Economic Concepts Regarding Early Pregnancy Testing

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Abstract

Early pregnancy testing plays a key role in determining the reproductive success of a dairy herd and thus its economic efficiency. Fundamentally, early pregnancy determination defines how quickly cows which fail to conceive to a breeding are identified and re-inseminated. Due to the relatively low conception rates, this technology impacts the majority of cows within a herd several times within a lactation cycle. The sensitivity and specificity of tests (attributes of test accuracy) will vary with tests as well as when they are applied post breeding. Pregnancy testing must be coordinated with the herd breeding program so that cows testing open are bred on a timely basis to ensure maximizing the economic value of testing. The value of testing is highly dependent on how soon successful rebreeding can occur. Embryonic death occurs relatively early post breeding and thus can influence the economic attributes of early pregnancy determination. Understanding the underlying structure of the decision process can help in estimating the value of various components of the test in the field application.

Résumé

La détection précoce de la gestation joue un rôle clé quand il s'agit de déterminer le succès reproductif - et donc l'efficacité économique - d'un troupeau laitier. Fondamentalement, c'est de la précision de la détection précoce de la gestation que dépend la rapidité avec laquelle on peut identifier une vache qui n'a pas été fécondée, pour pouvoir la réinséminer aussitôt. Étant donné les taux de conception relativement peu élevés, cette technologie a un impact sur la majorité des vaches d'un troupeau, plusieurs fois au cours d'un cycle de lactation. La sensibilité et la spécificité d'un test (ses attributs de précision) varient selon le test et le moment de son exécution après l'insémination. La détection de la gestation doit bien s'intégrer dans le programme d'insémination, de manière à ce que les vaches qui se révèlent non fécondées soient réinséminées régulièrement et en temps opportun pour bien rentabiliser le test de détection. La valeur d'un test dépend beaucoup de la rapidité avec laquelle on peut réinséminer et féconder une vache avec succès. D'autre part, la mort embryonnaire survient relativement tôt après l'insémination et peut donc influencer les attributs économiques de la détection précoce de gestation. Comprendre ce qui sous-tend la décision peut aider à estimer la valeur des diverses composantes du test de détection de la gestation en situation réelle.

Introduction

Reproduction efficiency is a critical concern of the dairy producer and his consulting veterinarian, for it ultimately affects the economic viability of the dairy by affecting milk yield per day of life as well as the flow of animal replacements.[3] Over the years, veterinary involvement in dairy cattle reproduction has been broadened from finding cows with reproductive disorders to now include concerns regarding the overall herd reproductive program.[4] The overall herd reproductive program is an amalgamation of a number of technologies (reproductive technology cycle) that ultimately affect the rate at which cows conceive and thus calve. This cycle starts with transition cow management, followed by first insemination strategies, pregnancy determination strategies along with rebreeding programs, and ends with the management of animal culling.[1,7] This paper will look at how early pregnancy testing fits in the reproductive technology cycle and the underlying economic structure of factors influencing its value. A decision algorithm will be discussed to structure the problem economically and to allow sensitivity analysis of input parameters. Finally, the algorithm will be presented in a visual analytic format allowing the user to directly manipulate parameters of the model.

Basic Economics

In general, it is recognized that a cow conceiving as soon as possible after the voluntary waiting period (VWP) is more valuable than a cow conceiving later. The exact value is due to many factors including the shape of the lactation curve, the value of milk relative to feed, and the value and availability of a replacement animal to name a few. An index of this value is ascribed to the cost of a day open. This cost value is expected to increase with days-in-milk as the open cow extends her lactation and reduces milk yield, reduces the flow of replacements, and has increased risk of becoming a reproductive cull. Gronendaal *et al* estimated it to range in value from 50 cents to near $3.00 per day open depending on the lactation yield of the cow, day-in-milk, and if management was following an optimal culling policy.[7]

To ultimately control the level of days open, herd managers and veterinary consultants have used a combination of technologies to improve pregnancy rate (proportion of eligible cows conceiving every 21 days).[4] We refer to this combination of technologies as the reproductive technology cycle (RTC). The portfolio of technologies can be actively constructed to match the management structure and ensure a high degree of compliance, or as is more common, be cobbled together in a haphazard manner with little oversight (Figure 1). Inefficiencies can exist at any or all phases of the RTC and should be viewed as potential economic opportunities for the management team of the dairy operation.

The portfolio of technologies selected, as well as the degree of compliance, will determine the herd's aggregate pregnancy rate (PR) – that is, the average pregnancy risk per 21 days for the entire reproductive life cycle, from first breeding management up to and including the herd's culling strategy. The herd aggregate PR determines the distribution of future calving intervals (CI) for a herd, and thus the economic value. The CI distribution is skewed to the right (Figure 2), reflecting the degree and timing at which cows conceive and the length of time management will attempt to rebreed cows. The shape of the CI distribution is affected by the underlying reproductive technologies used. Given the curvilinear form of the lactation cycle, it is economically advantageous to manage for shorter calving intervals to increase the average milk yield/day of lactation as well as the flow of replacement animals.

Figure 2 shows how the various technologies directly affect the distribution of calving intervals. Transition cow management and first-service technology will determine the number of short calving intervals. Systematic breeding programs have evolved to manipulate the underlying timing of ovulation to ensure that timed artificial insemination will have a relative degree of success.[11] Pre-synchronization programs have evolved in recognition that the stage of the estrus cycle, at which a systematic program is initiated, is important in influencing the conception rate at time of AI.[5]

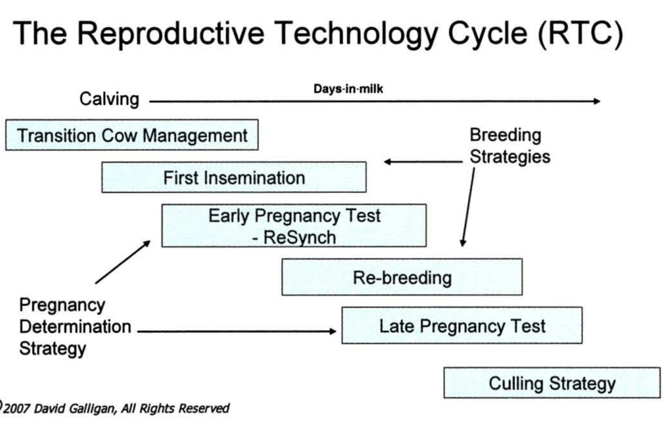

Figure 1. Components of the reproductive technology cycle for managing reproductive efficiency of the modern dairy cow.

Early pregnancy determination will affect how quickly non-pregnant cows are identified and rebred. The timing of pregnancy rechecks will determine how quickly cows that lose a pregnancy will be managed. Finally, the number of breeding attempts on a cow will depend on her value relative to the value of an immediate replacement,[1,3] and thus the degree of skewness for the distribution will be affected by the herd culling policy.

Early Pregnancy Determination

The determination of pregnancy has evolved over the years from crudely observing which cows ultimately re-calve, to observance of cows returning to estrus after breeding, to various diagnostic procedures (rectal exam, ultrasound, measurement of a metabolite indicative of pregnancy status).[8] Each of these approaches to pregnancy diagnosis differs in terms of the interval from breeding to diagnosis, as well as cost and management. Each test has common attributes of testing, such as sensitivity and specificity, to indicate their accuracy (Figure 3). Sensitivity is the probability of detecting pregnant cows from a population of truly pregnant cows (conception rate), while specificity is the probability of detecting open cows from a population of truly open cows (1-conception rate). Like other diagnostic tests, pregnancy testing follows Baysian principles where predictive values (positive and negative) are a function of the underlying prevalence of the condition of interest (pregnancy) as well as the attributes of the test (sensitivity, specificity). A nuance to the application in dairy reproduction is that a proportion of cows will experience early embryonic death, and thus the underlying prevalence (% cows pregnant) will be dependent on when the test is done relative to breeding. Furthermore, early pregnancy tests may vary in their ability to detect viable pregnancies depending on what is actually being measured as an index of pregnancy.

The value of any test is related to the subsequent decisions that management can make as a consequence of information from the test. Knowing that a cow is open earlier post-breeding can result in rebreeding sooner. This will reduce the accumulated days open on a proportion of cows, and thus has value. Cows which test pregnant can be scheduled for a recheck to ensure

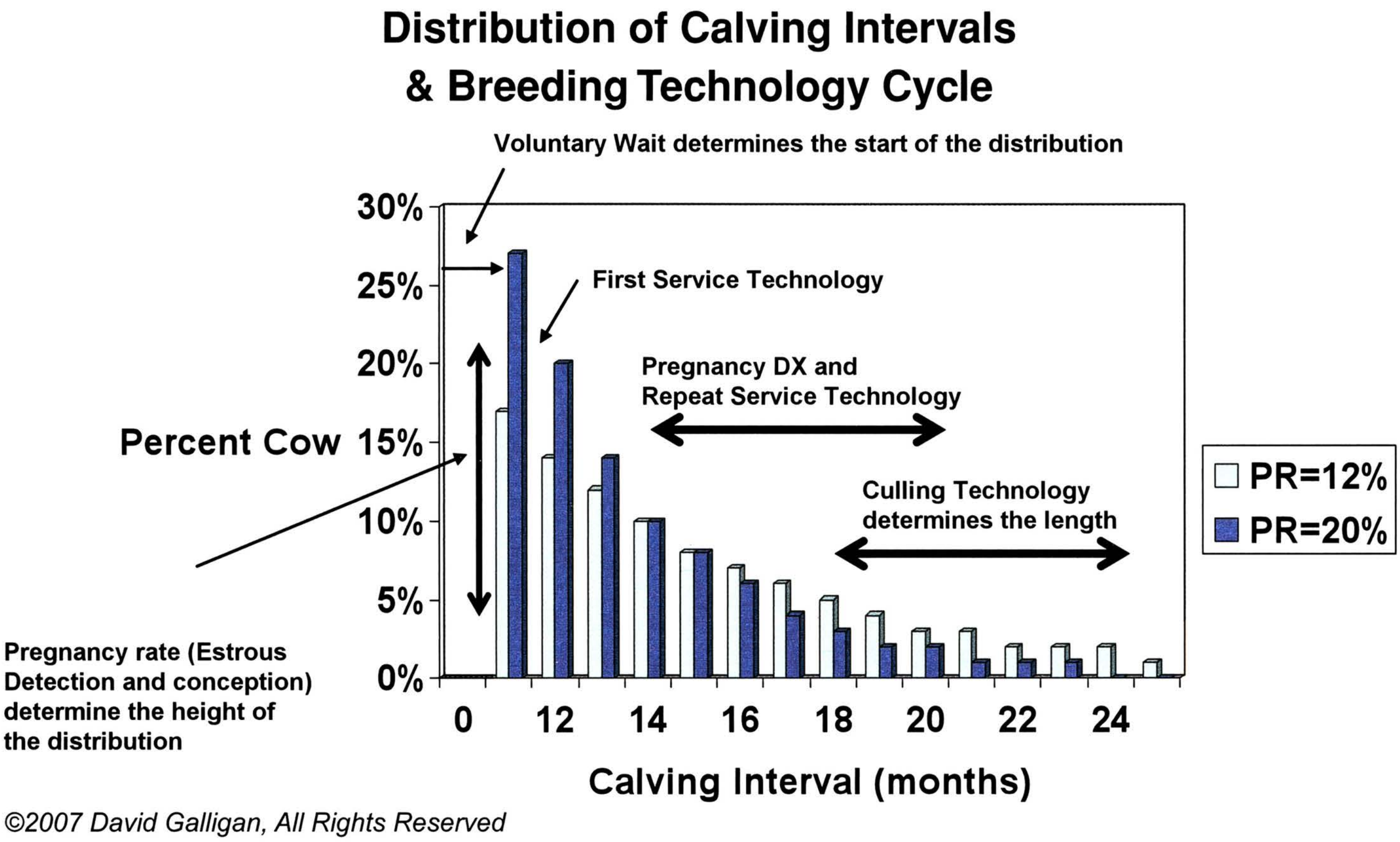

Figure 2. Pregnancy rates (PR) ultimately define the shape of the distribution of calving rates for a herd (PR = 12% and 20%).

the maintenance of pregnancy. Retesting of animals diagnosed pregnant is critical in finding animals that were either incorrectly diagnosed as pregnant or identifying animals that have lost their pregnancy due to early embryonic death.

Early embryonic death (EED) occurs after breeding in a proportion of cows, and typically diminishes with time post-breeding. Embryonic losses may be as high as 25 to 50% in the first 21 days post-insemination and is not easily observed. Pregnancy loss declines to 10 to 15% of pregnant cows between 28 to 42 days post-insemination, 5 to 10% of pregnant cows by 42 to 55 days post insemination, and 2% of pregnant cows between 55 to 100 days post insemination.[9] Our knowledge of the loss is dependent on when the initial post-breeding pregnancy test is done, as well as the time interval to the recheck. The rate of loss occurs independent of the test; however, our knowledge of its magnitude is dependent on when we do the test. A test done sooner will potentially declare a larger number of cows pregnant (depending on what is being measured and how it relates to a viable embryo), and embryonic death rates may then appear greater. This loss would have occurred anyway without the test, but we have knowledge of it as a consequence of earlier testing. A potential economic loss can occur if these false positive cows are allowed to accumulate additional days open before retesting and re-breeding occurs. Control of this potential loss can be done by timely retesting of all test-pregnant cows.

Frequencies

	Pregnant	Open
Test Pregnant	Sensitivity x Conception *A*	(1-Specificity) x (1-Conception) *B*
Test Open	(1- Sensitivity) x Conception *C*	Specificity x (1-Conception) *D*
	Conception	1-Conception

Figure 3. Calculation of frequencies based on test attributes (sensitivity, specificity) and underlying herd conception rate (at time of testing).

Value of Early Pregnancy Testing

Early pregnancy testing has its advantages and disadvantages, which must be evaluated economically to determine a strategy for use. The number of cows declared pregnant will be dependent on test sensitivity and underlying conception rate of the herd. The whole purpose of pregnancy testing is to detect open cows which can then be re-inseminated sooner than they would have without the test (cell d in Figure 3). The frequency of this scenario is dependent on the test specificity and the proportion of open cows (1-conception rate) at the time of the test (cell d in Figure 2). The economic value ascribed to this scenario can be estimated by the value given a day open times the number of days to earlier re-breeding. The actual cost per day open is influenced by the lactation stage (day-in-milk) of the cow when the test is being completed.[7] Timing of the pregnancy test must be coordinated with the subsequent re-breeding policy. For example, cows on an Ovsynch re-synchronization program can have blood samples taken for pregnancy diagnosis on the same day the initial gonadotropin-releasing hormone (GnRH) shot is given. Cows testing open go on to receive the complete synchronization program and subsequent re-breeding.

A test with low specificity has the potential to declare a lot of cows pregnant that are truly open (cell b in Figure 3). The magnitude of losses, in the form of accumulated days open, on these cows will be dependent on the how soon rechecks are done. A test with low sensitivity has the potential to diagnose pregnant cows as open (1-sensitivity) (cell c in Figure 3). The managerial response to these cows is to have them placed back into the breeding system, which will most likely result in a costly lost pregnancy. De Vries estimated the value of a new pregnancy averaged $278, while an abortion had an average value of $550.[2]

While the perfect test has a sensitivity and specificity of 100%, available tests should balance the trade-off between sensitivity and specificity and any misclassification errors. To evaluate these trade-offs, a pregnancy test information model was created which allows the user to vary input parameters reflective of herd conditions and test attributes.

Pregnancy Test Information Model

To look at the fundamental aspects of early pregnancy testing, a simple decision algorithm was developed based on one described by Pitcher and Galligan[10] for milk progesterone testing. This algorithm starts with the assumption that all cows have been bred and will be routinely checked for early pregnancy, and cows testing open are re-bred at the next appropriate breeding opportunity. All cows testing pregnant to the early pregnancy test will be retested for pregnancy at a future date (rechecks). All cows have the potential to conceive at the conception rate observed in the herd. When the early pregnancy test is used, all cows testing open are rebred sooner than they would have been. This is indicated by the earlier breeding days parameter in the model (example 10 days). Additional parameters in the model are identified in Table 1, as well as the base values used in the initial valuation.

Because of EED, the number of cows truly pregnant (conception rate) at the time of testing can vary as a function of days post-breeding. The model estimates the percent of EED at the time of testing based on EED curve of Vasconcelos.[9]

Depending on the attributes of the test, EEDs can either be diagnosed as pregnant (false positives) or open (true negatives). The user can designate what percent of the EEDs are assigned to false positive or true negative. For example, if a herd has an underlying estimated con-

Table 1. Basic parameters and range of values for sensitivity analysis.

	Base	Minimum	Maximum
Sensitivity	96%	90%	99%
Specificity	96%	90%	99%
Conception (herd average)	35%	15%	36%
Days open cost	$2.00	$1.50	$3.50
Earlier breeding days	10	7	14
Test cost	$2.50	$2.00	$3.00
Pregnancy value	$300	$250	$400
Extra breeding cost	$20	$15	$30
Retest pregnancy cost	$2.00	$1.00	$3.00
Retest day post-breeding	50	50	60
Old breeding day	45	45	55
%EED going to false positive	50%	0%	100%

ception of 30%, then the proportion of pregnant cows at day 28 can be estimated at 36.3% (ie, 6.3% will experience EEDs, 17% of pregnant cows at 28 days). For an economic analysis of the influence of EED on the value of early pregnancy diagnosis, 50% of these EED are allocated to false positives and the other 50% to true negatives (Table 1). This allocation can be varied to reflect the ability of the test to determine a viable embryo.

Truly pregnant cows, diagnosed as open and placed on a breeding program that would result in a loss of the current pregnancy, were assigned a value of -$300 (since the loss occurs relatively early in the breeding cycle).

At the base parameter levels in Table 1, the early pregnancy test was estimated to offer an economic net return of $1.70 per test dollar. To explore the sensitivity of this value to changes of parameters in the model, a tornado sensitivity analysis was done using BASE-COW.[6] Each parameter was varied over a range of possible values (Table 1) and the consequential impact on the value/test dollar was calculated (Figure 4).

The model was very sensitive to the cost associated with days open, with higher value associated with a higher cost per day open. Return per test dollar was also influenced by the test sensitivity (ability to detect pregnant cows as test pregnant). Sensitivity dominated specificity. Higher return per test dollar was predicted when conception rates are low, and thus there are more open cows to influence in terms of earlier re-breeding. The greater the value of earlier days to re-breeding was also influential, reflecting the greater opportunity to reduce accumulated days open on early bred cows. This emphasizes the need for pregnancy testing results to affect re-breeding management on a timely basis. The percent of EED to false positives, set at a base of 50%, was also influential on the return value. When 100% of the EEDs are assigned to a false-positive status, the

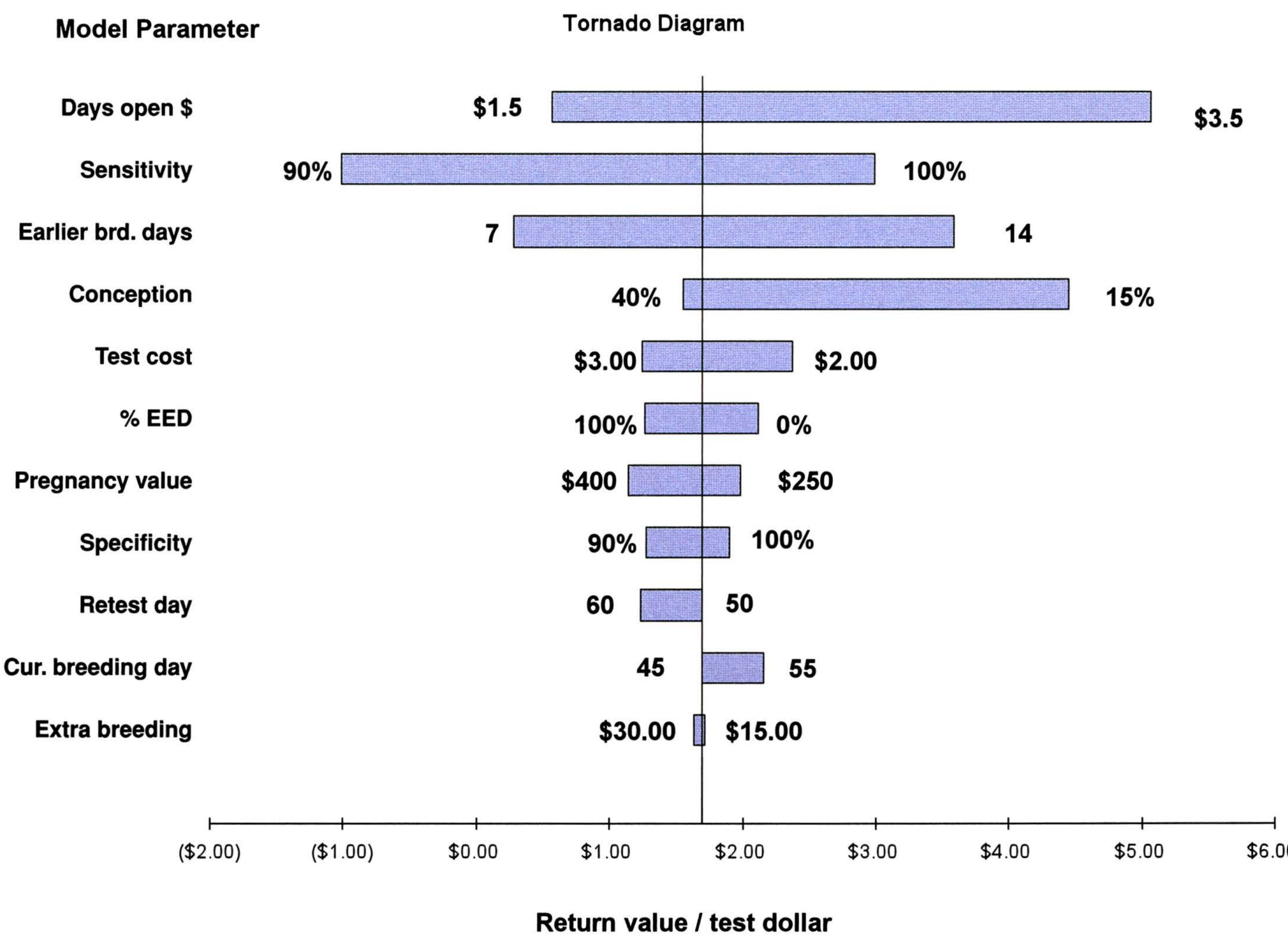

Figure 4. Tornado Graph for sensitivity analysis of parameters on the return value/test dollar.

return per test dollar decreases, due to this proportion of cows accumulating more days open till recheck and re-breeding.

Conclusions

The management of reproduction in the dairy cow is under continual evolution. A host of technologies are now used to control reproductive efficiency on the modern dairy herd. Early pregnancy diagnosis plays an important role in giving the producer a tool to ensure timely rebreeding of cows failing to conceive to a prior breeding. Pregnancy testing must be coordinated with the herd breeding program so that cows testing open are bred on a timely basis. When pregnancy testing is done relatively soon after breeding, there is the potential for detection of a high number of false positives (including cows that were pregnant and later are found open due to EED). This potential cost can be controlled by retesting to indentify open cows and timely re-breeding.

This model, which evaluates the frequency and cost of various test outcomes, suggests that under common field conditions, early pregnancy testing is a valuable option to be considered as part of the reproductive technology cycle.

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