What is Early Pregnancy Diagnosis Worth?

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Introduction

Early detection of inseminated cows that are found open at pregnancy diagnosis provides an opportunity to take measures to quickly re-inseminate these cows. When the time to re-insemination is reduced, the reproductive performance of the dairy herd should be improved (Oltenacu et al., 1990). Scheduled pregnancy diagnosis remains a key component of reproductive herd health programs aimed at improving reproductive performance (Thompson et al., 1995).

The most popular methods to diagnose weather cows are pregnant or open (if cows are not seen in estrus) are rectal palpation and ultrasonography. Pregnancy diagnosis by rectal palpation is the most frequently performed procedure (Rosenbaum and Warnick, 2004), but the use of ultrasonography is growing (Fricke, 2002). A survey of US veterinarians resulted in 522 responses (Rosenbaum and Warnick, 2004). Four hundred and one (77%) veterinarians diagnosed inseminated cows solely by rectal palpation, while 116 veterinarians (22%) also used ultrasound. Five veterinarians (1%) only used ultrasound.

The economics benefits of pregnancy diagnosis depend on several factors such as the time after insemination when the diagnosis is performed, the accuracy of the diagnosis, its effect on embryonic loss, the efficiency of estrus detection, and the measures taken when cows are found to be open. Among the more commonly taken measures when cows are found open at pregnancy diagnosis are:

- Treatment with prostaglandin. This causes a functional corpus luteum to regress, which results in a new ovulation and estrus typically around 3 or 4 days later. This measure is quite common (Heuwieser et al., 1997).
- Application of a pressure sensitive mounting device to improve estrus detection efficiency in open cows (Oltenacu et al., 1990).
- Start of a timed-AI program such as Ovsynch (day 0 GnRH, day 7 prostaglandin, day 9 GnRH, day 10 timed AI).

Earlier pregnancy diagnosis decreases the time to re-insemination of cows found open which reduces expected days open for those cows. Pregnancy diagnosis can be rapidly and accurately diagnosed with ultrasound at 26 days after insemination under most on-farm conditions (Filteau and DesCôteau, 1998). This is at least a week earlier than with rectal palpation. In the survey of Rosenbaum and Warnick (2004), median

days since last insemination to pregnancy diagnosis were 27 days for ultrasound and 34 days for palpation.

However, earlier pregnancy diagnosis using ultrasound may come at a cost. A veterinary-grade ultrasound machine equipped with one rectal transducer can be purchased for $8000 to $16,000 (Fricke, 2002). To pay for the machine, the cost per pregnancy diagnosis is typically higher. In the survey of Rosenbaum and Warnick (2004), median charge per pregnancy diagnosis, not including call fees, was $3 for palpation and $4.75 for ultrasound. For veterinarians that charged by the hour, the cost per pregnancy diagnosis was between $1.50 to $3.00 for palpation and between $2.40 and $4.50 for ultrasound.

Secondly, aside of the method that is used, earlier pregnancy diagnosis may decrease the accuracy of the diagnosis, which results in more wrong conclusions. Decreased accuracy implies that more cows that are truly open are diagnosed to be pregnant (a false positive) and more cows that are truly pregnant are diagnosed to be open (a false negative). Both errors of diagnosis are costly: a false positive diagnosis results in not timely re-inseminating the open cow, whereas a false negative diagnosis might lead abortion when prostaglandin is administered.

It is therefore conceivable that earlier pregnancy diagnosis is not necessarily more profitable if all effects are properly taken into account. In this paper we first look at the economic value of earlier pregnancy diagnosis using ultrasound. We also present some estimates of the cost of reduced accuracy.

Economics of Early Pregnancy Diagnosis

Although pregnancy diagnosis by rectal palpation or ultrasound is often done, we do not know of any comprehensive detailed studies that looked at the economic value of earlier diagnosis. DesCôteaux and Fetrow (1998) constructed a simple model (in a spreadsheet) to study the economics of early pregnancy diagnosis using ultrasound compared to pregnancy diagnosis by another means. Key assumptions in their calculations were the following:

- Pregnancy diagnoses were done by veterinarians visiting the farm every 7 days, 14 days, or 30 days.
- Cows were presented for pregnancy diagnosis by ultrasound between 27 and 32 days after insemination. Ultrasound was not used on cows that were outside this 6-day window at the day of the visit.
- This means that the proportion of open cows that can be examined weekly, bi-weekly, and every 30 days is respectively 85.7% (6/7), 42.8% (6/14), and 20% (6/30).
- 70% of the cows were found pregnant at the time of pregnancy diagnosis. This means that on average 1/70% = 1.4 pregnancy diagnoses per cow per year are needed.

- The time saved per cow found open at pregnancy diagnosis using ultrasound is the time to the next visit: 7, 14, or 30 days.
- Cost of a day open is $4.00.

The calculations are shown in Table 1 for a herd of 1000 cows. With weekly visits, 86% of the cows have their days open shortened by 7 days. At a cost of $4 per day open, this comes down to $28 per cow found open due to diagnosis by ultrasound. The value to the producer per exam is $8.40. When ultrasound is used bi-weekly or every 30 days, fewer open cows are within 27 to 32 days after insemination, but their days open saved would be much longer. The total dollars saved due to the ultrasound is therefore the same ($10,080). But because fewer cows are examined, the value per cow and per exam is higher. Note that these calculations do not include the cost of the pregnancy diagnosis.

Table 1. Evaluation of the economic value of early pregnancy diagnosis by ultrasound between 27 and 32 days post insemination compared to the diagnosis of those inseminations a the following visit. (Adapted from DesCôteaux and Fetrow, 1998).

1000	1000	1000	herd size
7	14	30	days between veterinarian visits
52.1	26.1	12.2	visits per year
1.4	1.4	1.4	pregnancy diagnosis per open cow per year
1400	1400	1400	number of pregnancy diagnoses per year
86%	43%	20%	%cows diagnosed by ultrasound (6 days / visit interval)
1200	600	280	number of pregnancy diagnoses by ultrasound per year
30%	30%	30%	%cows found open at ultrasound diagnosis (100 - 70% pregnant)
360	180	84	number of open cows influenced by ultrasound (cows found open)
2520	2520	2520	total days open saved (compared to next visit)
$ 10,080	$ 10,080	$ 10,080	total dollars saved (cost per day open $4)
			break even cost of pregnancy diagnosis by ultrasound:
$ 28.00	$ 56.00	$ 120.00	per cow found open
$ 8.40	$ 16.80	$ 36.00	per exam

DesCôteaux and Fetrow (1998) assumed that an ultrasound machine costs $15,000 and $1600 is needed annually for maintenance, insurance and interest. With the value of the early pregnancy diagnosis as a result of the use of the ultrasound in mind, we calculated the herd size that is needed to pay-off the ownership of the ultrasound machine in 2, 3, or 4 years at 903, 655, and 531 cows respectively (Table 2).

Table 2. Number of cows that are necessary to pay back a $15,000 ultrasound machine plus annual additional cost of $1600 in 2, 3, or 4 years.

	$ 8.40	$ 16.80	$ 36.00	value of pregnancy diagnosis by ultrasound
Yrs				
2	$ 18,200	$ 18,200	$ 18,200	cost of ultrasound machine
3	$ 19,800	$ 19,800	$ 19,800	cost of ultrasound machine
4	$ 21,400	$ 21,400	$ 21,400	cost of ultrasound machine
2	2167	1083	506	total pregnancy diagnoses needed to pay back ultrasound machine
3	2357	1179	550	total pregnancy diagnoses needed to pay back ultrasound machine
4	2548	1274	594	total pregnancy diagnoses needed to pay back ultrasound machine
2	903	903	903	herd size needed to pay back ultrasound
3	655	655	655	herd size needed to pay back ultrasound
4	531	531	531	herd size needed to pay back ultrasound

Sensitivity Analysis

The survey of Rosenbaum and Warnick (2004) showed a reduction of 7 days open when ultrasound was used. Therefore, the following sensitivity analyses assume a 7 day advantage only.

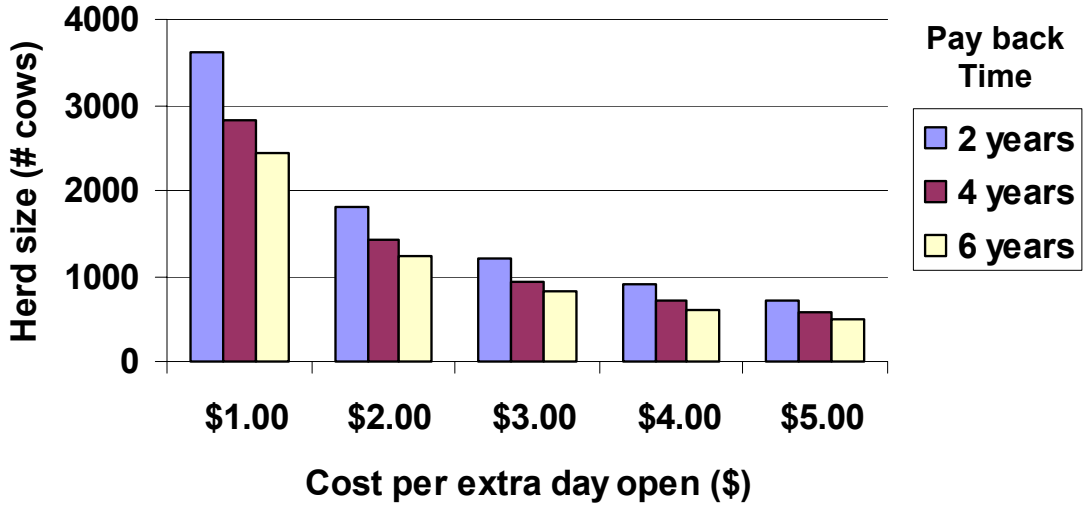

Figure 1. Herd size vs. cost per day open to pay back the ultrasound machine in 2, 4, or 6 years. Default assumptions as in Table 1.

The cost of an extra day open depends largely on how far in lactation cows found open will be re-inseminated and the average days open (de Vries et al., 2004). Fewer opportunities to get re-inseminated and longer days open increase the cost per extra

day open. Typical costs vary approximately from $1 to $5 per extra day open. Figure 1 shows that when the cost per extra day open is high, the ultrasound machine can be paid back in 2, 4, or 6 years in smaller herds.

One assumption in these calculations is that the cost of pregnancy diagnosis by ultrasound is only due to the cost of the ultrasound machine. There is no difference in labor cost assumed. Fricke (2002) reported that ultrasound is a rapid method for pregnancy diagnosis and experienced palpators adapt to ultrasound quickly. The speed at which ultrasound exams can be conducted depends on the efficiency of the operator and the availability and restraint of the cows, but can approach that of rectal palpation (Fricke, 2002). The use of the ultrasound machine is less demanding than rectal palpation. Therefore even very large herds would only need 1 ultrasound machine.

Figure 2 shows the time needed to pay back the investment in the ultrasound machine for various purchase costs of the ultrasound machine and herd sizes. Assumed is $21 savings per cow if pregnancy is diagnosed by ultrasound (7 days x $3 cost per extra day open). Average time to pay back the investment in the ultrasound machine is less than 7 years in all cases. Obviously, cheaper ultrasound machines and larger herds result in quicker pay back time.

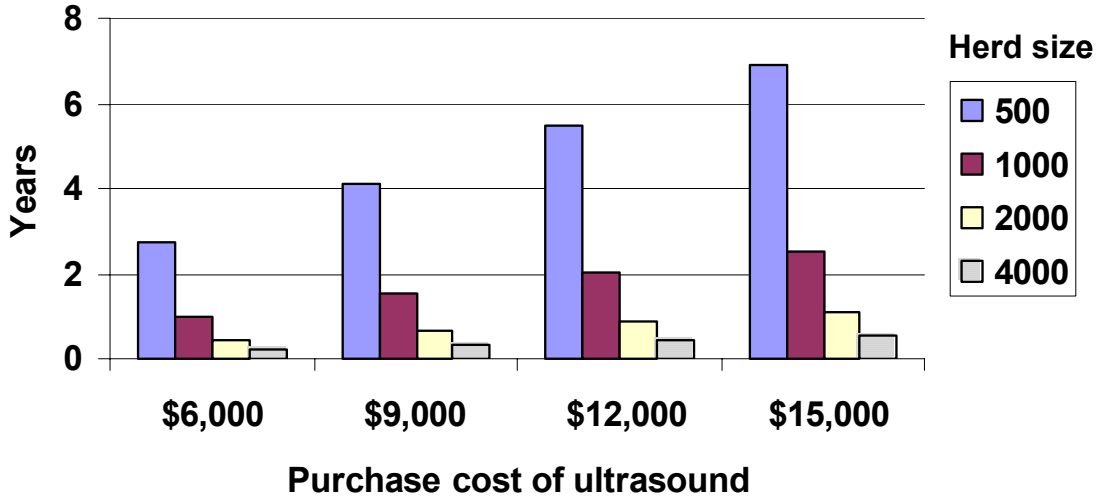

Figure 2. Time needed to pay back investment in ultrasound machine by herd size. Assumed is a $3 cost per extra day open and 7 reduced days open due to pregnancy diagnosis by ultrasound.

The time to pay back the ultrasound machine increases when the savings due to earlier pregnancy diagnosis are reduced. Figure 3 shows the pay back time when the costs per day open are $1.00, $2.00, and $3.00 respectively (savings of $7, $14, and $21 per open cow).

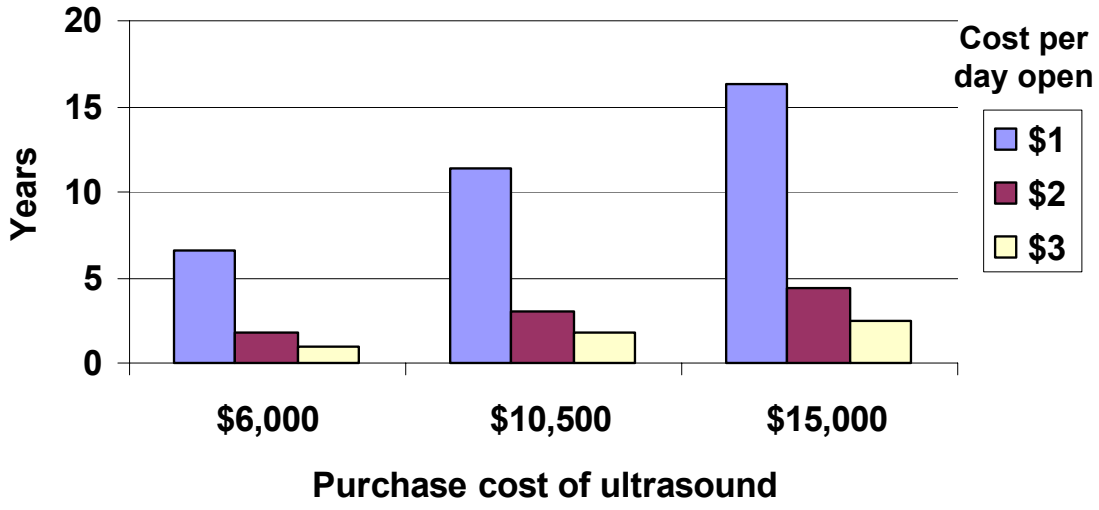

Figure 3. Time needed to pay back the investment in an ultrasound machine by cost of an additional day open for a 1000 cow herd.

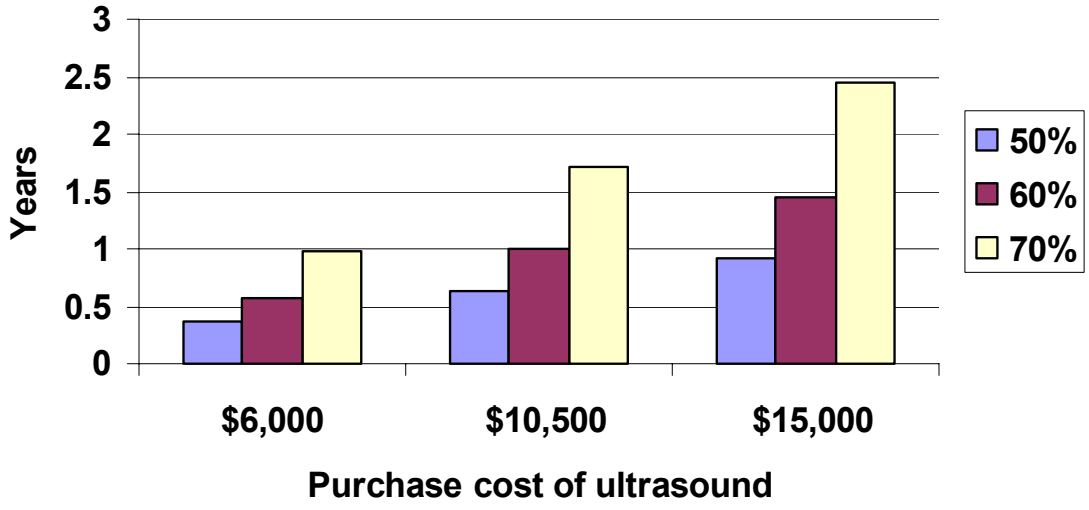

Figure 4. Time needed to pay back investment in ultrasound machine by % pregnant at pregnancy diagnosis for a 1000 cow herd. Cost per extra day open is $3.00.

In herds with poor reproductive performance, the percentage of cows found pregnant at the time of pregnancy diagnosis will be reduced. This may be both a result of a lower conception rate and lower estrus detection rate in cows that return to estrus before the pregnancy diagnosis is scheduled. More cows will be open and benefit from

early pregnancy diagnosis. Thus the value of ultrasound for early pregnancy diagnosis increases, which results in a decrease in the time needed to pay back the investment in the ultrasound machine (Figure 4).

The break-even cost per pregnancy diagnosis in Table 1 is $8.40 with weekly visits. This is the maximum a dairy producer should pay for one ultrasound exam. This value increases when reproductive performance is low, resulting in fewer cows pregnant at pregnancy diagnosis, and when the cost per day open increases (Figure 5). Herds with low reproductive performance have a high average days open and consequently a higher cost per extra day open. The results in Figure 5 may be compared with the median charge of $4.75 for ultrasound found in the survey of Rosenbaum and Warnick (2004).

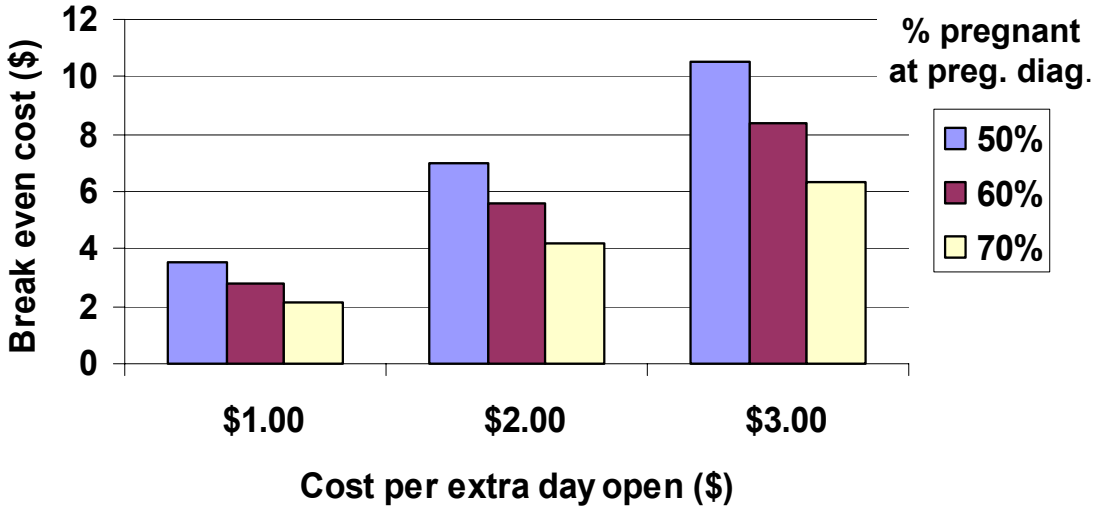

Figure 5. Break-even cost per pregnancy diagnosis when 50%, 60%, or 70% of the cows are found pregnant at the time of pregnancy diagnosis.

Refinements of the Estimates of the Value of Early Pregnancy Diagnosis

The model by DesCôteaux and Fetrow (1998) is relatively easy to understand and the sensitivity analyses are easy to perform. However, many of the assumptions are strong simplifications of the true dynamics in the herd when cows are presented earlier for pregnancy diagnosis. A comprehensive economic analysis of the sum of all effects is complex and not easily done. Consequently, the economics shown above with the simple model are only crude estimates of the value of early pregnancy diagnosis.

For example, the model assumes that earlier pregnancy diagnosis by a certain number of days results in the same number of days saved. Clearly, this depends on the measures taken after the exam and the efficiency of estrus detection. For example, if the pregnancy diagnosis does not result in all open cows being re-inseminated earlier then some of the advantage of early pregnancy diagnosis is lost.

Secondly, when pregnancy diagnosis is scheduled earlier, open cows will have had less time to show estrus and accordingly be re-inseminated based on estrus display. Although the average time to estrus of open cows is approximately 22 days after insemination, there is quite range and some cows will not show estrus until after day 27 (Figure 6). Therefore, more open cows will be presented to pregnancy diagnosis which adds costs of labor and, if used, prostaglandin to induce estrus.

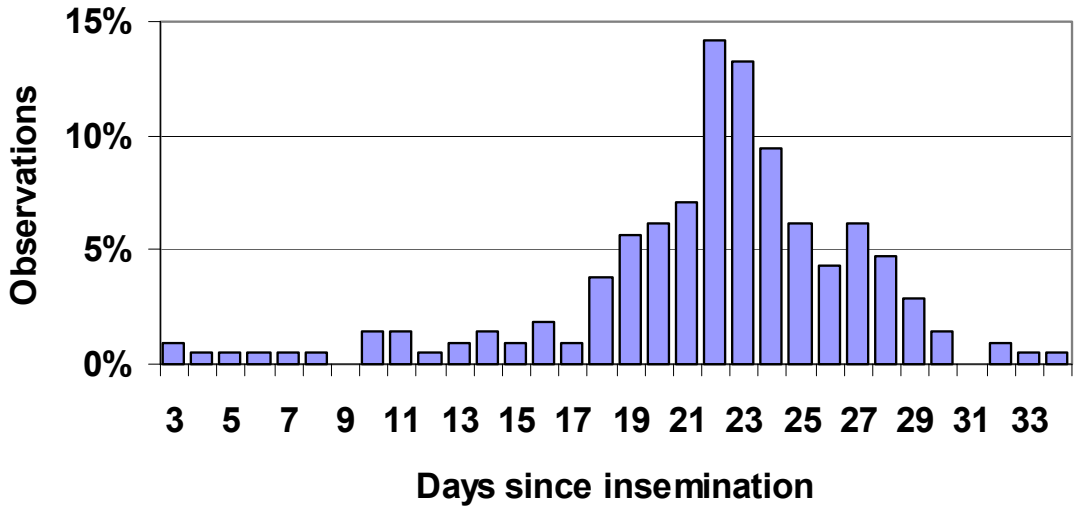

Figure 6. Distribution of cows detected in estrus before day 35 (Source: J.A. Bartolome, unpublished data)

Third, the true conception rate at insemination is approximately 76% in high producing dairy cows but due to embryonic and fetal mortality is reduced to not more than approximately 28% at calving (Santos et al., 2004). The risk of pregnancy loss is the highest early in gestation between days 2 and 42. Because the pregnancy diagnosis can be made earlier by ultrasound compared to palpation, the pregnancy loss after pregnancy diagnosis is higher than for rectal palpation. Of cows diagnosed pregnant at 28 days after insemination, 10 to 16% had lost their pregnancy by day 56 after conception (Fricke, 2002). Therefore it is suggested that cows diagnosed pregnant by ultrasound are again diagnosed around day 60 after insemination (Fricke, 2002). This results in additional cost.

The calculations above also do not include the value of additional practical applications of ultrasound beyond pregnancy diagnosis, such as identification of cows

carrying twins, detection of ovarian and uterine problems, and determination of fetal sex (Fricke, 2002). All these applications may improve reproductive efficiency on the dairy.

A fifth simplification of reality is that the model does not account for errors in pregnancy diagnosis. Accuracy is the degree to which a measurement (pregnancy diagnosis) represents the true value of the attribute being measured (cow being truly open or pregnant). Accuracy can be expressed through sensitivity and specificity, and through positive and negative predictive values (Table 3).

Table 3. Calculation of sensitivity, specificity, predictive value positive and predictive value negative (100 cows diagnosed).

		Diagnosis		
		Open	Pregnant	
True status of cows	Open	A = 40	B = 5	A+B = 45
	Pregnant	C = 1	D = 54	C+D = 55
		A+C = 41	B+D = 59	A+B+C+D = 100

Specificity = A/(A+B) = 40/45 = 88.9%
Sensitivity = D/(C+D) = 54/55 = 98.2%
Predictive value negative = A/(A+C) = 40/41 = 97.6%
Predictive value positive = D/(B+D) = 54/59= 91.5%

Specificity is the probability that a cow is diagnosed to be open, given that the cow is truly open: A/(A+B) = 40/45 = 88.9%. This is also known as the true negative rate. Sensitivity is the probability that the diagnosis is pregnant, given that cow is truly pregnant: D/(C+D) = 54/55 = 98.2%. This is also known as the true positive rate. The predictive value negative is the probability that the cow is truly open, if the diagnosis is open: A/(A+C) = 40/41 = 97.6%. Predictive value positive is the probability that the cow is truly pregnant if the diagnosis is pregnant: D/(B+D) = 54/59 = 91.5%.

It is important that cows that are diagnosed open are truly open (Fricke, 2002). Otherwise, cows that are truly pregnant but falsely assumed to be open would abort if prostaglandin is given, which is a common practice. The cost of the abortion is higher than the opportunity cost due to assuming that a cow is pregnant while in reality she is open. Therefore, the predictive value negative and the sensitivity should be near 100%.

The accuracy of rectal palpation varies widely and depends on the skill of the practitioner and the time post insemination (Oltenacu et al., 1990). Kelton et al. (1991) reported an average sensitivity of 82.6% and average specificity of only 52.6% for 9 clinicians. Typically, better accuracies are reported. When ultrasound is used, pregnancy diagnosis can be accurately diagnosed at 26 days after insemination (Filteau and DesCôteau, 1998). Sensitivity and specificity using ultrasound were 97.7 and 87.7% between days 26 and 33 after insemination (Pieterse et al., 1990). In the survey of Rosenbaum and Warnick (2004), median days since last insemination when the

veterinarians were comfortable to administer prostaglandin to cows found open was 35 days for palpation and 28 days for ultrasound.

Oltenacu et al. (1990) found that the value of increases in sensitivity and specificity from 95% to 97.5% was worth $0.10 to $4.70 per cow. We are currently developing a model that includes many of the refinements discussed above to better estimate of the value of early pregnancy diagnosis in various reproductive programs. Preliminary results indicate that a reduction in sensitivity and specificity from 98% to 92% reduces net revenue by $10 to $20 per cow per year.

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Notes