REPRODUCTIVE INNOVATIONS: CONTROL OF SOW ESTRUS AND BREEDING

Roy Kirkwood
Department of Large Animal Clinical Sciences
Michigan State University
Lansing, Michigan 48824-1314
E-mail: kirkwood@cvm.msu.edu

ABSTRACT

The increasing successful use of artificial insemination is facilitated by a greater knowledge of the biology of the sow during her estrous period. The realization of the importance of establishing an adequate sperm reservoir in the oviduct at an appropriate time relative to ovulation has led to advances in the management of artificial insemination. In particular, knowledge of when a sow is likely to ovulate during a natural or induced estrous period, and mechanisms influencing sperm transport have been valuable. The future of artificial insemination will likely involve a single semen dose having a reduced sperm number. This will be made possible by knowledge of the effect of site of sperm deposition on sow fertility.

INTRODUCTION

The basic principle of artificial insemination is simple; place enough viable sperm in the right place at the right time, and keep it clean. However, reproductive performance of females bred by AI is often poorer than that achievable with natural breeding. There are several reasons that sows may perform relatively poorly following artificial insemination. Using current insemination technology, 3×10^9 sperm in 80 to 100 ml extender are deposited in the cervix. This large number is necessary because most of the sperm will be lost due to back-flow of semen, as well as entrapment and death in the cervix and uterus. However, the use of new catheters designed to allow trans-cervical/uterine deposition of sperm will reduce semen backflow. Further, by limiting sperm losses, the number of sperm in the original semen dose can be reduced.

The ultimate objective of AI is to ensure a sufficient number of sperm are in the first part of the oviduct (the sperm reservoir) at the time of ovulation. If time of ovulation is not known, then multiple inseminations are required. However, if time of ovulation can be reliably predicted, then a single insemination should suffice. This paper will focus on technologies available to achieve the objective of good fertility following a single insemination of fewer sperm.

CONTROL OF ESTRUS

Estrus Stimulation

In sows, wean-to-estrus intervals greater than 5-days are associated with reduced farrowing rates and litter sizes (Wilson and Dewey, 1993; Steverink et. al., 1999). The reason for this is unclear but may involve poor synchrony between time of ovulation and time of breeding because these sows are more likely to be early ovulators (see below). As such, and especially associated with once daily estrus detection, it is probable that many of these sows will have already ovulated when estrus is detected. In consequence, this sub-population of sows will be subject to post-ovulatory inseminations, which are associated with poorer fertility and potentially uterine infection (Rozeboom et al., 1997; Tarocco and Kirkwood, 2001). Therefore, when records indicate a higher likelihood of delayed estrus (eg. seasonal or associated with primiparous sows) gonadotrophins (PG600 or Pregnecol) can be used to induce a more prompt return to estrus (Kirkwood, 1999). These hormone preparations are effective for inducing shorter wean-to-estrus intervals and therefore will create a population of sows that will be late ovulators. If the breeding SOP calls for insemination at estrus detection and 24 hours later, then many of these sows will have intervals from last insemination to ovulation of >24 hours (Table 1), which may reduce fertility. Therefore, when estrus is hormonally induced, be prepared to modify breeding management to include a day-3 insemination.

Table 1. Effect of PG600 on wean-to-estrus (WEI) and estrus-to-ovulation (EOI) intervals.

	Control		PG600	
WEI	No. sows	EOI	No. sows	EOI
<4 days	4	45.0	20	57.6
4 days	13	46.9	35	47.3
5-6 days	34	39.3	13	32.0

Knox et. al., 2001

Estrus Synchronisation

The feeding of Regumate is an effective means of controlling estrus in gilts and sows (eg. Foxcroft et. al., 1998). Ideally, the animals should be individually fed so that they consume at least 15 mg/d (but preferably 20 mg/d). While there is likely no problem with overdosing (except economic), underdosing Regumate (<13 mg/d) has been shown to be associated with cystic follicles in gilts (Davis et. al., 1979; Kraeling et. al., 1981). However, if fed appropriately expect 85 to 95% of sows to exhibit estrus on days 4 to 8 after last feeding.

Note that the first Regumate feeding must be on the day of weaning, **not** the day after weaning. Feeding of Regumate for 7-days from weaning improved litter size of primiparous sows (Kirkwood et. al., 1986). Presumably, the feeding of Regumate captured the effect of skip-a-heat breeding but with fewer non-productive sow days (Table 2). Further, early

weaning is associated with reduced sow fertility but, when 12-day weaned sows were fed Regumate to delay estrus for an additional 12 days, fertility was improved (Table 3).

Table 2. Effect of 10-d of Regumate or skip-a-heat breeding on fertility of primiparous sows.

	Control	Ship-a-heat	Regumate
Farrowing rate, %	74.8	87.2	89.5
Next litter size	8.7	11.2	10.2

Morrow et. al., 1989

Table 3. Effect of a Regumate on fertility of early weaned sows.

	12-d, Regumate	12-d, control	24-d, control
	6.2	7.3	5.6
Interval to estrus, d			
Estrus by 7-d, %	97	64	87
No. corpora lutea	16.9	15.4	14.9
Embryo survival, %	77	68	68
No. embryos	13.0	10.5	10.1

Koutsotheodorus et. al., 1998

The duration of Regumate feeding does not appear to be critical. Feeding for 7-days has the advantage of simply shifting sows from one breeding week to the next. However, there is some evidence that sows will benefit from feeding Regumate for as little 3-days from weaning (Table 4).

Table 4. Effect of short-term feeding of Regumate on fertility of primiparous sows.

	Control	Regumate 0-3 days	Regumate 2-7 days
No. sows[1]	201	202	207
Farrowing rate, %[1]	76.1	82.2	71.5
Litter size[1]	9.8	10.1	10.4
No. corpora lutea[2]	17.2	17.9	16.6
Ovaries: only CL[2]	60	78	46
4-cell embryos, %[2]	61	97	67

[1]Forgerity et. al., 1995; [2]Martinat-Botte et. al., 1995

BREEDING MANAGEMENT

The basic principles of artificial insemination are simple; deposit enough viable sperm in the right place at the right time, and keep it clean. Using current insemination technology, 3×10^9 sperm are deposited in the cervix. This large number is necessary because most of the sperm will either be lost due to back-flow of semen, as well as entrapment and death in the cervix and uterus (Steverink et. al., 1998). When fewer sperm were deposited and semen backflow

was considered excessive during the insemination, sow fertility was reduced. If backflow is excessive, insufficient sperm will remain in the sow, fertilization rate will be compromised, and an increased regular return rate will be observed.

In reality, it is not the number of sperm deposited in the cervix or uterus that ultimately controls fertility, it is the number of sperm in the oviduct at the time of ovulation that is important. The proportion of inseminated sperm that actually get to the oviduct is variable, but <2% is a reasonable figure. The sperm in the oviduct enter an arrested state and constitute the sperm reservoir potentially available to fertilise ova, being released in the peri-ovulatory period. The number of functional sperm available for fertilisation will impact sow fertility and depends on the number originally entering the sperm reservoir and the interval between sperm entry to the reservoir and their redistribution at the time ovulation; the latter being influenced by timing of insemination relative to ovulation. Taking the above into consideration, objectives for successful AI will include ensuring an adequate number of sperm reach the sperm reservoir, and depositing the sperm at an appropriate time relative to ovulation.

EFFECT OF TRANSCERVICAL INSEMINATION

It is known that progressively fewer sperm need to be inseminated the closer to the uterotubal junction that they are deposited. Recently, insemination catheters that allow semen deposition into the body of the uterus, or into the proximal uterine horn, have become available. When deposited near the uterotubal junction using either surgical (Krueger and Rath, 2000) or endoscopic techniques (Martinez et. al., 2001a) extremely low numbers of sperm (10×10^6) are required. At this time these strategies would only be justified if dealing with semen of extremely high genetic value, or for sex pre-selected semen. Very recently, a new catheter has been designed that allows entry into a uterine horn to within 25 cm of the uterotubal junction (deep intrauterine insemination). Acceptable fertility was seen with insemination of 50 to 150 $\times 10^6$ sperm (Martinez et. al., 2001b; Roca et. al., 2003). This catheter remains to be commercially exploited but several companies have developed other AI catheters that are capable of being passed via manual manipulation through the cervix of the sow to allow deposition of the semen dose into the uterine body (transcervical or uterine insemination). These latter catheters are composed of a regular cervical catheter and a longer, smaller diameter, flexible inner catheter that is advanced through the cervix to the uterine body. When used, the cervical catheter should be inserted and left for a couple of minutes to allow the cervix to relax before advancing the inner catheter. As a viable option, this technique does allow sperm numbers to be reduced to 1×10^9 per insemination dose (Watson and Behan, 2002). Field trials have confirmed that farrowing rates and litter sizes statistically comparable to standard AI can be maintained with reduced sperm numbers using this technique (Table 5), although there is occasionally some suggestion of a reduction in litter size. It is likely that the timing of insemination relative to ovulation becomes progressively more important as the number of sperm deposited is reduced (Rozeboom et. al., 2004).

Timing of Insemination

It is accepted that sows having a short wean-to-estrus interval will tend to exhibit a longer duration of estrus and conversely, sows having a long wean-to-estrus interval will tend to have a short duration of estrus. Further, ovulation is believed to occur at about 70% through estrus, independent of the duration of estrus. The effect of this is that sows having a short wean-to-estrus interval (eg. 4 days) will tend to be late ovulators while sows having a long (eg. >5 days) wean-to-estrus interval will tend to be early ovulators (Table 6).

Table 5. Effect of sperm dose and site of deposition on sow fertility.

Site of deposition	Sperm dose ($x10^9$)	Farrowing rate, %	Litter size
Cervix	1	65.8	10.3
	2	91.8	12.6
	3	91.1	12.5
Uterine body	1	86.9	12.1
	2	92.5	12.3
	3	90.5	12.3

Watson and Behan 2002.

Table 6. Effect of wean-to-estrus interval (WEI) on estrus-to-ovulation interval.

Interval to ovulation	4-d WEI	5-d WEI	6-d WEI
0-24 h	5%	16%	45%
24-32 h	19%	36%	17%
32-40 h	34%	25%	18%
>40 h	42%	23%	9%

Kemp and Soede, 1996.

Sow fertility following AI depends on the time of insemination relative to ovulation (Kemp and Soede, 1996). To maximise fertility, deposition of fresh-extended semen into the sow should occur during the 24-hours before ovulation. However, if the semen is relatively old, or the number of sperm inseminated is relatively low, then the high fertility window for insemination may be only 12 hours (Waberski et. al., 1994).

The most common protocol for the induction of estrus in weaned sows is the injection of 500 to 750 IU of eCG (e.g. Pregnecol) or a combination of 400 IU eCG and 200 IU of hCG (PG600). There is a wealth of literature demonstrating the efficacy of this approach for induction of a fertile estrus after weaning but while efficacious for induction of estrus, injection of eCG or PG600 will not provide adequate synchronization of ovulation. Further, by inducing an earlier onset of estrus with either eCG or PG600, the EOI may increase, making the prediction of time of ovulation even more difficult. However, because gonadotropin treatment results in a sow population having longer estrus-ovulation intervals, this knowledge can be used in a protocol of induced ovulation to allow a more precise timing of insemination relative to ovulation.

It is known that ovulation typically occurs at about 42 hours after hCG injection. When ovulation is induced using porcine luteinizing hormone (pLH), the interval from injection to ovulation is shorter, at 36 to 38 hours (Cassar et. al., 2005). Therefore, if sows are expected to ovulate at >36 hours after estrus detection, induction of ovulation using pLH (Lutropin) will provide for a relatively predictable time of ovulation. Since the target is to inseminate sows during the 24-hour period before ovulation, if time of ovulation can be accurately predicted, then breeding management for optimal sow fertility will be relatively simple. Indeed, when time of ovulation can be accurately predicted, a single insemination resulted in sow fertility comparable to that following two inseminations (Table 7).

Table 7. Sow fertility to single or double insemination at an estrus induced by eCG with or without induction of ovulation by pLH.

Variable	Control	eCG	eCG+LH	eCG+LH*
No. sows	119	103	103	102
Farrowing rate, %	68.7	69.0	84.2[c]	86.1[c]
Litter size	11.1 $\pm$ 2.6	10.7 $\pm$ 3.2	10.3 $\pm$ 3.1	10.6 $\pm$ 3.5

eCG+LH*, sows received single insemination 40 hours after LH injection

CONCLUSIONS

The future of artificial insemination of swine will involve a single insemination of fewer sperm. To achieve this, some measure of control of time of ovulation will be used to permit improved timing of insemination. In association with transcervical insemination, improved timing relative to ovulation may facilitate the commercial uptake of insemination of frozen-thawed sperm and, potentially, sex-sorted sperm.

LITERATURE CITED

Cassar, G., R.N. Kirkwood, K. Bennett-Steward, and R.M. Friendship. 2005. Effect of single or double insemination on fertility of sows bred at an induced estrus and ovulation. J. Swine Health Prod. 13:254-258.

Davis, D.L., J.W. Knight, D.B. Killian, and B.N. Day. 1979. Control of estrus in gilts with a progestogen. J. Anim. Sci. 49:1506-1509.

Forgerity, Y., F. Martinat-Botte, F. Bariteau, H. Corbe, M. Plat, C. Macar, P. Poirier, P. Nolibois, and M. Terqui. 1995. Utilisation d'un progestagene (regumate) au moment du tarissemente de la primipare. 1. Amelioration de la fertilite et de la productivite après un traitement progestif court. J. Rech. Porc. En France 27:45-50.

Foxcroft, G.R., F.X. Aherne, and R.N. Kirkwood. 1998. Natural and hormonal synchronization of puberty, estrus and farrowing. Proc. V. Int. Symp. Swine Reprod. and AI, Mexico 1998.

Kemp, B. and N.M. Soede. 1996. Relationship of weaning-to-estrus interval to timing of ovulation and fertilization in sows. J. Anim. Sci. 74:944-949.

Kirkwood, R.N. 1999. Pharmacological intervention in swine reproduction. Swine Health Prod. 7:29-35.

Kirkwood, R.N., W.C. Smith, and K.R. Lapwood. 1986. Influence of oral administration of allyl trenbolone on subsequent litter size of primiparous sows. N.Z. J. Exp. Agric. 14:477-480.

Knox, R.V., S.L. Rodriguez-Zas, G.M. Miller, K.L. Willenburg, and J.A. Robb. 2001. Administration of P.G.600 to sows at weaning and time of ovulation as determined by transrectal ultrasound. J. Anim. Sci. 79:796-802.

Koutsotheodoros, K., P.E. Hughes, R.A. Parr, F.R. Dunshea, R.C. Fry, and J.E. Tilton. 1998. The effects of post weaning progestagen treatment (Regumate) of early weaned primiparous sows on subsequent reproductive performance. Anim. Reprod. Sci. 52:71-79.

Kraeling, R.R., P.J. Dziuk, V.G. Pursel, G.B. Rampacek, and S.K. Webel. 1981. Synchronization of estrus in swine with allyl trenbolone (RU-2267). J. Anim. Sci. 52:831-835.

Krueger, C. and D. Rath. 2000. Intrauterine insemination in sows with reduced sperm number. Reprod. Fertil. Dev. 12:113-117.

Martinat-Botte, F., Y. Forgerity, J. Bussiere, M.C. Maurel, M. Plat, C. Macar, P. Poirier, P. Nolibois, and M. Terqui. 1995. Utilisation d'un progestagene (regumate) au moment du tarissemente de la primipare. 2. Mecanismes physiologiques. J. Rech. Porc. En France 27:51-56.

Martinez, E.A., J.M. Vazquez, J. Roca, X. Lucas, M.A. Gil, I. Parrilla, J.L. Vazquez, and B.N. Day. 2001a. Successful non-surgical deep intrauterine insemination with small numbers of spermatozoa in sows. Reproduction 122:289-296.

Martinez, E.A., J.M. Vazquez, J. Roca, X. Lucas, M.A. Gil, I. Parrilla, J.L. Vazquez. 2001b. Deep intrauterine insemination in sows with a low number of spermatozoa: A new and simple procedure. Theriogenology 55:248.

Morrow, W.E.M., A.D. Leman, N.B. Williamson, R. Moser, C. Pijoan. Improving parity-two litter size in swine. J. Anim. Sci. 1989; 67: 1707-1713.

Roca, J., G. Carvajal, X. Lucas, J.M. Vazquez, and E.A. Martinez. 2003. Fertility of weaned sows after deep intrauterine insemination with a reduced number of frozen-thawed spermatozoa. Theriogenology 60:77-87.

Rozeboom, K.J., D.L. Reicks, and M.E. Wilson. 2004. The reproductive performance and factors affecting on-farm application of low-dose intrauterine deposit of semen in sows. J. Anim Sci. 82:2164-2168.

Rozeboom, K.J., M.H.T. Troedsson, G.C. Shurson, J.D. Hawton, and B.G. Crabo. 1997. Late estrus or metestrus insemination after estual inseminations decreases farrowing rate and litter size in swine. J. Anim. Sci. 75:2323-2327.

Steverink, D.W.B., N.M. Soede, E.G. Bouwman, and B. Kemp. 1998. Semen backflow after insemination and its effects on fertilisation in sows. Anim. Reprod. Sci. 54:109-119.

Steverink, D.W.B., N.M. Soede, G.J.R. Groenland, F.W. van Schie, and B. Kemp. 1999. Duration of oestrus in relation to reproduction results in pigs on commercial farms. J. Anim. Sci. 77:801-809.

Tarocco, C. and R.N. Kirkwood. 2001. The effect of estrus duration and number of artificial inseminations on fertility of gilts and multiparous sows having a four-day wean-to-estrus interval. J. Swine Health Prod. 9:117-120.

Waberski, D., K.F. Weitze, C. Lietmann, W. Lubbert zur Lage, F.P. Bortolozzo, T. Willmen, and R. Petzoldt. 1994. The initial fertilizing capacity of longterm-stored liquid boar semen following pre- and postovulatory insemination. Theriogenology 41:1367-1377.

Watson, P.F. and J.R. Behan. 2002. Intrauterine insemination of sows with reduced sperm numbers: results of a commercially based field trial. Theriogenology 57:1683-1693.

Wilson, M.R. and E.D. Dewey. 1993. The association between weaning-to-estrus interval and sow efficiency. Swine Health Prod. 1:10-15.