1954)</td>
<td>Sow and Gilt</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>Baker, Self, Chapman, Grummer &amp; Casida (1956)</td>
<td>Gilt</td>
<td>25</td>
<td>43</td>
</tr>
<tr>
<td>Lasley (1957)</td>
<td>Sow</td>
<td>birth</td>
<td>41</td>
</tr>
<tr>
<td>Reddy, Mayer &amp; Lasley (1958)</td>
<td>Gilt</td>
<td>55</td>
<td>23</td>
</tr>
<tr>
<td>King &amp; Young (1957)</td>
<td>Sow</td>
<td>28</td>
<td>39</td>
</tr>
<tr>
<td>Lerner, Mayer &amp; Lasley (1957)</td>
<td>Gilt</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Baker, Chapman, Grummer &amp; Casida (1958)</td>
<td>Gilt</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
<td>48</td>
</tr>
</tbody>
</table>

Some of the reported estimates of prenatal death in pigs over the whole period of pregnancy are shown in Table 3. That the major portion of this loss occurs by the 25th day of pregnancy has been shown by slaughter at different

In Table 3, the last three experiments referred to were designed to study the effects on embryonic death of planes of nutrition and systems of breeding and the figures given are over-all estimates. The percentages for embryonic death given by Reddy, Mayer & Lasley (1958) and Day; Anderson, Emmerson, Hazel & Melampy (1959) were obtained from control animals during hormonal experiments.

Estimates for prenatal death in sheep are not so numerous. Hulet, Voigtlander, Pope & Casida (1956) give 20% embryonic death up to 18 days, 30% up to 40 days and Dutt & Simpson (1957) give 48% by full term.

Data given by Day (1957) for 200 mares over a period of 10 years gives the disparity between positive pregnancy-diagnosis around 40 days and subsequent known pregnancies as being about 11%.

IV. CAUSES OF PRENATAL DEATH

Stimulated by the development of artificial insemination and the information thus made available, a considerable amount of work has been done in studying the effect of the bull on embryonic death. Some of the earlier work is now less valuable since it was carried out at a time when the full significance of *Vibrio foetus* as a cause of embryonic death had not been appreciated. When the practice of incorporating antibiotics in semen extenders was first advocated, various workers showed that, in addition to its other effects, this practice caused a significant reduction in the frequency of increased return intervals and a reduction in the non-return decline (Olds, Oliver & Seath, 1951; Adler & Rasbech, 1952; Foote & Bratton, 1952; Erb & Flerchinger, 1954, and others), and it was therefore taken to be reducing embryonic death. These effects were especially marked with bulls of low fertility. With the increased knowledge of the characteristics of *V. foetus* infection (Terpstra & Eisma, 1951; Lawson & MacKinnon, 1952; Boyd, 1955, and others), and when investigations were made as to the effects of antibiotics on the semen of known *V. foetus*-infected bulls (Willet, Ohms, Frank, Bryner & Bartlett, 1955), it became obvious that in many cases the improvement following the addition of antibiotics could be explained on the basis of their control of *V. foetus*.

While the addition of antibiotics to semen extenders tends to bring the conception rate of low-fertility bulls closer to that of high-fertility bulls, there still remains, of course, a variation in fertility between bulls, as measured by conception rate. In an attempt to determine the relative importance of fertilization failure and embryonic death in this variation, Kidder, Black, Wiltbank, Ulberg & Casida (1954) and Bearden, Hansel & Bratton (1956) found that, while the fertilization rate of low-fertility bulls was significantly below that of high-fertility bulls (71.9% and 76.9% for low-fertility bulls as against 100% and 96.6% for high-fertility bulls, respectively, for the two authors), there was no significant difference in the incidence of embryonic

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death (14.9% and 19.2% for low-fertility bulls as against 25.5% and 10.5% for high-fertility bulls, respectively). In the work of Bearden et al., heifers that had been tested for V. fetus and found to be negative were used. This data would suggest that failure of breeding with high-fertility bulls is largely due to embryonic death, whereas for low-fertility bulls it is due both to embryonic death and fertilization failure, so that the question still remains to what extent the bull, even when considered highly fertile on the basis of his non-return rate, is responsible for this residual embryonic death.

Knudsen (1956) has demonstrated that during the first stages of reduction division in spermiogenesis, chromosomes with inverted segments bearing abnormally arranged genes can arise. During pairing and crossing-over between a normal chromosome and an inverted chromosome, a loose chromosome fragment may be formed. This then becomes incorporated at random in the resulting sperm. This type of sperm appears normal and can fertilize but the genetic constitution of the embryo will be unbalanced and may result in its death. Several of the bulls in his study caused an increase in the return intervals of females that they served, which was taken to reflect embryonic death.

Although there is ample evidence to show that the conception rate for bull semen decreased significantly for each additional day of storage (Campbell, 1953; Fryer, Marion & Farmer, 1958), and this fact is applied in practice at many artificial insemination centres in the use of daily collections of semen, Willet & Ohms (1955) and Salisbury, Bratton & Foote (1952) have claimed that the age of semen can also increase the frequency of embryonic death as indicated by the non-return decline from 28-35 days to 60-90 days. It has not yet been shown if age of the sperm within the female reproductive tract is a factor, although ageing of the ovum prior to fertilization may cause defects that increase embryonic death (Blandau & Young, 1939; Barrett, 1948). In the pig, an increased embryonic death-rate has been found with 3-day-old semen as compared with fresher semen (Dziuk & Henshaw, 1958). This was despite the use of antibiotics in the 3-day-old semen only. Stratmand & Self (1958) found that, within certain limits, the volume of semen was of greater importance than sperm number in relation to embryonic death in artificially inseminated sows. In sheep, a negative correlation has been observed between sperm motility in semen used for artificial insemination and embryonic death (Dutt & Simpson, 1957).

While it is now generally accepted that the specific bovine venereal infections such as those by V. fetus and Trichomonas foetus can cause death of the fertilized ovum and embryo, the possible part played by non-specific infections is not clear. Attempts to demonstrate the existence of low-grade non-specific infection as a cause of embryonic death in repeat-breeder cows, without any other apparent abnormality, have not been successful, either by direct culture or by response to uterine infusions of antibiotics (Ulberg, Black, Kidder, McDonald, Casida & Mcnutt, 1952). Hawk, Kiddy, Wilson, Esposito & Winter (1958), in examining uteri obtained 16 days after breeding, recovered various microorganisms including Pseudomonas, Escherichia coli, etc., but none could be determined as being responsible for embryonic death. The possibility that
variations in hormonal status or in nutritional factors might increase susceptibility to such organisms arises from the observations made by Rowson, Lamming & Fry (1953), Black, Simon, Kidder & Wiltbank (1954) and by Hignett (1959).

Since heritability figures for infertility generally appear to be low (Trimberger & Davis, 1945; Dunbar & Henderson, 1950; Olds & Seath, 1950; Squiers, Dickerson & Mayer, 1952; Pou, Henderson, Asdell, Sykes & Jones, 1953), it is probable, though of course not necessarily so, that heritability of prenatal death is also low.

Artificial-insemination records show that by the third insemination the number of non-returning animals approaches the region of 90%. This, coupled with the work of several authors (Trimberger, 1956; Erb & Ehlers, 1957, 1958; Erb & Holtz, 1958) who have found that the chances of conception are not decreased significantly when the service is given on a cycle of greater length than that accepted as being within the normal range, suggests that embryonic death in the individual bovine animal, other than the genuine repeat-breeder, does not tend to repeat itself in that animal. The fact that it occurs in one cycle does not necessarily influence subsequent fertility. However, in the pig, Perry (1960) found that the sire could have a significant effect on the repeatability of embryonic loss in the successive litters of his daughters. Whether this is due to an inherited factor or to environment is not yet clear. Baker et al. (1958) also suggest that different gilts had an individually characteristic ability to maintain living embryos.

Experiments to determine the effect of systems of mating have shown a correlation between inbreeding and increased prenatal death. In cows, Hawk, Tyler & Casida (1955) and Mares, Menge, Tyler & Casida (1958) have found that figures for prenatal death up to 150 days are higher for inbred dams than those for the corresponding outbreds. Hawk et al. give 26·7% and 13·3% prenatal death for inbred and outbred dams, respectively, and Mares et al. give 28·4% and 19·2%, the difference in the latter investigation being statistically significant. Inbred embryos also had a tendency to higher prenatal death than outbred. Casida (1956) cites Tyler as having made a similar study but a distinction was made between late embryonic death (22 to 35 days) and early foetal death. No effect of the dam was found on late embryonic death, although inbreeding of the embryo increased it. For foetal death, he obtained essentially the same results as the previously mentioned workers.

In the pig, Baker et al. (1958) found that, while the breed of pig used in their experiment had a significant effect on ovulation rate, it had no effect on embryonic death. Again, as in cattle, the system of mating seems to be of importance. King & Young (1957) give the inbreeding of the dam as having a greater effect than the inbreeding of the embryo on litter size. The influence of the dam would appear to operate through a significant effect on ovulation rate rather than through embryonic death. Squiers, Dickerson & Mayer (1952) had also found this to be true although it was not confirmed by Pomeroy (1952) with more limited numbers of animals.

The influence of the level of nutrition on embryonic death has received considerable attention mostly in the pig, in which animal it has been shown to
affect fertilization, rate of ovulation and prenatal death. Several groups of workers have demonstrated that continuous unlimited feeding or a high plane of nutrition increased the ovulation rate but also increased the embryonic death up to 25 days (Self, Grummer & Casida, 1955; Haines, Warnick & Wallace, 1955, 1959; Gooda, Warnick & Wallace, 1960). Self et al. (1955) in two trials give 68% and 47% embryonic death for full-fed gilts with a corresponding 43% and 20% for limited-fed gilts. On a full-feeding regime, Haines et al. (1959) report 22-1% embryonic death up to 25 days and 9-7% from 25 days to parturition, as compared with 11-6% and 8-5% under limited feeding. Waldorf (1957), however, suggested that after 25 days foetal death is increased by limited feeding. Gossett & Sorensen (1959) observed similar effects on embryonic-death rate but found ovulation rates on high and low levels of energy intake to be comparable. A further indication of the effect of level of nutrition, in this case as reflected by backfat thickness, is shown by a positive correlation between backfat thickness and embryonic death (Self et al., 1955; Rathnasabapathy, Lasley & Mayer, 1956; Dean, Reddy, Lasley & Tribble, 1958). A possible benefit in breeding management of a short period of maximum feeding followed by a lowered after-breeding level has been suggested (Self et al., 1955). Contrary to the previously mentioned work, King & Young (1957) found a negligible effect of level of nutrition on embryonic death but showed that a low level significantly depressed conception.

Conflicting reports of the effect of the level of nutrition on conception rate in cattle have been noted (Brannang, 1954; Joubert, 1954), the former work being carried out with twins. The effect of full feeding on ovulation in sheep is well known. That embryonic death may also be increased is suggested (El-Sheikh, Hulet, Pope & Casida, 1955; Foote, Pope, Chapman & Casida, 1959).

There would appear to be little information available as to the effect of specific dietary factors on prenatal death in farm animals, although Hignett (1959, and earlier) and others have indicated a large field of study in the importance of these factors in infertility in general.

Arising from the work on the effect of nutrition and systems of breeding on embryonic death in the pig, the question of a possible relationship between ovulation rate and embryonic death can be considered. Perry in his earlier work (1954) concluded that there was a linear relationship between the ovulation rate (as measured by the number of corpora lutea) and embryonic death. However, Casida (1956) refers to several investigations where this correlation was not clearly shown. Data given by King & Young (1957) showed a relationship that they describe as being intermediate between that obtained by Perry and by the American authors. In further studying this relationship, Perry (1959) found that it was linear in a certain group of pigs (average embryonic death 24%) but that in another group the embryonic death was higher (average 38.5%) and was not proportional to the number of ova ovulated. This additional mortality is thought by Perry to be superimposed on that which would show a linear relationship to the number of ova present.

Since hormonal dysfunction is obviously a possible cause of pregnancy failure, the effect of exogenous hormones on prenatal death have been studied.
Progesterone has received most attention. In the bovine animal, such work as has been done indicates a beneficial response to progesterone administration. This response includes some success in the maintenance of pregnancy in cows that had aborted repeatedly (Woelffer, 1953), an improvement in pregnancy-diagnosis figures at 5 months (Johnson, Ross & Fourt, 1958) and a greater number of embryos at 34 days in repeat breeders (Wiltbank, Hawk, Kidder, Black, Ulberg & Casida, 1956). An improvement in the maintenance of pregnancy has also been reported in mares (Day, 1957). Although more investigations have been carried out in the pig than in other farm animals, the results are not conclusive. Exogenous progesterone has been found to increase embryonic death (Sammelwitz, Dziuk & Nalbandov, 1956; Spies, Zimmerman, Self & Casida, 1959) or to have no effect on embryonic death (Haines, Warnick & Wallace, 1958) but when combined with an oestrogen to improve embryonic survival (Reddy et al., 1958; Day et al., 1959). An increase in embryonic death in the ewe with the use of progesterone has been reported (Kiracofe & Gossett, 1960).

In a number of the studies made of factors affecting prenatal death, a relationship to the age of the animal and as between parous and non-parous animals has been mentioned. On the information available, it would seem that there is a species difference. Erb & Holtz (1958) found that heifers had a higher embryonic death than cows in their fourth and fifth reproductive periods, results being inconsistent after the fifth period, while Warnick, Grummer & Casida (1949) concluded that in the pig embryonic death was significantly higher in parous than in non-parous animals. Both Perry (1956) and King & Young (1957) suggested that embryonic loss increased in older sows.

Prompted by the difficulties involved in maintaining high fertility in early season lambing, the effect of body temperature, as controlled by environmental temperature and by shearing, has been studied. An increase in body temperature was found to be largely responsible for the early season infertility and included in its effects an increase in embryonic death (Hulet, El-Sheikh, Pope & Casida, 1956; Dutt & Simpson, 1957; Dutt, Ellington & Carlton, 1959).

A more recent field of study in relation to prenatal death is that of isoimmunization. However, no effect on fertility in cattle following isoimmunization with blood and semen was found by Kiddy, Stone, Tyler & Casida (1959). Ashton (1959) suggests that from artificial-insemination records the figure for the loss in pregnancy between 1 month and 3 months agrees with that which can be estimated as being due to dam-foetus ß-globulin incompatability.

V. CONCLUSION

The literature reviewed indicates clearly that the knowledge of the causation of the death of the fertilized ovum and embryo remains incomplete. While numerous factors have been shown to influence embryonic death either by increasing or decreasing it, there is no factor or combination of factors so far investigated, whose control has eliminated it in a group or population of animals. This residual embryonic death which appears to be relatively constant in amount, particularly in the bovine animal, would seem to have to be
accounted for by a more universally active factor than any of those so far investigated.

REFERENCES


ERB, R. E. & FLRECHINGER, F. H. (1954) Influence of fertility level and treatment of semen on non-return decline from 29 days to 180 days following artificial service. J. Dairy Sci. 37, 998.


HAMMOND, J. (1921) Further observations on the factors controlling fertility and foetal atrophy. J. agric. Sci. 11, 337.


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