EPIDEMIOLOGIC APPROACH TO SOLVING BEEF HERD PRODUCTION OR DISEASE PROBLEMS*

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Diagnosis of production or disease problems on a herd basis is often more challenging than diagnosis of individual animal disease. In herd diagnostics, the influence of environmental factors and interactions between individuals must be considered in addition to individual animals. While the identification of etiologic factors is the definitive diagnosis needed to correct individual animal health problems, identification of the conditions that allow expression of the etiologic factors is necessary to solve herd problems. The steps and objectives of individual animal and herd diagnostics are compared in Table 1. Control of disease at the herd level is widely believed to be more financially beneficial to livestock producers than treatment of individual ill animals. A knowledge base of veterinary medicine, epidemiologic methods, and modern animal husbandry is essential for successful herd diagnostics.

Table 1. Individual animal diagnostics vs. herd diagnostics.†

	Individual	Herd
History	Define problem; case history	Define problem; herd database; data on potential risk factors; epidemiologic patterns
Physical Examination	Case	Affected/normals; environment - feed, physical; management practices
Rule-outs	Specific diseases	Risk factors
Diagnostic	Laboratory tests; radiographs	Laboratory tests; data analysis
Diagnosis	Specific disease	Active risk factors
Solution	Treatment of case	Modify risk factors in herd
Plan Implementation	Veterinarian	Management
Monitor Outcome	Case progress; modify treatment	Herd performance; modify intervention

† Adapted from Hancock, DD: The other epidemiology. Population Medicine News 3(32), 1990.

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Beef herd production shortfalls are identified by comparing actual production parameters to ranch goals. Production shortfalls are classified into the following major categories:

1. Low weaning rates
   Reasons include low pregnancy rates, excessive abortion rates, and/or excessive calf mortality rates.
2. Low weaning weights
   Reasons include calves underage at weaning (extended calving intervals) and/or low calf growth rates.

The importance of fertility to optimal production is underscored by its involvement in both of the major production shortfall categories.

The majority of beef cattle production problems or diseases (including infectious diseases) are of multifactorial causation, occurring only when a certain combination of *risk factors* are present (1). Risk factors are host, agent, or environmental characteristics that must be present to result in disease. Our knowledge of the risk factors of beef herd production or disease problems is based on personal experiences, the knowledge of others, and the veterinary and animal husbandry literature. For example, documented risk factors of perinatal mortality in beef cattle include dystocia (2-5), inadequate passive transfer of immunoglobulins (3,4), poor maternal nutrition (2,4,7-10), in utero infections (11), buildup of enteric pathogens in the calving area (8), congenital defects (12), and adverse weather (13). Risk factors that can be controlled by management are called *key determinants*. The goal of a herd investigation is to make an *epidemiologic diagnosis*: identification of the risk factors that cause the production shortfall or disease outbreak. The herd problem can then be solved by changes in management that eliminate or alter the risk factors that are key determinants (1).

This paper presents an organized approach of herd investigation to arrive at an epidemiologic diagnosis. There are 5 steps in conducting a herd examination:

1. Collection of history
2. Examination of animals
3. Examination of environment
4. Analysis of data
5. Preparation of written report

If a food animal practitioner is called to resolve a herd problem, such as perinatal calf mortality, for which many of the risk factors are known, an investigation protocol prepared prior to the herd visit can be used as a guide to the herd examination. First, the documented risk factors of the herd problem are arranged in a *path model chart* (Figure 1). The risk factor path model chart provides a useful format for discussion of a herd problem with a producer. It illustrates several principles of herd disease or production problems: 1) they are multifactorial in causation; 2) there are many areas of management that could be deficient; 3) infectious agents are only part of the problem; and 4) the only way to insure success in solving the herd problem is to conduct a complete investigation that evaluates the extent of involvement of all possible risk factors in the herd. An investigation protocol can be developed from the path model by listing the historical questions, animal examinations, and environmental examinations that must be performed to determine the extent of involvement of each risk factor in the herd. A detailed herd examination, preceding systematically through the 5 steps listed above will identify the presence or absence of known risk factors and possibly incriminate previously unknown risk factors.

HISTORY COLLECTION

Collection of a thorough history by far the most important step in the herd investigation. Practitioners that are successful in solving beef herd problems take the time necessary to collect a complete history and charge their clients accordingly. There are 3 phases to the history: 1) definition of the production or disease problem; 2) collection of the herd management and production database; and 3) collection of information helpful in identification of the risk factors responsible for the problem.

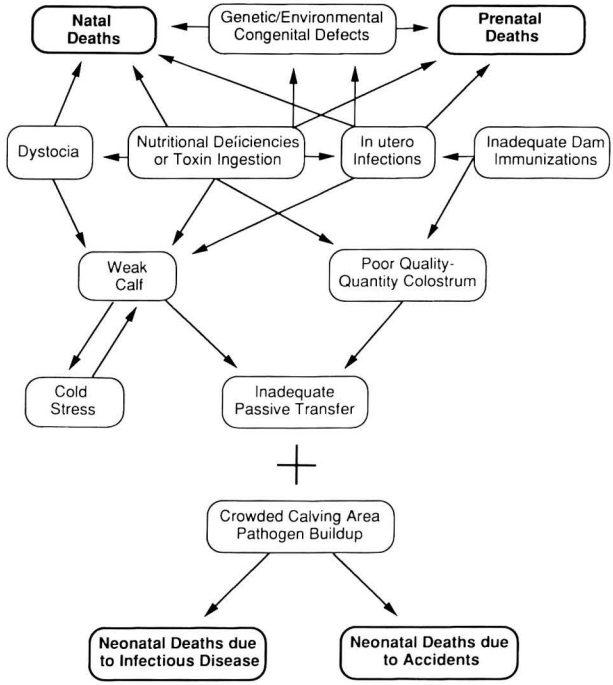

Figure 1. Path Model of Risk Factors of Perinatal Calf Mortality in Beef Herds.

Definition of the Herd Problem

The first step in history taking is to define the herd problem. The owner's chief complaint must be recorded and verified. Sometimes owners, especially those that are new to livestock production, become alarmed over production levels or disease losses that are not excessive or fall within acceptable "normal ranges". A knowledge of these "normal ranges", such as expected abortion rates in cows that have been confirmed pregnant (up to 3%), is necessary to determine if a herd problem truly exists. Following the chief complaint in a disease outbreak, the owner will usually describe his or her perception of the clinical signs of affected animals, the signalment of affected animals, and morbidity/mortality rates. Reports of any laboratory testing done in the past, such as clinical pathology or necropsies, should then be examined. Perceived morbidity/mortality rates must be confirmed by records, because there is sometimes a marked difference between the perceived level of disease and that which is actually occurring (1). If records are not available, prospective studies of losses and their causes may be necessary. Length of clinical course and effectiveness of owner administered therapy should be determined. The details of treatment schedules must be examined to determine if drugs are administered in proper dosages, by correct routes, and at necessary intervals to maintain therapeutic levels for proper durations.

Epidemiologic parameters are then collected to determine the *who*, *when*, and *where* of the problem (14,15). Risk group analysis (*who*) should be performed by computing *attack rates* (number affected/number at risk) for each sex, age group or production group. This information will sometimes help single out a risk factor for disease, such as a different feeding program that is only present in the

group of animals with the highest incidence of disease. Attack rates for age groups can be very useful in pinpointing causes of disease. For example, if in the course of investigating a neonatal beef calf mortality problem it was determined that the attack rate was greatest for calves less than 1 week of age, the suspected risk factors would include dystocia, failure of passive transfer, and buildup of enterotoxogenic E. coli. Herd infertility problems are epidemiologically described by determining the attack rates of pregnancy failure and the calving histograms of different age groups, different breeds, and animals in different breeding pastures (16).

The owner should be questioned on temporal relationships of the problem (*when*). How long has the problem existed? What was the date of the first case (*index case*)? The number of new cases plotted against time on a graph represents an *epidemic curve* (17). Clues to identifying risk factors of disease problems are sometimes revealed by the spatial distribution of affected animals (*where*). A map of the ranch is drawn and a dot is placed at the location of each affected animal (*point map*) (18). Areas where cases are clustered should be closely examined, especially for sources of toxins. Temporal relationships and group attack rates, separate or combined, form disease patterns that are very helpful in diagnosis. Table 2 illustrates the attack rates for different age groups that would be expected with various causes of perinatal calf mortality.

Table 2. Patterns of prenatal calf mortaility due to various causes.*

Herd Problem	Age Group Losses**			Calf Survivability
	Prenatal	Natal	Neonatal	
Normal	1-3%	4-5%	2-3%	90-93%
In utero infection or toxin	+++	+	+	45-60%
Dystocia	Normal	+++	++	75-85%
Maternal malnutrition	Normal/+	+	+++	75-85%
Inclement weather	Normal	++	++	75-85%
Pathogen buildup	Normal	Normal	++	75-85%
Maternal malnutrition, inclement weather, and pathogen buildup	Normal/+	++	+++	60-75%

* Adapted from Reference 11.

** Prenatal period - 42nd day pregnancy to parturition, natal period - birth to 24 hours, neonatal period - 1 day to 28 days.

\+ Slightly elevated

++ Moderately elevated

+++ Greatly elevated

Herd Management and Production Database

The herd database is composed of a large body of facts on the herd's resources and management including the areas of nutrition, disease prevention, reproduction, replacement heifer rearing, ranch labor, record keeping, and genetics. The information can be assembled by interviewing the ranch manager during the herd visit or by completion of a comprehensive questionnaire by the rancher prior to the herd visit. The latter is best, because it gives the rancher time to obtain reports and data from ranch records and enables the veterinary practitioner to utilize an evaluation of the history data in planning the herd visit. This information on current management practices forms the foundation of the herd investigation, because *beef herd production and disease problems are corrected by changes in herd management.*

Collection of Data on Potential Risk Factors

The third stage of history taking is to collect information that when combined with the results of examinations of animals and environment will identify which risk factors are active in the herd (the ***why*** of the problem). For example, the following information must be obtained to evaluate the influence of dystocia as a risk factor for perinatal calf mortality:

1. Determine the percentage of replacement heifer and cow parturitions that require assistance (dystocias);
2. Determine the percentage of replacement heifers and cows that deliver dead, full-term calves (stillbirths);
3. Determine the birth weights of calves of replacement heifers and cows;
4. Determine the breeds and birth weights of bulls used to service replacement heifers; and
5. Determine if early assisted deliveries are practiced, and how often the calving heifers and cows are checked during the day and night.

If the problem has not occurred in the past, the critical history question is: "*What has changed?*" Knowledge of recent introduction of new animals, treatments, feed changes, or weather changes can be very helpful in solving disease problems. The effect that any changes may have on the risk factors selected as rule-outs should be considered. All historical information and other data gathered from animal and environmental examinations *should be recorded in written form.* A blank notebook can be used or precoded questionnaires developed from the specific risk factor path model for the herd problem.

EXAMINATION OF ANIMALS

Examination of individual animals includes complete physical examinations of representative samples of healthy and sick animals, possibly necropsy of several dead animals, and sometimes collection of samples from live or dead animals for laboratory analysis. For example, to evaluate the involvement of inadequate passive transfer of colostral immunoglobulins in a herd with excessive calf mortality the following animal examinations would be performed:

1. Body condition scores on replacement heifers and cows;
2. Immunoglobulin measurements on 10 calves 1 to 7 days old; and
3. Necropsies on all dead calves to detect cases of colisepticemia or other infectious diseases.

The healthy animals should be examined first to determine if the disease is more widespread than suspected. One of the greatest difficulties in herd investigations is to decide how many animals to examine or sample. Enough sick animals should be examined to elucidate the entire range of clinical abnormalities present in the outbreak. The number of animals examined will vary depending on the amount of variation in clinical signs. Generally, up to 10 sick animals are examined. Similar numbers of apparently healthy animals should also be examined. Body condition scores are sensitive indicators of a herd's energy intake. Thin cows are key determinants of herd production problems such as inadequate passive transfer (4) and impaired fertility (16).

If samples are collected for laboratory analysis, they should consist of equal numbers of *affected* and *unaffected* animals to provide values for comparison. Seven to 10 animals are generally sampled to determine a herd's mineral status. That sample size may be insufficient to accurately reflect the mineral status of some herds (19-21). In the interest of cost-effectiveness, laboratory analyses should only be performed if the results will identify or rule out a key determinant. Unless a management level question can be posed that will be answered by a laboratory result, samples should not be submitted (21). Little benefit is derived from performing laboratory tests to demonstrate something already known. For example, submission of fecal and intestinal samples from calves with neonatal diarrhea for rota or corona viruses demonstration is not justified, because of the nearly 100% probability that most calves in any herd undergo infections with these viruses (serologic surveys indicate that infection of the cattle population with these 2 viruses approaches 100%) (22). If laboratory samples meet the above criteria, they should be properly collected, preserved, and promptly delivered to the diagnostic laboratory. The quality of the laboratory results will be directly proportional to the quality of the samples on arrival. The laboratory samples should be accompanied by a good history of the herd problem. Often the experiences of laboratory diagnosticians will enable them to offer helpful suggestions toward herd diagnosis if they are aware of details of the problem.

The opportunity to perform one or more necropsies is an invaluable aid in arriving at a diagnosis in disease outbreaks. If there are no dead animals the day of the herd visit, it is often worthwhile to sacrifice an ill animal. A reluctant owner usually will agree to do so after he is reminded of the value of the animal, which may die later, compared to the ongoing financial losses due to the disease. If there are several dead animals, as many as possible should be necropsied to observe the complete pathological picture. A sharp knife is critical! Other equipment that is necessary include a steel, pruning shears, hatchet, bottles of 10% formalin, whirl-top plastic bags, culturettes, red top tubes for blood or body cavity fluid collection, and sterile plastic tubes for exudate or milk samples. If a diagnosis cannot be made from the gross lesions, tissues should be saved for microscopic, microbiologic, or toxologic examination. When the diagnosis is difficult it is important to collect samples of all tissues, including often overlooked bone marrow and brain. Two sets of samples should be collected: 1 set fixed in 10% formalin for histopathology and the other set stored frozen for future microbiologic or toxologic analysis, as indicated by histopathology results.

EXAMINATION OF ENVIRONMENT

Examination of the environment is performed after animals are examined, because findings from animal examinations often point to specific environmental factors that should be investigated. For example, necropsy findings of eroded, hyperemic abomasums and duodenums should initiate a search for a heavy metal source in the environment (23).

Examination of the environment includes observations on feed and water sources, geography, and location and stocking rates of animals. For example, examination of the environment in an investigation

of a calf diarrhea outbreak would include the following evaluations of the calving area: 1) stocking density; 2) sanitation; 3) rotation of feeding sites; 4) shelter; and 5) drainage. In general, when the environment is examined, special attention should be given to identifying sources of poisons such as faulty storage of herbicides or fertilizers, poisonous plants, or moldy feed. The quality and quantity of feed sources should be examined. Water sources should be of adequate amounts and free of algae. Laboratory analyses of feed and water may be necessary. The topography of the ranch should be inspected for sheltered areas that would protect animals during storms. Heavy stocking densities are often associated with parasite or pathogen buildup.

ANALYSIS OF DATA

All the information collected during the investigation is then assembled and evaluated to yield a diagnosis. In disease investigations, a *pathologic diagnosis* is made from the animal examinations and laboratory results. The pathologic diagnosis will usually describe the lesions in the organ system involved and possibly identify a specific infectious agent or toxin responsible for the lesions. The pathologic diagnosis should be considered an intermediate diagnosis that is a stepping stone to the epidemiologic diagnosis. Infectious agents are present throughout the cattle population and *rarely cause disease by themselves*. Almost all food animal pathogens are *"opportunists"* rather than the *"sole causes"* of disease. Kahrs states that host and environmental influences play a more prominent role than viruses in the production of disease associated with endemic bovine viruses (24). The causes of an infectious disease herd problem that can be modified to solve the problem are the herd management deficiencies that allow the agents to progress beyond inapparent or subclinical infection to overt disease. The pathologic diagnosis is an important step toward a herd diagnosis, because many of the risk factors of food animal diseases are known. However, only through analysis of the findings of the animal and environmental examinations, and historical data collected during a herd investigation can all the risk factors responsible for a specific herd problem be identified.

Identification of disease patterns is a very important aspect of the analysis of data collected in the investigation. Assembling temporal data into epidemic curves and the disease attack rates of various breed, age, sex, and production groups into graph or chart form is helpful in visualization of disease patterns.

Definitive proof of a casual relationship between a previously undocumented risk factor and a herd problem is very difficult, even for epidemiologists. It requires accurate collection of data on exposure to the risk factor, the outcome of exposure and analysis of the data. A 2x2 table can be used to identify a *potential causative risk factor*. Further sampling, other techniques of analysis, or a response trial can be performed to conclusively link the risk factor with the herd problem.

The 2x2 table is used to classify the affected and non-affected animals according to their exposure to the risk factor (Table 3) (25). The degree of association between the risk factor and a herd disease problem is measured by calculating an *odds ratio* (OR) from the table. The odds ratio is the ratio of the odds of being affected for animals exposed to the risk factor to the odds of being affected for animals not exposed to the risk factor. It is calculated from the 2x2 table by the following formula: odds ratio is equal to A x D divided by C x B. Odds ratios of 1 imply that there is no association between the postulated risk factor and being affected; odds ratios greater than 1 imply that the risk factor is associated with an increased risk of being affected; odds ratios less than 1 imply that animals with the postulated risk factor have a decreased risk of being affected. An odds ratio of 4.5 indicates that cattle that are classified as positive for the risk factor are 4.5 times as likely to be affected than animals negative for the risk factor. A risk factor with an odds ratio of 3.0 or greater may be

considered by many clinicians to be worth eliminating or altering to correct a herd problem, however, first the observations should be proven to be statistically significant (26). The chi-square test is designed to determine the probability that the observations occurred due to chance alone. These calculations can be done by hand or by computer software programs, such as Vetstat[a] or Epistat[b], that have been developed to perform epidemiologic calculations useful in herd health practice situations (27).

Table 3. A 2x2 table classifying each affected and non-affected animal according to their exposure to a proposed risk factor.

	AFFECTED	NON-AFFECTED
Risk factor +	A (affected with risk factor)	B (non-affected with risk factor)
Risk factor -	C (affected without risk factor)	D (non-affected without risk factor)

A 2x2 table was used by the authors to determine if infection with Haemophilus somnus was a potential risk factor for non-pregnancy in a beef herd. Twenty four cows were classified in a 2x2 table (Table 4) as pregnant or non-pregnant and high (1024 or greater) or low (512 or less) H. somnus microagglutination test titer. The odds ratio calculated was 5.5, indicating that cows with high H. somnus titers were 5.5 times as likely to be non-pregnant as cows with low H. somnus titers. Chi-square analysis revealed that the finding was insignificant or likely due to chance. Classification of a larger number of cows may have yielded a more convincing relationship, but was not possible. Instead, an H. somnus vaccination response trial was initiated prior to the next breeding season.

Odds ratios developed from single 2x2 tables are not accurate in herd situations because multiple risk factors directly influence the same production parameter and interact with each other at the herd level. For example, low pregnancy rates may be found in a group of cows fed moldy grain. Analysis of a 2x2 table may reveal that the OR for moldy grain and non-pregnancy is high. This is not proof that the moldy grain caused the low pregnancy rates, because many other risk factors including age and body condition influence pregnancy rates. Maybe only older cows and thin cows, groups that are expected to have low pregnancy rates, were fed the moldy grain. The effect of age and body condition on pregnancy rates can be controlled by an analysis of multiple 2x2 tables called the Mantel-Haenszel procedure which is included in the above two software programs (22,24). The Mantel-Haenszel technique calculates an adjusted odds ratio for moldy grain and non-pregnancy.

[a]Vetstat® - Dr. Ben Norman, Extension Veterinarian, University of California, Davis, California 95616.

[b]Epistat® - Dr. Tracy L. Gustafson, 2011 Cap Rock Circle, Richardson, Texas 75080.

Table 4. A 2x2 table classifying 24 cows as pregnant or non-pregnant and high or low H. somnus microagglutination test (MAT) titer.

	NON-PREGNANT	PREGNANT
High H. somnus MAT titer (1024 or greater)	4	8
Low H. somnus MAT titer (512 or less)	1	11

Following identification of the risk factors associated with the disease or production problem, a plan of prevention can be formulated based on herd management changes that eliminate or alter the key determinants.

WRITTEN REPORT

A written report is critical to the successful resolution of a herd disease or production problem. It should consists of the following 5 parts:

1. Definition of problem
   Review the nature and severity of the problem in a few brief statements.
2. Summary of findings
   List all of the data collected from the various parts of the herd examination. Include graphs and laboratory results.
3. Epidemiologic diagnosis
   List the pathologic diagnosis followed by a list of key determinants identified in the herd investigation.
4. Strategic herd plan
   Explain in detail the management changes that eliminate or alter the key determinants. Long-term, as well as short-term recommendations should be included. Discuss the degree of expected success and cost-effectiveness.
5. Follow-up plans
   Outline the methods of monitoring the effectiveness of the preventive measures. Effective follow-up is critical to the success of solving herd problems. Modifications of the strategic plan are always necessary during its implementation. In cases where a diagnosis cannot be made, due to a complex disease causation, follow-up plans may include more intensive sampling in one area or a protocol for a response trial to determine if a certain management procedure will control the herd problem. A response trial can be used to confirm an unproven diagnosis or to find a cure with incomplete knowledge of the cause of the herd problem. Response trials should be supervised by an epidemiologist to insure their validity. A very important spect of the investigation follow-up is to insure that adequate records are kept to document the improvement in herd health and productivity that results from implementation of the recommended management changes.

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SUMMARY

The general approach to the epidemiologic investigation of beef herd production or disease problems is presented. The goal of the investigation is to identify the risk factors associated with the herd problem. The investigation goes beyond identification of diseases to evaluations of animal husbandry practices that could be risk factors of the herd problem. Active risk factors are the result of herd management deficiencies and they can be inactivated by improvements in herd management. A procedure is outlined to develop an investigation protocol from a path model chart of the documented risk factors for any herd production or disease problem. Collaboration with a veterinary epidemiologist is necessary to positively identify new risk factors of herd problems. Protocols have been published for the investigation of impaired fertility (16) and neonatal diarrhea (28).

A comprehensive epidemiologic investigation to identify the causes of a beef herd production or disease problem, and follow up implementation and monitoring of management changes to solve the problem is time consuming, expensive, and greatly warranted. It is greatly warranted because such a thorough approach is so highly effective in increasing herd production and profits that it has an extremely favorable cost-benefit ratio. Many practicing veterinarians would like to become more involved in herd level animal health and production. That goal can be readily reached by utilizing an epidemiologic approach in the solution of their client's herd production or disease problems.