Conceptus Competition for Nutrients in the Porcine Uterus: Different Strategies Exhibited by the Meishan and Yorkshire Pig Breeds

Kimberly A Vonnahme, graduate assistant,
and Stephen P. Ford, professor,
Department of Animal Science

ASL-R667

Summary and Implications

Previous research from our laboratory demonstrated that Meishan conceptuses develop more slowly and synchronously to day 30 of gestation than conceptuses of U.S. pig breeds. Furthermore, the reduced size of the Meishan conceptus on day 30 allows more Meishan than Yorkshire conceptuses to occupy the same amount of limited uterine space. As a result, Meishan litter size is significantly larger than that of U.S. pig breeds (13–14 vs. 9-10 piglets/litter). An additional consistent, but unexpected, finding in the Meishan pig was the observation that there was significantly greater amounts of unoccupied uterine space in the Meishan than the Yorkshire female at term. We previously demonstrated that an additional strategy of the Meishan female to increase fecundity was to super-vascularize its placental membranes so that oxygen and nutrient transfer from the sow could be accomplished over a reduced surface area, negating the necessity of further placental growth. These data suggested that when a Meishan conceptus dies, the placenta of its neighbors need not grow into this newly vacated space, whereas the Yorkshire conceptus might increase the size of its less vascular placenta to use the opportunity. Therefore, it was our objective to confirm that Yorkshire conceptuses, but not Meishan conceptuses increase their placental size when adjacent conceptuses are experimentally destroyed on day 40 of gestation. To accomplish this objective, pregnant Meishan and Yorkshire females were laporatomized on day 40. One uterine horn was randomly chosen to be receive alternative fetal crushing (i.e., every other fetus in the horn was crushed by mechanical pressure), whereas the other uterine horn served as the control horn. At slaughter on day 111 of gestation (term = 114 days), we found no differences in fetal weight between the control and treated horns regardless of breed. Similarly, there was no difference in placental weight or surface area or implantation site length (the length of placental attachment in the uterine horn) between the control and treated horns in the Meishan. In contrast, however, there was a marked increase in placental weight and surface area, as well as implantation site length for conceptuses in the treated horn of the Yorkshire gilts versus the control horn. Furthermore, the unoccupied spaces between Meishan conceptuses in the treated horn were 2-fold greater than for conceptuses in the control horn, whereas there were no differences in the length of unoccupied spaces between conceptuses in the Yorkshire's control or treated horns. These data suggest that in the Meishan treated horn, conceptuses do not use this extra space as effectively as conceptuses in the Yorkshire treated horn. The inability of Meishan placenta to grow into adjacent unoccupied spaces may not be detrimental to conceptus survival due to its greater ability to increase vascular density in response to increasing fetal demands. If U.S. pig breeds have the potential to increase placental vascularity, rather than increase in placental size to nourish the growing fetuses, the potential exists for increasing litter size due to a decrease in uterine competition throughout gestation.

Introduction

Many factors have been hypothesized to influence conceptus survival and litter size in the pig. However, the intervals of greatest conceptus loss can be grouped into two time periods. The first major loss of conceptuses occurs around the time of elongation and attachment, or the peri-implantation period. During this time period up to 30% of the conceptuses are lost in association with significant conceptus asynchrony in U.S. and European pig breeds. The second period of loss occurs after day 30, the point at which uterine capacity begins to become limiting to the rapidly expanding conceptus. It has been well established that more conceptuses survive the peri-implantation period in the prolific Chinese Meishan pig than survive in U.S. and European breeds because Meishan conceptuses develop more slowly and synchronously. Furthermore, uterine capacity is less limiting in the Meishan due to similar size of the uterus across these breeds of pigs, and the markedly smaller Meishan conceptus size. In addition, the placenta of the Meishan conceptus is much more vascular, which facilitates an increased nutrient and oxygen delivery to the fetus over a smaller surface area than needed by the conceptus of U.S. pig breeds. These two facts result in a 3–5-piglet increase in litter size in the Meishan versus commercially relevant pig breeds. Comparisons between the Meishan and Yorkshire breeds have been useful in determining the physiologic factors that effect conceptus loss throughout gestation in the pig.

We have consistently observed reduced amounts of unoccupied uterine space within the gravid uterine horns of the Yorkshire female versus that of the Meishan throughout the postimplantation period. More specifically, we have routinely observed unoccupied spaces in the gravid Meishan uterine horns, which are equal to or exceed space occupied by viable conceptuses within the same litter. We rarely see significantly unoccupied space in the uterus of the Yorkshire breed except in cases of unusually high fetal loss. With these data in mind, we hypothesized that if a Meishan conceptus dies by day 40, the placenta of its neighbors will not grow into this newly vacated space, whereas the

Yorkshire conceptus will use the opportunity to increase its placental size. Therefore, it was our objective to confirm that Yorkshire conceptuses, but not Meishan conceptuses increase their placental size when adjacent conceptuses are experimentally destroyed on day 40 of gestation.

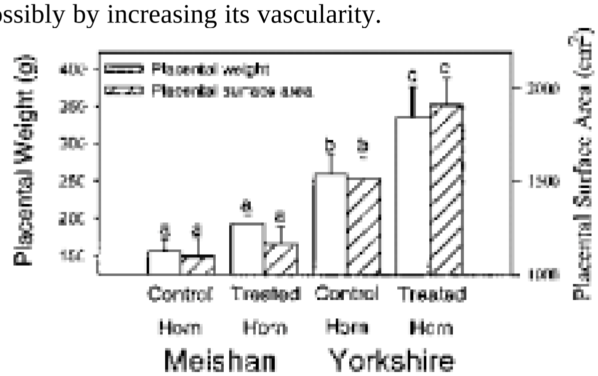
Materials and Methods

On day 40 of gestation, straight-bred Yorkshires and Meishans were laporatomized and one uterine horn was randomly assigned to receive alternating fetal crushing (treated horn), whereas no fetuses were crushed in the other horn (control horn). We chose to reduce fetal number on day 40 for 3 reasons: 1) the fluid levels in the placenta are decreasing, allowing ease in locating and crushing of the fetus; 2) the size of the fetus is large enough to easily locate, but early enough in development to allow for ease in crushing; and 3) day 40 is a time point when conceptus loss will be naturally occurring due to the limitations of uterine capacity. After surgery, females were returned to their pen until slaughter on day 111 of gestation. At slaughter, gravid uteri were collected and immediately placed on ice for transport to the laboratory. Measurements obtained at the laboratory included uterine horn length, conceptus number, fetal weight, crown rump length, placental weight and surface area, implantation site length, and the length of unoccupied spaces between conceptuses.

Results and Discussion

The number of conceptuses did not differ between breeds on day 40, before alternate fetal crushing occurred averaging ~7.5 fetuses per uterine horn (Table 1). The interfetal distance and uterine horn length obtained during surgery were greater in the Yorkshire compared with that of the Meishan on day 40. However, measurements taken at slaughter demonstrated that there was no difference in uterine horn length between Meishan and Yorkshire females, demonstrating neither breed had an unfair advantage for increased uterine capacity by possessing longer uterine horns. Further, measurements taken at slaughter demonstrate that although there was an appropriately reduced number of fetuses in the treated horns (approximately half that of the control) there was no affect of breed. Percentage of survival (calculated as the number of viable conceptuses at slaughter versus the number remaining after fetal crushing) was not different between the control or treated horns, or between the Yorkshire and Meishan females, averaging ~88%.

Although there was no difference between fetal weight and size between breeds (averaging ~1100 g), there were marked differences in the weight and size of the placentae between the two breeds. There was no difference in placental weight or placental surface area between the control and treated horns in the Meishan (Figure 1). There was, however, a marked increase not only in placental weight but also placental surface area for conceptuses in the treated horn of the Yorkshire gilts versus the control horn. As derived in other studies, placentae from the Yorkshire breed were also significantly heavier and larger than the placentae from the Meishan females. Similarly, there was no difference in the implantation site length between Meishan conceptuses in either the control or treated horn, whereas the implantation site length of the Yorkshire conceptuses gestated in the treated horn was increased ~27% compared with the control horn. Furthermore, there was an increase in the length of unoccupied space in the Meishan treated horn compared with the Meishan control horn, whereas there was no difference in the unoccupied space length between conceptuses in the Yorkshire's control or treated horns. Although the Meishan had a reduced placental weight and size and took up less space in the uterus, fetal weights were similar. This suggests that the placenta is finding an alternate way to nourish its fetus, possibly by increasing its vascularity.



To summarize how the composition of the interfetal differences differed between the Meishan and Yorkshire breeds, the percentage of unoccupied space is noted as well as the percentage of space occupied by placentae in Table 2. Although there was a significant difference in the average interfetal distance between the Yorkshire control and treated horns, there was no difference in the percentage of unoccupied space of these horns. Likewise, the percentage of the space occupied by placentae was similar between the Yorkshire control and treated horns. The Meishan females also had a significant difference in the average interfetal space on day 111. However, the percentage of unoccupied space was significantly reduced in the control horn compared with the treated horn. Likewise, the percentage of space occupied by placentae was significantly greater in the control horn versus the treated horn. When comparing across breeds, the unoccupied space of both Yorkshire horns and the Meishan control horn was similar averaging ~21% of the interfetal space. However, the unoccupied space of the Meishan treated horn was 2-fold greater, demonstrating Meishan conceptuses do not use this extra space as effectively.

This study demonstrates that a difference indeed exists between Meishan and Yorkshire conceptuses in their response to the death of an adjacent fetus on day 40 of gestation. Uterine horn length and fetal numbers are similar between Meishan and Yorkshire females and between treated and control horns of both breeds on day 111. Placentae were ~29% heavier, ~26% larger, and occupied ~27% more space when recovered from the uterine horn subjecting to alternate fetal crushing than when recovered from the control horn of the Yorkshire females. Furthermore, the percentage of unoccupied space of the interfetal distance was similar between the control and treated horns in Yorkshire females. In contrast, Meishan placental weight, surface area, and implantation site length were similar across the control and treated horns. Meishan conceptuses in the treated horn had a greater percentage of unoccupied space compared with the control horn, indicating these conceptuses did not use the extra space to grow their placentae. These data suggest that the Yorkshire conceptus will increase the size and surface area of its placenta in response to adjacent unoccupied uterine spaces after day 40 of gestation, whereas Meishan conceptuses will not. This failure of the Meishan placenta to grow into adjacent unoccupied spaces may not be necessary due to its greater ability to increase vascular density in response to increasing fetal demands.

Table 1. Effects of alternate fetal crushing on conceptus survival and uterine length.

	Yorkshire		Meishan	
Measurement	**Control Horn (n=5)**	**Treated Horn (n=5)**	**Control Horn (n=5)**	**Treated Horn (n=5)**
Surgery Data (Day 40)				
Number of fetuses	7.0 ± 1.0[a]	8.4 ± 0.9[a]	7.0 ± 0.7[a]	7.4 ± 0.8[a]
Interfetal distance (cm)	63.0 ± 3.9[a]	54.4 ± 5.6[a]	40.0 ± 6.0[b]	34.6 ± 4.4[b]
Horn length (cm)	457.8 ± 44.7[a]	444.8 ± 35.3[a]	264.0 ± 21.2[b]	250.4 ± 14.9[b]
Slaughter Data (Day 111)				
Number of fetuses	6.2 ± 1.0[a]	3.4 ± 0.4[b]	6.0 ± 0.7[a]	3.8 ± 0.7[b]
Percentage of survival	87.7 ± 5.2[a]	87.0 ± 5.4[a]	87.8 ± 9.7[a]	93.3 ± 6.7[a]
Horn length (cm)	326.6 ± 32.8[a]	300.0 ± 19.4[a]	281.6 ± 39.8[a]	261.6 ± 25.4[a]

[a,b] Mean ± SE within a row with different superscripts differ ($P < 0.05$).

Table 2: Composition of interfetal distances between the treated and control horn of Yorkshire and Meishan pigs.

	Average interfetal distance	**Unoccupied space (% of interfetal space)**	**Space occupied by placentae (% of interfetal space)**
Yorkshire control horn (n=5)	34.5 ± 3.5 cm[a]	19.4 ± 5.2 %[a]	80.6 ± 5.2 %[a]
Yorkshire treated horn (n=5)	48.4 ± 2.8 cm[b]	29.2 ± 3.1 %[a]	70.8 ± 3.1 %[a]
Meishan control horn (n=5)	23.0 ± 3.6 cm[c]	15.4 ± 7.2 %[a]	84.6 ± 7.2 %[a]
Meishan treated horn (n=5)	36.7 ± 3.0 cm[a]	46.2 ± 3.9 %[b]	53.8 ± 3.9 %[b]

[a,b,c]Means ± SE (%) within a column with different superscripts differ ($P < 0.05$).