1

Evidence-based Practice of Swine Medicine

Christopher J. Rademacher and Locke A. Karriker

1.1 Introduction

Successful swine veterinarians are curious, empathetic, and evidence based. Swine medicine affords the opportunity to use a wide range of skills that can be applied at the individual animal, population, or system level to improve animal health and welfare. Veterinarians are crucial protectors of human health by preserving food and product safety. They minimize zoonotic disease risks that impact a variety of species. Conserving resources and improving efficiencies are specifically part of the Veterinarian's Oath in many countries.

This chapter seeks to provide a firm base for new veterinarians as well as integrating concepts scattered throughout the book for seasoned veterinarians. At its core, evidence-based swine medicine is the process of accumulating data from a wide range of sources, evaluating it and processing the relevant pieces into information that supports solving the problem, and with reflection about case outcomes, contributing to the knowledge base that can be applied to the next problem.

This book contains accumulated knowledge on swine diseases supported with knowledge about organ systems, veterinary technical skills, and strategies that facilitate application of the knowledge. This chapter provides an overview of the process of moving from data accumulation to knowledge that is ready to apply to a case.

Pigs are used primarily not only for food but also for biomedical research, including the development of genetic lines with potential for xenotransplantation to humans, due largely to functional and physical similarities with human physiological systems and organ structure. Additionally, pigs are raised and displayed in competitive shows and are enjoyed as pets in some cultures. Because of their primary role as human food and the presence of meaningful zoonotic disease shared between pigs and humans, a healthy pig is important, and because of the global and cross-cultural distribution of pigs, an effective swine veterinarian must be able to assess and improve health in a wide variety of housing and use contexts.

1.2 Be the Pig's Advocate

Modern pork production is efficient and technologically advanced, which serves to bring a wide variety of expertise to food production operations. Among this variety of expertise and focus on efficiency, there is a critical need for someone to advocate for the health and welfare of the pig, above and beyond what contributes to the efficiency of the operation. Although everyone can contribute to this advocacy, veterinarians are uniquely positioned for this role with a knowledge of how to assess and correct deficiencies in the health and welfare of the animal. Being the pig's advocate requires the use of evidence-based medicine (EBM) to develop *in situ* strategies for health improvement that both consider the best science information available and the realities of the pig's environment and intended use. The primary use of pigs as food comes with an obligation to maximize the health and well-being of the animals while they are alive. A successful advocate must have the skill set to impact the health of the live animal directly and also via communication and persuasion of the other people in caretaker, technical resource, and a variety of other roles that impact the pig.

1.3 Introduction to EBM

Swine veterinarians are presented with significantly more data to digest and apply than ever before. If we consider a single source, the National Library of Medicine's online reference database PubMed as an indicator, the number of research studies that are returned using "pig" as a search

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term is 343,530 (https://pubmed.ncbi.nlm.nih.gov/?term=pig, accessed December 20, 2023). If one attempted to keep up with all the research indexed with the term "pig" or "swine" in PubMed during 2022, they would have to read approximately 23 papers every single day. Clearly, not all of these references are relevant to swine medicine practice. However, a subset of these studies is not only relevant but also challenges our paradigms about disease and treatment. Evidence-based practice requires the skills to find, evaluate, and apply the studies that are relevant from among the entire lot.

The accelerated pace of clinical practice combined with the advancement of production technology means that swine veterinarians are now presented with extraordinary amounts of data from the farm and patient populations as well. Indeed, the task of accurately assessing the clinical picture of a population is a precondition to identifying and translating useful research conclusions. The modern swine veterinarian is placed squarely at the collision of these two converging data streams and several others, including an accelerated pace of regulation from a growing number of regulatory agencies and increasing social inquisition with expectations for input. Each data stream must be screened for relevance, assessed for quality, and applied to the local case in the context of local norms and values.

Concurrent with the growth of the data stream is the severity of consequences for continuing poor medical practices. If we assume a 265-pound market pig will yield 70% useful carcass and that carcass will be utilized in 8-ounce increments, a treatment decision on a pig destined for market affects approximately 371 consumers. Most of these consumers eat edible pork products from the pig, but some will receive heart valves and other medical and cosmetic products. These products no longer stay on a single farm and affect a single consumer but rather enter complex global food chains where individual parts of individual pigs may be consumed in different countries. When production technologies leverage decisions over large populations at the barn and system level, the impact can be substantial and widely disseminated.

These confluences in human medicine—larger, faster data streams; increased accountability for using best practices; and the constant driver of increasing efficiency—led to the organization of EBM efforts decades ago. The organization of EBM efforts really did not introduce new concepts to research but rather sought to transfer skills for finding and critically evaluating the best quality data to clinicians that could apply the conclusions to patients. More recently, EBM has gained traction in veterinary medicine. Inherently, the consideration of populations, rather than just individual patients, in the practice process has required evidence-based veterinary medicine to rely heavily on epidemiology techniques.

Historically, veterinary training centered on knowledge transfer that included facts accessible only as part of that training. For example, a swine veterinary student would learn the appropriate dose of chlortetracycline in pigs and put that knowledge into practice. It was knowledge that could be used and marketed because farmers did not easily directly access it. Now an internet connection provides access to that information. Swine veterinarians now bring value by determining how and when to apply that factual information and troubleshoot treatment failures. Understanding the details of the study that generated the evidence, such as study design, potential biases, and characteristics of the statistical analysis, help to inform the correct application of its conclusions. The tools used to create that understanding from the data streams we are presented with are collectively EBM. Applying these tools further, to assess farm data that might inform a diagnosis, for example, is evidence-based practice.

1.3.1 EBM Principles

Originally defined in the human medical context, EBM is the "Conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Doig 2003). Holmes and Ramsay (2007) describe the practice of EBM as "integrating individual clinical expertise with the best available external clinical evidence from systematic research." Furthermore, they define "evidence" as "good data and conclusions collected from high-quality studies" and suggest that evidence-based veterinary medicine "concepts and principles are the same [as for human medicine] even if there is variability in the details." Several summaries of EBM (Nakayama 2006; Slater 2010) describe it as having three critical elements:

1. Create and adequately report evidence from clinically oriented basic research.
2. Gather, evaluate, and present evidence in synthesized, accessible forms using practice and research guidelines, including systematic reviews.
3. Practice EBM by finding and applying evidence.

Kochevar and Fajt (2006) expanded the steps of EBM in the veterinary medicine context to five specific steps: (1) specify an answerable question, (2) find the best evidence, (3) critically evaluate the evidence for external and internal validity, (4) combine the evidence with clinical expertise and the relevant local values of the case, and (5) evaluate the performance of evidence-based practice and seek ways to improve it and the clinical outcomes.

1.3.2 Evidence-based Swine Veterinary Practice

Swine veterinary medicine has characteristics that distinguish it from both human and companion animal medicine. Several of these will influence how we value, modify, and apply EBM principles. Key differences include the following:

- Diagnosis of population and subpopulation conditions.
- More limited individual animal clinical information.
- Treatments are often applied to populations.
- Influence of stakeholders other than the patient and owner in treatment decisions, such as consumers, activists, and public interests.
- A more restrictive treatment menu.
- A greater need for economic efficiency.
- Involvement of non-veterinarians in implementation of health interventions.
- A relatively small population of clinical researchers.
- A relatively stronger motivation to perform field-based clinical trials.
- Significant volumes of group-level performance and health data.
- Proprietary constraints to sharing of data and performance outcomes.

1.3.2.1 Hierarchy of Evidence for Information Used in Practice

Evidence-based human and companion animal medicine tends to focus on a unidirectional movement of information starting from the research arena, moving through a series of assessments to finally be applied in clinical medical practice. Consequently, there is a focus on evaluation of research trials and a consensus on the relative strength of different research trial structures in terms of the confidence in the conclusions they reach. This hierarchy of research evidence (Cockcroft and Holmes 2003) is based on study design. This hierarchy accepts blinded, controlled, randomized trials as the strongest evidence and computer models (*in silico*) as the weakest evidence when considering primary research studies. When considering sources of evidence for decision-making, systematic reviews, especially of randomized, controlled trials with appropriate meta-analysis, are the strongest evidence. It is important to recognize that frequently studies that are lower on the hierarchy are the only available evidence and should still be considered by the veterinarian. The hierarchy doesn't exclude certain study types, but it provides a mechanism to compare studies, especially when they have conflicting outcomes. It also is useful to inform *a priori* study design when a clinician-scientist sets out to objectively answer a question with research. Strong evidence in this context has both high confidence in the conclusions of the trial and relevance to the actual treatment subjects' biology. Recognizing and incorporating the most valuable evidence does not minimize the veterinarian's experience, understanding of client capabilities, incorporation of local norms and values, or the use of hard-won clinical lessons. At the same time, it is very important to be cautious of the trap of overcoming bias, whether the veterinarian's own or those of their clients. In many cases, their clients may be particularly susceptible to their biases, and this is one thing that is difficult for new veterinarians to overcome. Table 1.1 is an abridged list of study designs with swine examples that are meant to illustrate characteristics of

Table 1.1 Hierarchy of evidence ranked from strongest to weakest with swine examples.

Type	Study design (in order of strongest to weakest)	Example reference
Systematic reviews with appropriate meta-analysis (strongest)	Systematic reviews with meta-analysis are comprehensive analyses that compile and assess existing research on a specific topic, employing a structured approach to identify, select, and synthesize relevant studies. Meta-analysis involves statistical pooling of data from these studies to provide a quantitative summary, enabling a more robust and precise estimation of the overall effect or outcome.	Won et al. 2022. The effectiveness of commercial vaccination against *Lawsonia intracellularis* in mitigating the reduction in ADWG, the increased mortality and fecal shedding of the vaccinated pigs: a systematic review and meta-analysis. Vet Sci 9(10):536. https://doi.org/10.3390/vetsci9100536.
Blinded, controlled, randomized trials	Blind, controlled, randomized trials are prospective experiments where participants are randomly assigned to different groups, including the treatment being tested and control groups receiving a placebo or standard treatment. Blinding separates treatment administration and any measurements to reduce bias and ensure the validity of the study's results.	Opriessnig et al. 2009. Comparison of efficacy of commercial one dose and two dose PCV2 vaccines using a mixed PRRSV–PCV2–SIV clinical infection model 2–3-months post vaccination. Vac 27(7):1002–1007. https://doi.org/10.1016/j.vaccine.2008.11.105.

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Table 1.1 (Continued)

Type	Study design (in order of strongest to weakest)	Example reference
Observation study–cohort study	A cohort observational study is a prospective method that follows a group of individuals (a cohort) over a specific period to analyze how certain variables or exposures impact their outcomes or behaviors, often compared to a cohort without the exposure of interest. Treatments are not randomly assigned; cohort treatments are observed and not influenced by the investigator.	Alonso et al. 2013. Epidemiological study of air filtration systems for preventing PRRSV infection in large sow herds. Prev Vet Med 112(1–2):109–117. https://doi.org/10.1016/j.prevetmed.2013.06.001.
Observation study–case-control study	A retrospective case–control study is a research design where outcomes of interest (cases) are identified and exposures(s) (factors) of these cases are contrasted with the exposure history of non-cases (controls). A cohort case–control study begins by selecting a group of individuals with a particular outcome or exposure (the cohort) and compares them to a control group without that characteristic.	Perri et al. 2018. An epidemiological investigation of the early phase of the porcine epidemic diarrhea (PED) outbreak in Canadian swine herds in 2014: a case-control study. Prev Vet Med 150:101–109. https://doi.org/10.1016/j.prevetmed.2017.12.009.
Case series	A case series is a study design that presents a collection of detailed case reports. It aims to describe patterns, trends, or variations among a group of case reports but lacks the rigorous comparison found in controlled experiments.	Madson et al. 2012. Rickets: Case series and diagnostic review of hypovitaminosis D in swine. J Vet Diagn Invest 24(6):1137–1144. https://doi.org/10.1177/1040638712461487.
Case report	A detailed account of a unique or atypical clinical situation, diagnostic challenge, treatment approach, or outcome in a single or group of pigs. It documents valuable experiences improving the understanding and management of health issues but lacks the rigorous comparison found in controlled experiments.	Sitthicharoenchai et al. 2020. Cases of high mortality in cull sows and feeder pigs associated with *Streptococcus equi* subsp. *zooepidemicus* septicemia. J Vet Diagn Invest 32(4):565–571. https://doi.org/10.1177/1040638720927669.
In vitro (benchtop) studies	*In vitro* studies conduct experiments in a controlled setting using isolated swine cells, tissues, or organs outside of the living organism. These studies aim to investigate cellular and molecular processes, drug interactions, disease mechanisms, or therapeutic approaches pertinent to swine health and veterinary medicine.	Lee YJ, Lee C 2016. Ivermectin inhibits porcine reproductive and respiratory syndrome virus in cultured porcine alveolar macrophages. Arch Virol 161:257–268. https://doi.org/10.1007/s00705-015-2653-2.
Expert opinion (expert consensus)	Expert opinion reports involve the synthesis of expert knowledge and experience to provide recommendations for the diagnosis, treatment, and management of health issues in swine. These studies typically integrate a consensus of expert perspectives.	Mauroy et al. 2021. Semi-quantitative risk assessment by expert elicitation of potential introduction routes of African swine fever from wild reservoir to domestic pig industry and subsequent spread during the Belgian outbreak (2018–2019). Transbound Emerg Dis 68:2761–2773. https://doi.org/10.1111/tbed.14067.
Computer modeling (weakest)	Computer modeling utilizes computational techniques to simulate and analyze disease spread, treatment efficacy, system dynamics, and other topics. They leverage mathematical models and simulations to predict outcomes that are difficult to reproduce in live animals. Strength of the model is determined by the assumptions upon which the model was built.	Liang R, Lu Y, Qu X, et al. 2020. Prediction for global African swine fever outbreaks based on a combination of random forest algorithms and meteorological data. Transbound Emerg Dis 67:935–946. https://doi.org/10.1111/tbed.1342418651682,2020,2.

study design at each level. Again, some questions cannot be answered with study designs higher on the list due to design, cost, or ethical issues. Just because a study employs a design that is lower on the hierarchy does not mean it is not valuable information. In fact, in many cases, studies with less strength of evidence are the only structured observations of the problem or interventions that are available.

A review of the study designs in this hierarchy reveals four trends as one moves from strongest evidence (systematic reviews with analysis) to weakest evidence (computer modeling) that are important in practice:

- Systematic observations are more valuable than random observations (internal validity).
- Decreasing bias or a more thorough understanding of its influence on the conclusion strengthens conclusions (internal validity).
- Explicit and complete reporting of the trial conditions, materials, and methods increases evidentiary value (external validity).
- Greater similarity to actual production conditions where the treatment will be applied increases clinical value (external validity).

Leveraging each of these trends means the application of specific tools and techniques. For example, systematic observations (or data points) can be analyzed using statistical tests to quantify the effect of the treatment being tested relative to biological variation or random chance. The use of comparators, such as positive and negative controls, is another tool to make observations more systematic, with their absence being a major limitation for case studies and case reports. Blinding clinical evaluators to treatment is a tool to reduce information bias. For example, the person applying treatments should be a different person than the subjective evaluator of the animal's clinical status.

The unique characteristics of swine medicine described earlier present opportunities to further leverage the application of these tools and the improvement in strength of conclusions beyond the traditional EBM function of evaluating research studies for treatment evidence. These can be judiciously applied to all the data streams that converge on swine clinical practice, including those used for diagnosis and evaluation of populations.

1.3.2.2 Modified Bradford Hill Criteria in Swine Practice Context

Sir Austin Bradford Hill (1965) suggested that in practice, we can't "...sit around awaiting the results of [sufficient] research" to determine causality before acting to treat patients. He suggested several criteria that could be considered to strengthen associations and potentially suggest causality. These are summarized within the swine practice context in Table 1.2.

Table 1.2 Evidence supporting association and causation in swine medicine for selected criteria from Sir Austin Bradford Hill.[a]

Criteria[a]	Supports association	Supports causation
Strength of association	The presence of a specific pathogen or risk factor and a disease occur concurrently in observational studies with varied magnitude of relationship.	In multiple studies, including prospective challenge studies, the disease consistently occurs, and as the intensity of the exposure increases, the frequency or severity of the disease increases.
Consistency	Limited reports or all evidence is under very similar settings, such as same investigator, facility, and location.	Extensive repetition of experiments with consistent outcomes over a range of investigators, places, facilities, circumstances, seasons, and so on.
Specificity	The occurrence of a particular swine disease is specifically associated with a unique pathogen or risk factor, rather than being linked to a broad range of potential causes.	When the risk factor/pathogen is present, a specific clinical outcome occurs, and when the pathogen/risk factor is absent, the specific clinical outcome does not occur. Outcome can be described with a case definition.
Temporality	The temporal sequence of exposure to a potential pathogen/risk factor relative to the onset of disease is unknown or poorly defined.	A consistent pattern where exposure to the identified pathogen/risk factor consistently precedes the development of the disease or clinical outcome and the timing is predictable.
Biological gradient	Where a dose–response relationship is hypothesized to exist, only one or a limited number of exposure levels have been tested.	Evidence exists that increasing levels of exposure to the pathogen or risk factor, over several levels of exposure, result in a corresponding increase in the incidence or severity of the disease in swine.

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Criteria[a]	Supports association	Supports causation
Plausibility	Providing a biological or physiological explanation for how the identified factor could lead to the development of the swine disease.	Supporting the association with evidence of plausible biological mechanisms or pathways through which the identified factor directly contributes to the initiation or progression of the disease in swine.
Coherence	Ensuring that the identified association aligns with existing knowledge and understanding of swine physiology and disease processes at the population or animal level.	Confirming that the proposed causal relationship is coherent with existing knowledge of swine biology, disease mechanisms, and relevant scientific principles at the cellular, microbiological, chemical, or histopathological level.
Experimentation	Reliance on observational and/or natural infection experiments or interventions in swine populations to demonstrate a relationship between the identified factor and the development of the targeted disease.	Implementing controlled challenge experiments or interventions that manipulate the presence or absence of the factor to conclusively show its role in causing the swine disease.
Analogy	Drawing on analogies from similar situations in other species or contexts to support the likelihood of a causal relationship in swine.	Confirming that changes in analogous situations in other animal species or contexts also occur in the swine case context, such as cellular, physiological, and chemical changes that can be directly measured and compared.

[a] Modified from Hill (1965).

1.4 Roles of Swine Veterinarians

While the overarching goals of swine veterinary practice are going to be similar, there are going to be aspects of swine veterinary medicine practice that will be different depending upon the role that the veterinarian is playing within the business structure they are working within. Another aspect that will define their practice will be what their clients ultimately expect from the veterinarian. Veterinarians who work predominately within a companion animal practice may work with clients who have more focus on individual animal swine medicine or the needs of small populations of animals. They will be expected to be able to collect antemortem samples (blood/serum), perform examinations, and write certificates of veterinary inspection (or health papers) for exhibition swine and may be expected to administer treatments and vaccinations on their clients' animals.

Swine veterinarians working within a mixed or swine-dedicated veterinary practice are going to be working primarily with commercial clients who are producing pigs for the market and use as food. Note that throughout this chapter and the rest of the book, animals that are at the end of their target growth will be referred to as destined for "market," "slaughter," or "harvest" or referred to as "entering the food supply." The language and goals include maximizing the throughput and efficiency of their operation by improving animal health. This is routinely done by routine visits to the operation by the veterinarian or veterinarians from a practice that make observations and suggestions for improvements, do targeted disease surveillance through routine antemortem and postmortem samplings, and establish the medication and vaccination schedules for each stage of production. There may be multiple veterinarians within the same practice that may work for the same client, so good documentation and communication are vital for the appropriate follow-up.

Veterinarians who work for production companies would have similar goals, as their client is their employer. Their roles may be more diversified than those of swine veterinarians from more traditional veterinary clinics. Veterinarians within production companies work closely with the production staff and leadership on health-related items within the production system. Depending on the structure and geography of the business, they may be specialized in working primarily with breeding herds or just the growing pig herds (nursery, finishers, or wean-finish). If all the production is in one geographical location, then they will work with all phases of production. There is the opportunity for more specialized roles within production companies, including leadership roles in areas of production management, animal care and well-being, as well as executive leadership positions. Due to the nature of working in more of a support role within a production hierarchy, there are the needs to be able to influence people with recommendations, so soft skills such as personality profiling, conflict management, and situational leadership are necessary abilities needing to be acquired if a veterinarian is to be successful within this type of organizational structure.

1.4.1 Skills and Expertise Needed

No matter what type of practice a veterinarian finds themselves in, there is a consistent set of skills and expertise that they need. Some of these skills will be acquired during a formal veterinary education, but most are refined with experience in the early years of a veterinarian's career. Perhaps the single most important skill is how to be an effective communicator and trainer. No matter how good one is at any of the other traditional veterinary clinical practice skills, if they are not able to effectively communicate their findings or plan to improve the situation to the client and their staff, it won't improve animal health and welfare. To be effective at communication, one must remember to communicate at a level that the audience is familiar with and can readily understand. Veterinarians accumulate technical terms during their veterinary education, but many of these may be foreign to the intended audience. To be an effective communicator, it is advantageous to figure out how to simplify and translate these into language that clients and staff can easily relate to and understand. At the same time, technical precision with terminology is critical for constructive discussions with peers and allied professionals.

Table 1.3 provides definitions for important technical terms that swine veterinarians are likely to encounter in practice and research, especially when diagnostic testing strategies, test characteristics, or test results are the subject of communication. Training is closely tied to communication, as a significant piece of what a veterinarian does is to train staff on the farm. Some of the most important training is how to detect clinical signs of disease and which pigs may need additional attention and potentially treatment. Since most adults are visual learners, having access to a great set of training resources is also essential.

Clinical disease recognition skills and how to develop a differential list by clinical signs observed, history, and gross necropsy lesions are perhaps two of the most foundational skill sets that a practicing swine veterinarian can develop. This allows for the development of a presumptive diagnosis and initiation of treatment while awaiting the results of diagnostic tests. This takes some time and experience to refine this skill set and can be augmented by

Table 1.3 Glossary of terms relevant to swine medicine with references.

Agent	A factor whose presence or relative absence (e.g. nutritional diseases) is causally associated with disease.
Aggregate sample	A discrete sample collected in such a way that it may contain analyte from more than one animal. Examples include processing fluids, pen-based oral fluids, and environmental samples (e.g. air or water samples). Compare with ***composite (pooled) sample***.
Analyte or target	The substance intended to be detected or identified by an assay.
Analytical sensitivity	An assay performance attribute best expressed as the "limit of detection," i.e. the lowest concentration of an analyte that can be detected with ≥95% probability. Compare with ***diagnostic sensitivity***.
Analytical specificity	An assay performance attribute addressing the degree to which it exclusively detects or measures the intended target. Compare with ***diagnostic specificity***.
Antibody	Proteins produced by the humoral immune system in response to the presence of a foreign antigen.
Assay	A technical procedure designed to detect the presence or measure the quantity of a defined analyte in a sample. Compare with ***test***.
Carrier (carrier state)	An animal that harbors a specific infectious agent without exhibiting clinical signs and a potential source of infection to susceptibles in the population.
Census	Sampling, or collecting data from, each member of the population.
Clinical signs	Objective evidence of disease perceptible to an observer. Compare with ***symptoms***.
Composite (pooled) sample	A sample created by combining two or more discrete samples in equal or unequal proportions, depending upon the intent of the testing. Sample identities may be lost by pooling; hence, retesting of the original discrete samples may be required to achieve a definitive interpretation of the results.
Confirmatory test	A well-defined testing procedure performed for the purpose of corroborating or refuting the results of a screening test.

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Contagious	Transmission of an infectious agent by direct or indirect contact.
Convenience sampling	A nonprobability sampling method in which the sampling unit(s) most easily accessed are selected for sampling. In the field, for example, selecting the first pigs that approach the person who entered the pen to collect samples.
Diagnostic sensitivity	An assay performance attribute estimated as assay-positive animals (numerator) among all true-positive animals tested (denominator). Diagnostic sensitivity is not a constant; it may vary significantly over the course of an infection. Compare with ***analytical sensitivity***. Note: for aggregate samples, test performance is also estimated as positive samples (numerator) among positive sources tested (denominator). However, this is more accurately described as a probability of detection because it is dependent on three factors: distribution of the target in the source sampled (e.g. prevalence and/or concentration), sampling procedure(s), and the assay's diagnostic sensitivity.
Diagnostic specificity	An assay performance attribute estimated as assay-negative animals (numerator) among all true-negative animals tested (denominator). Diagnostic specificity is a constant, i.e. it should not change over the course of an infection. Compare with ***analytical specificity***.
Diagnostic transition stages	Changes in diagnostic sensitivity that occur over time for specific combinations of specimen and assay as animals pass through disease transition stages (Henao-Diaz et al. 2020; Thurmond 2003).
Discrete sample	A sample with known identity: what was sampled, how it was collected, where, and when. Discrete samples may be from individual animals (e.g. serum) or may be aggregate samples (e.g. pen-based oral fluids). Compare with ***composite (pooled) sample***.
Disease transition stages	The host- and pathogen-specific stages of infection over time. Most simply, these may be described as latent (time from entry to shedding of the agent), infectious, and noninfectious (recovery) phases (Henao-Diaz et al. 2020; Thurmond 2003).
Disease	A condition characterized by structural or physiological dysfunction in the affected animal.
DIVA	"Differentiating infected from vaccinated" animals using a marker vaccine and companion diagnostic test (van Oirschot 1999).
Endemic	The constant occurrence of a disease (or presence of an infectious agent) in a population.
Epidemic	The occurrence of a disease (or presence of an infectious agent) in excess of its usual frequency.
Epidemiological unit	A group of animals with approximately the same likelihood of exposure to an infectious agent because they share a common environment (e.g. animals in a barn or pen or feedlot) or because of common management practices. Compare with ***herd***.
Fixed spatial sampling	A sampling design based on collecting samples from pens spaced equidistant to each other over the length of a barn (Rotolo et al. 2017).
Fomites	(Singular is "fomes."). Inanimate objects that convey infection to others because they are contaminated with the infectious agent. Examples include truck tires, gloves, boots, door handles, bedding, and food. Also see ***vehicle***.
Herd	A population of animals living together in which the distribution of infection is assumed to be relatively ***homogeneous***. On a production site, each segregated group of pigs (each building or room) is considered a separate herd (USDA:APHIS 2003). Compare with ***epidemiological unit***.
Incidence	Rate of disease occurrence measured as the number of new cases (numerator) in a defined population (denominator) over a specified period of time.
Infection	The entry and replication or development of an infectious agent in a living body. Infection is not synonymous with disease because most infections are inapparent. The presence of viable infectious agents upon fomites is contamination, not infection.
Infectious	The quality of being able to establish an infection.
Infectiousness	An infectious agent's capacity to exit an infected host and enter, survive, and multiply in a susceptible host.
Infectivity	The ability of an infectious agent to establish an infection. Quantified as the proportion of individuals who became infected by a defined dose and route of exposure.

Meat juice	The serosanguinous exudate recovered from muscle tissue (meat) after a freeze-thaw cycle. Also see ***processing fluid***.
Monitor	The systematic, ongoing collection and assessment of health data in a population for the purpose of detecting changes over time. Compare with ***surveillance***.
Nonprobability sampling	Any of a number of subjective sampling methods. In swine medicine, commonly used nonprobability sampling methods include ***targeted sampling*** and ***convenience sampling***. Results of nonprobability sampling are not generalizable to the general population. Compare with ***probability sampling***.
Nucleic acid	Macromolecules, either DNA or RNA, that carry genetic information.
Oral fluid	By definition, the fluid collected by inserting an absorptive collector into the mouth (Atkinson et al. 1993). In swine, a fluid mixture of saliva, buccal transudate, and matter from the environment (feedstuffs, manure) is collected by allowing pigs to chew on an absorptive device, e.g. a cotton rope suspended in the pen.
Pathogen	An infectious agent capable of causing disease.
Pathogenic	Possessing the capacity to cause disease.
Pathogenicity	The quality of being pathogenic. Often misused as a synonym for ***virulence***.
Pooled sample (see *composite sample*)	
Premises	A location where pigs are raised, housed, or passed through during commerce.
Prevalence	At a defined point in time, the number of positive individuals is the numerator and the total number of individuals in the population is the denominator. Compare with ***incidence***.
Probability sampling	A sampling design in which all sampling units in the population have the same probability of being selected. Compare with ***nonprobability sampling***.
Processing fluid	The serosanguinous fluid recovered from piglet tissues (testicles and tails) after a freeze-thaw cycle. Also, see ***meat juice***.
Production site	A physical location with pork production facilities and ancillary structures under common ownership or management.
Proportion	A fraction in which the numerator is included in the denominator. Like a ratio, a proportion is a statement of relative frequency. Some (but not all) proportions are rates.
Rate	A measure of the frequency of an event in a defined population. Rates usually have a time component. Incidence, for example, is the rate of new cases over a specific period of time.
Ratio	A fraction in which the numerator is not included in the denominator. All ratios are rates.
Sample (sampling)	In infectious disease surveillance, either the material on which testing is performed (noun) or the process of collecting data or material for testing (verb).
Sampling unit	Level at which samples are collected, e.g. an individual pig, a pen, or a barn.
Serum	The liquid recovered from clotted blood.
Screening test	A testing procedure intended to detect a target in expected-negative individuals or populations. Nonnegative screening results may lead to confirmatory testing or diagnostic workup.
Spatial autocorrelation	Positive spatial autocorrelation is a pattern of infection in which sampling units in close proximity are more likely to be of the same infection status than distant sampling units. Positive spatial autocorrelation is consistent with pig-to-pig transmission.
Specimen	Biological material collected from a body for the purpose of examination, e.g. secretions, excretions, blood, serum, oral fluids, feces, urine, and tissues.
Strain (virology)	A genetically stable virus variant that differs significantly from a reference virus in its phenotypic characteristics (Kuhn et al. 2013).
Subclinical	An inapparent infection, i.e. infection in the absence of clinical signs. Asymptomatic applies to humans; subclinical is appropriate for animals. Also see ***clinical signs*** and ***symptoms***.
Surveillance	The systematic, ongoing collection and assessment of health data in a population with the intent of taking an action when a specific threshold or condition is met. Compare with ***monitor***.

(Continued)

Table 1.3 (Continued)

Symptoms	Often used incorrectly as a synonym for ***clinical signs***. "Something that a person feels or experiences that may indicate that they have a disease or condition. Symptoms can only be reported by the person experiencing them. They cannot be observed by other persons and do not show up on medical tests. Some examples of symptoms are pain, nausea, fatigue, and anxiety" (www.cancer.gov/publications/dictionaries).
Targeted sampling	A nonprobability sampling method in which pigs exhibiting clinical signs consistent with the pathogen of interest are selected for sampling. Targeted sampling increases the probability of detection at lower cost (fewer samples).
Test	Evaluation of a subject for an attribute using an assessment instrument. All assays are tests, but not all tests are assays.
Vehicle	Any nonliving thing or substance that carries an infectious agent to a susceptible individual, e.g. fomites, air, water, and food (Schwabe 1964).
Virulence	A measure of pathogenicity. For example, an influenza A virus isolate that causes death in ≥6 of 8 susceptible chickens (4–6 weeks of age) within 10 days of intravenous inoculation is classified as highly virulent (Swayne and Suarez 2000).

visual documentation of clinical signs and gross necropsy results along with diagnostic reporting. A thorough understanding of clinical bacteriology and virology is also important. A thorough understanding of each pathogen from its ecology, structure, how it's inactivated, its epidemiology, how immunity is achieved, and effective treatments or vaccinations is vital to being able to successfully develop multiple mitigation strategies to minimize each pathogen's impact. Every pathogen is different in many of these aspects, so a thorough review of each will be provided in the upcoming chapters. Having a good understanding of clinical pharmacology is gaining importance in dealing with bacterial pathogens, especially in terms of resistance and the ever-changing regulations surrounding the use of medically important antimicrobials.

Some nontraditional training that some swine veterinarians are starting to receive as additional training is in the area of advanced data analysis. The swine industry is not short in data that is collected, but data summarization and good statistical analysis and interpretation are beginning to become the expectation for veterinarians. The use of newer data analysis programs such as Power BI® or Tableau® are programs that allow veterinarians and producers the ability to automatically summarize and query data without the ability to access and modify the data. Advanced training in trial design and statistical analysis and interpretation is important for a couple of reasons. One is that there will be the expectation that the veterinarian will be involved in product testing, such as comparing different vaccines or therapeutic treatments. In these types of evaluations, it is vital that good statistical design principles are used with proper sample size so that meaningful conclusions can be made. Another reason is that veterinarians will come across a lot of literature (peer-reviewed and not) that will use statistics to justify the author's or company's findings. It is in the best interest of the veterinarian to be able to know how to ask the right questions on how the data was collected and analyzed to understand how the conclusions were drawn.

1.5 Five Production Inputs Model

One approach in thinking about swine clinical disease problems is to think more holistically and ensure that as many aspects of the production process are considered as possible. An example is illustrated in Wellock et al.'s (2008) evaluation of protein supply, weaning age, and enterotoxigenic *Escherichia coli* infection. A review of the epidemiological triad (Thrusfield and Christley 2018) is important since the expression of clinical disease in many cases is the result of a complex interaction between the agent (the microbe causing the disease), the host (the pig in our case), and the environment that the pig experiences. Figure 1.1 illustrates this interaction and examples of targets at each interface that could be addressed or potentially manipulated to improve the likelihood of a favorable outcome.

Too often, veterinarians can get solely focused on the pathogen and do not consider host and environmental factors that contribute to the expression of the clinical disease that the pathogen is causing. A more in-depth analysis of the epidemiological triad involves using the five production inputs model. The five production inputs model of integrating cause and risk factors includes consideration of nutrition, environment, disease, genetics, and management. This model is very useful as it

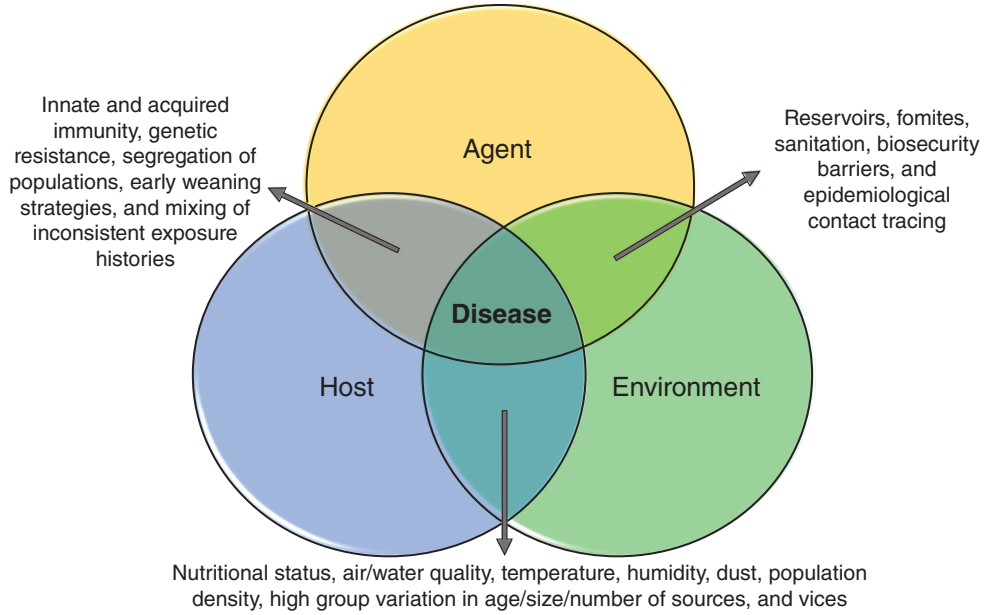


Figure 1.1 The epidemiological triad and areas for focus at each interface.

helps ensure multifactorial causes contributing to the clinical issue of concern are looked at and evaluated. Another advantage is that it allows for other nontherapeutic interventions that can help reduce the incidence of clinical disease. The disease (pathogen) component is typically the first focus of veterinarians and is the primary focus of the chapters in this book. The nutritional aspect of veterinary medicine has become more important in recent years as feed prices have dramatically increased. High feed prices have promoted the use of alternative feed ingredients, including the use of dry distiller grains (DDGs). An example of this is the increase in the clinical expression of *Brachyspira* spp. when diets high in DDGs are being fed to pigs that might be subclinically infected when compared to being fed more traditional diets (Wilberts et al. 2014). Another example is the level of protein being fed to pigs post weaning and the impact that higher levels of crude protein in the post weaning pig can have on the expression of *E. coli*. The environment also plays a key role in the health and welfare of pigs, as is mentioned throughout this book but especially in Chapters 3 and 5. Improper ventilation design or execution that causes chilling of post weaning pigs frequently results in *E. coli* outbreaks, where the clinical disease is actually the manifestation of an improper rearing environment for the pigs. Genetics (Chapter 4) is an input that can be confusing many times, as genotype and phenotype expression are very complex, especially when focused on clinical significance. One example of genetic impact of disease expression would be the presence or absence of the fucosyltransferase modified glycan receptor for F18 *E. coli* that either allows or denies the attachment of *E. coli* to the intestinal epithelium in nursery pigs. Finally, management, especially with all the people involved in the various processes of raising pigs today, is a very integral part of livestock production and can have a tremendous influence on the health, welfare, and success of raising animals. With the urbanization of the world and increasingly fewer people with an agricultural background, training workers in basic husbandry practices is becoming an integral part of any successful operation. New entry-level workers generally have limited, if any, experience and knowledge on how to raise pigs. In these cases, some simple, basic husbandry items can contribute to disease conditions, such as failing to make sure that the water is on and functioning properly or how to bring pigs slowly back onto water if they have been deprived for more than 24 hours.

The five production inputs model works to integrate the interactions of different factors that may be working together at the same time and are influencing the health of a pig. They also serve to evaluate potential root cause(s) of the outbreaks, rather than just focusing on treating the clinical symptoms of the disease. This can be useful in preventing future outbreaks by finding potential multiple intervention points. Figure 1.2 demonstrates the interaction of possible contributing factors associated with a simple example case of post weaning colibacillosis.

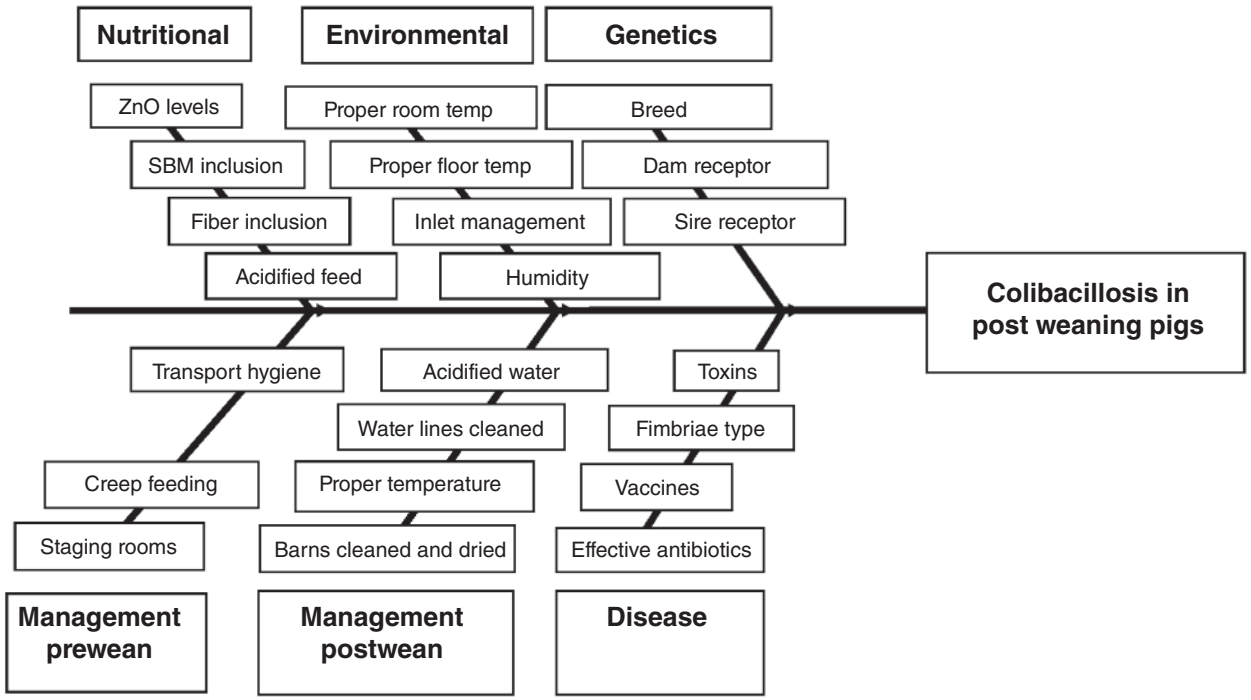


Figure 1.2 Fishbone or Ishikawa diagram illustrating the organization of observations in each of the five production inputs in a case of colibacillosis among weaned pigs.

1.6 Understanding Pig Flow

1.6.1 Defining Pig Flows

In commercial pork production, the assembly of individuals into groups and the movement of those groups of animals through different phases of production and/or facilities is referred to as "pig flow." Pig flows generally have some common characteristics but also may have unique features. Describing a flow means defining the sources of pigs, locations where they might be housed, the movement between those locations, and the design of the facilities among other things. Once a particular flow is established, it may remain functional for many iterations or subsequent groups of pigs, which means that describing a lot of pigs as part of a specific flow provides meaningful summary information about that lot's experiences, exposures, and management or, in other words, provides part of the signalment. Pig health and performance can vary significantly between pig flows because of the significant role management and the pig's environment play in disease (Figure 1.1). These significant variances can exist between groups of pigs with a common origin farm if they are moved to growing phase facilities at different locations with different management processes. Changes to characteristics of a pig flow can successfully impact health even when the changes do not include disease-specific interventions. Some disease processes are exacerbated by how the pig flow is constructed or being managed. In some cases, the veterinarian should challenge the decisions of how flows are being managed, as some disease conditions can be mitigated by making a change in how the flow is being managed. An example is making the decision to depopulate a continuous flow nursery to eliminate endemic disease if the source farms are stable. Specifically, Diana et al. (2019) demonstrated an association between production flows and tail, ear, and skin lesions.

1.6.2 Commingled Versus Single Sourced Flows

From a health perspective, typically the most likely way to introduce a pathogen to a group of pigs is by adding pigs to the group with a different health status. As a result, a common health management approach is to limit the number of unique sources of pigs in a group or in a flow. Another characteristic of pig flow that improves health is the formation of static rather than dynamic groups. Static groups do not add new pigs during the lifetime of the group and typically do not remove animals except

for mortalities. As such, the group/lot has a static membership. Static groups are easier to define as a "lot" for business and expense-tracking purposes, and the term "lot" is frequently used instead of "group" as reference in many systems. Ideally, static groups are composed at birth with animals that are born on a single farm in a narrow timeframe (commonly 1 week). These static groups then move through the housing system to market. Static groups also facilitate lot-level recordkeeping versus using individual animal identification for the purposes of documenting treatment, animal movements through regulatory jurisdictions, and cost accounting. As most breeding herds farrow in weekly production cycles, each weaning is placed into a room or barn, depending on the size of the post weaning facility (nursery or wean-finish barn). In some cases, only one breeding herd contributes to the filling of a room or barn, and in others (single farm flow), there are multiple breeding herds that contribute (commingled flow). When doing disease investigations, it is important to understand if the disease process is limited to a particular site or whether this is a repeated disease issue seen in multiple sites within the flow. If the problem is found to be repeated in several sites within the flow, then recommendations might involve making changes that will control or eliminate the issue from the entire flow.

1.6.3 All-in/All-out Versus Continuous Flow

Animal groups that practice "all-in, all-out" (AIAO) pig flow create an opportunity to interrupt disease transmission between successive groups on a site. The objective is to transfer all animals from the site before the next group of younger animals begins filling the site. Ideally, AIAO is accomplished at the site level, meaning the entire site is empty before new pigs arrive. However, on larger sites and in the farrowing phase, AIAO by room, barn, or airspace may be practiced in conjunction with biocontainment practices that lower the risk of personnel movements between rooms, barns, or airspaces.

1.6.4 Barn Fill Time

Larger barns house more pigs and, therefore, require a larger source farm to fill in a short timeframe. Ideally, a barn is rapidly filled to functional capacity in the shortest time possible to optimize function of any engineered environment, keep the pigs in a narrow age range, and facilitate group-level management, such as using an automated feed system that provides the entire barn with the same diet. A group of growing pigs that has a narrow age range is more likely to exhaust maternal antibodies, consistently allowing for vaccines and other interventions to be applied at the correct timing for all members of the group.

1.6.5 Defining Lots or Groups

Once a room or barn is filled, or a breeding group assembled, this constitutes a lot or a group. Breeding groups on sow farms are often assembled during breeding, with all animals bred in a week considered part of the same group. Group size at the sow farm depends on facility size. Growing pig groups are determined by the flow coming from the breeding herd but typically range from 500 to 2400 head, and the age spread typically ranges from a few days to no more than 2 weeks to feed them consistently according to a common feed budget. The group (lot) once established is how productivity, inventory, mortality, treatments, environmental, feed, and many other accounting functions are tracked. They serve as cohorts for comparisons of different groups on the same site or between different sites and can be useful in determining the timing of disease occurrences, especially if those infections are endemic and coming with the pigs from the breeding herds.

1.7 Field Investigation and Case Management Process

Figure 1.3 describes the basic process of collecting evidence, developing a presumptive diagnosis, selecting appropriate diagnostics, refining the diagnosis, implementing treatment, and following up on outcomes. Additionally, chapters in this edition of *Diseases of Swine* that provide useful information or tools for each step are indicated. Key tools for making the useful, systematic observations that characterize EBM are described in the following sections.

1.7.1 Fishbone Diagrams

Often, information can be accumulated throughout the investigation (ad hoc) from a variety of sources. Figure 1.4 demonstrates how an Ishikawa or "fishbone" diagram can assist in ordering or classifying information to help determine relevance to a specific problem or chief complaint. Using it allows for individual risk factors, observations, test results, data, or elements of history to be sorted into broader categories, including but not limited to the elements of the five production inputs model. Once organized into broader categories, it often helps to focus further investigation or may even identify multiple potential intervention points or action items. Figure 1.2 illustrates its use in a case of colibacillosis in post weaning pigs.

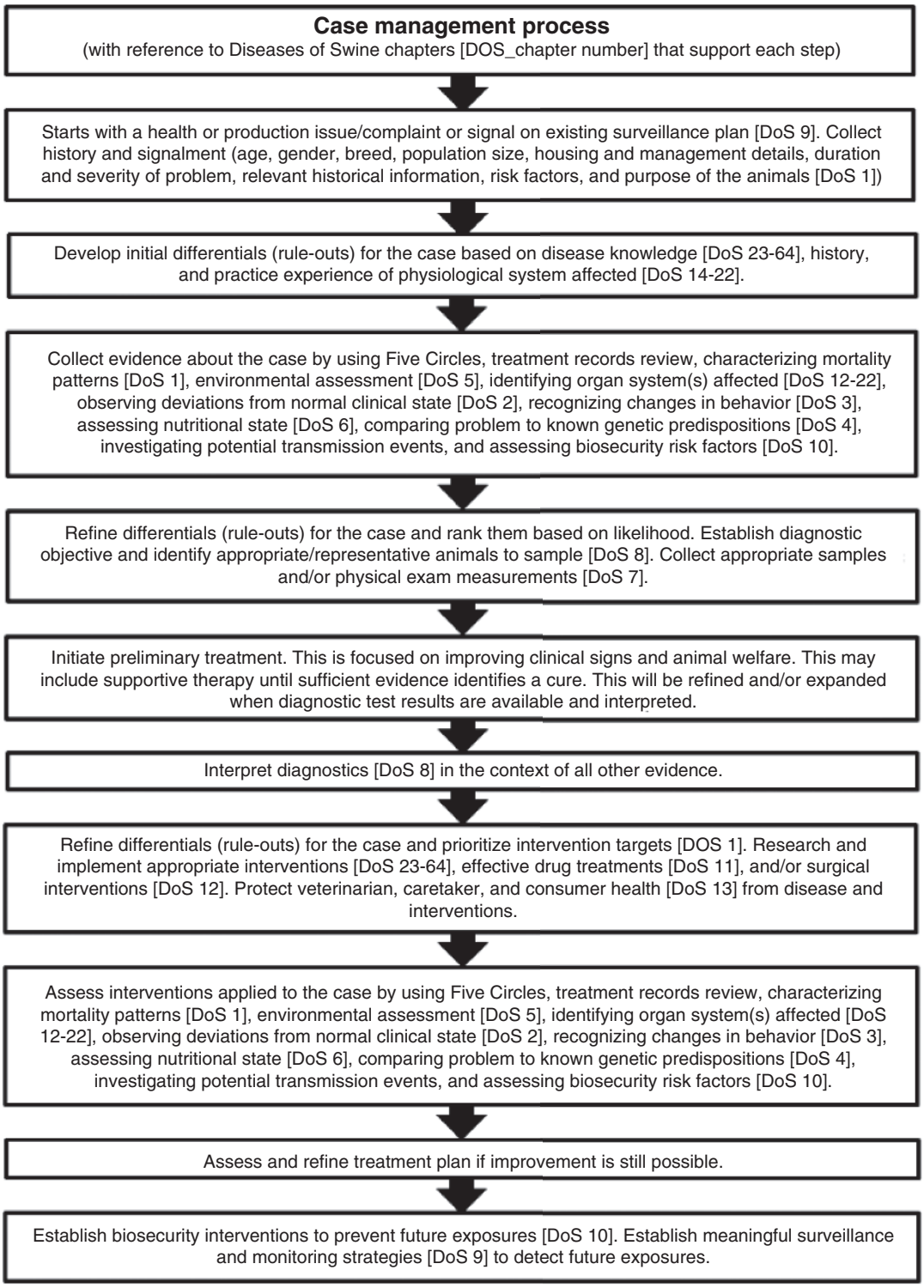


Figure 1.3 Case management process.

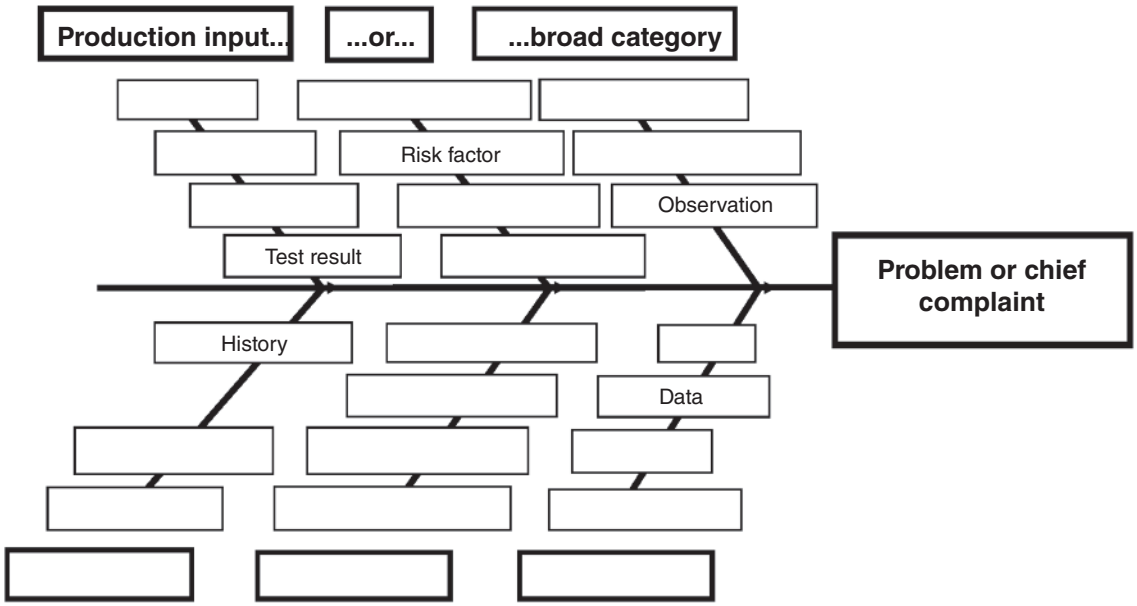


Figure 1.4 General structure of an Ishikawa or "fishbone" diagram.

1.7.2 DAMNIT-VP Scheme

This approach focuses on producing a complete differential list to ensure that all possibilities are considered, so as to avoid too narrow a focus on infectious diseases. The following list helps identify the terms associated with each letter of the acronym:

D = Degenerative
A = Anomaly
M = Metabolic
N = Nutritional or neoplasia
I = Inflammatory, infectious, or immune-mediated
T = Trauma or toxicity
V = Vascular
P = Parasitic

One of the disadvantages of this acronym is that it does not help prioritize the list. It also encourages veterinarians, especially those in their early careers, to generate a very long list of possible, yet not probable, differentials. It is very easy to focus on pathogens only, and this list is helpful to take a more comprehensive approach to the development of a differential diagnosis list.

1.7.3 Open-ended Questions

The process of data collection should not be restricted to the veterinarian's observations. It is very helpful to ask others working on the farm or within the operation for their perspectives. This should be done not only by upper management individuals (i.e. managers or owners) but also by the workers themselves. Often, the managers make many assumptions as to what they believe is being done on the farm, but the actual workers have a different perspective. This may be due to lack of training, poor communication of protocols, or inadvertent deviations in protocols of which participants are unaware. This is why it is useful to ask the same questions to different people in the same production system for confirmation and to assess consistency. Questions should be formulated as open-ended rather than seeking a simple yes or no answer. It is also helpful to have employees demonstrate how to perform a task ("show me how") rather than providing an explanation ("tell me how"). This ensures that the actual process and technique are observed and allows evaluation of significantly more details than are apparent in a verbal description. This has been especially useful in troubleshooting intensive, high-impact procedures such as heat detection and artificial insemination.

As a site visit is performed, it is also important to examine storage and utility areas and investigate refrigerators or medicine cabinets. This process should help support and validate the different workers' answers to questions regarding processes and protocols. For example, an operation that claims routine vaccination of sows pre-farrowing and yet has no vaccine on site may need further evaluation and discussion to ascertain vaccine management and handling procedures. A second example may be a protocol

describing a temperature to store semen but no thermometer in the semen storage unit.

1.7.4 Five Circles Approach to Population Evaluation

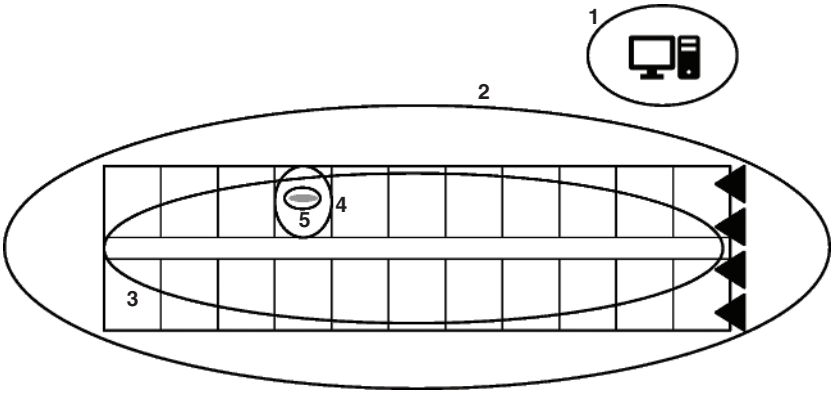
One of the most important concepts of a proper herd evaluation is to be consistent! It is critical to ensure that herd examinations are performed in a consistent manner to be thorough and efficient and minimize the opportunity for missing something important. A checklist may be helpful for specific, routine evaluations but often not practical for a complete and thorough investigation. It is important to have alignment with the producers/caretakers on priorities for each visit. This may adjust how you approach the site visit. Checklist approaches limit the problem-solving ability of the veterinarian and are especially poor approaches to new problems. There are too many areas of interest as well as too many differences in facility type and design to make a single, valid checklist across all farms. Farm-specific checklists or checklists for aspects of an operation can, however, be useful.

One systematic approach involves the concept of the Five Circles (Figure 1.5). The overall objective is to be systematic in the evaluation of an operation to make sure that all relevant information is evaluated when looking after pigs' health and welfare. Each successive circle becomes more focused, culminating in the evaluation of individual pigs. The most important question the veterinarian must be able to answer after going through the Five Circle process is: "Is there currently a disease or welfare issue or is one imminent?"

The concept of the Five Circles is to obtain a systematic and complete picture of the clinical status of the site. It provides a systematic view, which is important in deciding what interventions need to be implemented to mitigate the effects of the current disease. It starts with a big-picture overview and then narrows the focus to individual pigs. It helps separate unrelated individual pig afflictions from whole herd disease problems, both of which need to be addressed, but priorities and recommendations will be different depending on context and the client's goals and objectives. The role of the veterinarian is to help guide the client to maximize the impact of any intervention. Information obtained from this systematic approach will also help differentiate what issues are primarily due to pathogens and which ones are being confounded or even caused by management practices or management failures. It will help veterinarians formulate a more complete assessment of the prognosis and expected outcomes of the current health situation. Once mastered, the process can be quick and very efficient.

1.7.4.1 Circle 1: Evaluation of Records and Electronic Information

Unlike the remaining circles of the population evaluation sequence, records evaluation often proceeds with a physical visit to the site and starts with centralized, group data on performance, recent production processes (such as moving to a new phase or production site), and morbidity and mortality. Records review prior to the visit may include past diagnostic reports, production performance reports, documentation of treatments (generally an indicator of morbidity), documentation of mortality, and



1—Evaluation of electronic records, history, and previous diagnostics
2—Complete circle evaluation of the *outside* of the building/site
3—Complete circle evaluation of the *inside* of the building
4—Complete circle evaluation of individual *pens*
5—Complete circle evaluation of individual *animals*

Figure 1.5 The "Five Circles" approach to population evaluation.

documentation of interventions. Production phase, farm size, and management structure will impact how much information is available for review prior to visiting the site, where records review will continue with locally maintained records kept on site.

Data collection begins with a history and signalment gathered by using open-ended questions to further refine the problem. Good open-ended questions can be effective in gathering data as the caretakers are in the barns and with the pigs most often, but be mindful that they come with their own biases about what is going on and what is causing the problem. It is necessary to be thorough with questions drawing on past experiences to formulate the line of inquiry. Questions should be directed not only at new information but also to verify the information received from other sources.

Information collected will be things such as age(s) and number of animals affected, clinical signs observed, treatments given so far, and the response to these treatments; vaccination histories as well as the flow history can be insightful in beginning the development of a differential diagnosis list as well as things to investigate during the site visit. A review of both on-site and off-site records is important data to note and should be cross-checked with the history and signalment from the on-site personnel. Once all the background information has been obtained, it is time to begin the process of developing the diagnostic question with the remaining circles.

1.7.4.1.1 Breeding Herd Records

Computer records can be accessed either through daily/weekly reports provided to the farm or through direct access to a computer. The number and variety of reports that are available from computerized sow record systems precludes discussion here. It is important for the swine veterinarian to understand and objectively evaluate different herd performance parameters. The greatest advantage of computerized record systems is their ability to summarize relevant data in many different ways and compare it to relevant internal or external benchmarks to help identify those performance parameters where there are opportunities for improvement.

When looking at reports, it is important to remember that data is usually summarized based on time or by a cohort. In a time-based report, data is simply attributed to a particular period (e.g. days, weeks, months, years). For example, January breeding and farrowing numbers summarize data for all the sows that were bred in January as well as the sows that farrowed in January, which are two distinct groups of animals. This information is helpful in monitoring the overall herd performance, but it is not helpful in evaluating cause and effect within a particular group. To better evaluate a particular group, a cohort-based report must be used. In this case, all parameters reported are specific to a common group of animals, so the breeding and farrowing data pertain to the same group of animals, although accumulated at different dates. This cohort-based report is also very useful in evaluating the effects of different interventions. For breeding herds, there are many different types of records that are kept on site. These records can vary in form and content from hand notes to daily and weekly production totals posted on a whiteboard all the way to an actual computer on site with a computerized breeding herd-tracking software program. Log sheets are very helpful in ensuring jobs are routinely done. For example, a simple semen log can track the date, time, and current temperature of the semen storage unit and initials of the individual who rotated the semen (e.g. manually resuspended semen in extender by gently rocking the semen bags/bottles back and forth). The advantage of having this type of manual record is that it ensures this important job is done routinely, and having individuals write down their initials facilitates accountability. It is a reality that in operations with multiple workers, duties are sometimes not performed because a worker believes that someone else was doing the job. Whiteboards are commonly used to evaluate daily and weekly production totals in breeding herds and can be useful in quickly looking for any recent abnormalities that can be focused on during the visit. These numbers are updated daily, whereas computer-based reports may not be as current.

1.7.4.1.2 Growing Pig Records

A status report may be available that describes all the groups currently in production within a flow. Most of these reports are in a spreadsheet type format with a single line for each group or lot. An example of a type of this report is in Table 1.4.

This summary allows for visualization of the number of groups within a flow and their relative performance. This type of information is useful in evaluating if there are issues with a distinct group, a single site, or the entire flow. It also gives a reference to when the mortality is occurring within a flow, if the problem is with the source of the pig themselves. Sow farm health is an important driver in wean-to-market mortality and accounts for 68% of the variation (Magalhães 2021), so reports like this are helpful to understand in diagnosing the extent and source of elevated mortality.

On-site records for production sites should ideally have inventory, mortality, environmental, water consumption, and treatment information. The minimum requirement for treatment records for Food and Drug Administration compliance include date, animal ID, product name, dose,

Table 1.4 Example of current status report.

Source	Sow farm 121												
Group ID	**Site ID**	**Date group started**	**Weeks on inventory**	**Avg weight in**	**Total dead**	**Current mortality**	**Number head started**	**Current inventory**	**Last deed delivery**	**Medication of last feed delivery**	**Weekly mortality**	**% Weekly mortality**	**Projected marketing date**
2023188051	Ewington 5	2/13/2023	5.2	14.8	18	1.7%	1075	1057	Starter	No meds	7	0.7%	7/17/2023
2023188061	Ewington 6	2/20/2023	4.2	14.2	12	1.1%	1058	1046	Starter	No meds	10	0.9%	7/24/2023
2023188071	Ewington 7	2/27/2023	3.2	13.7	7	0.7%	1005	998	PS2	DenCTC	2	0.2%	7/31/2023
2023188081	Ewington 8	3/6/2023	2.2	13.2	3	0.3%	960	957	PS1	DenCTC	1	0.1%	8/7/2023

route, person administering (or initials), and product withdrawal time. Mortality records are helpful in determining the total number of pigs in the original lot, number of mortalities, reasons for mortalities, and the chronology of mortalities to date. It may also be useful to designate the mortality as acutely affected (acute) or chronically affected (chronic). This is important to help understand the progression of the mortality in the group. A good practice is to also record a presumed "death reason" and educate clients on how to rigorously evaluate mortalities and record such details. However, research has shown there are significant differences between recorded and actual death reasons. To facilitate this process, the focus should be on the actual observations that can be accurately made by caretakers. For example, it is difficult for a caretaker to diagnose *E. coli*-associated diarrhea as cause of death. Instead, the mortality should be recorded as due to diarrhea. There should also be a secondary categorization to identify whether the animal died on its own or was euthanized. Practical and more valid mortality records can be collected by simply narrowing down the options provided, focusing on general clinical signs rather than a specific disease etiology, and training all individuals on how to properly categorize mortalities. Environmental records may include daily water consumption and daily high and low barn temperatures. This information is easy to collect in today's modern facilities and can be helpful (especially the water) in predicting an oncoming disease outbreak issues with proper water delivery, or other water system malfunctions. The high and low barn temperature recordings are helpful in identifying possible concerns with the ventilation and climate control systems. It is advisable to utilize an independent high–low thermometer to record temperature fluctuations in addition to using the barn's electronic control system in order to validate the proper function of the controller. Finally, these records can be used to validate that each group of pigs is being checked at once daily.

The most important part of any data collection is the desire to act when an abnormality is detected. When a veterinarian requests data to be collected by workers or caretakers, effective communication should outline the importance of the data, how it will be used, at what threshold they are expected to act, and the consequences of failing to act. For example, simply recording the daily temperature of the semen storage unit has no value unless action is taken when the temperature is outside of the desired range.

1.7.4.2 Circle 2: Outside of the Building

The second circle involves walking around the outside of buildings to assess the overall site. This second circle is especially important when visiting a new site. Evaluation of the outside of a building has value both clinically for the pigs and practically with respect to informing the veterinarian about the caretakers' attention to maintenance and facility management.

As one walks around the site, biosecurity risks for the operation will be better understood. Are there any other hog sites in proximity? Is the health status of these other operations known? How close are public roads to hog buildings? What appears to be the traffic pattern for this particular site (feed delivery, removal of dead carcasses, employee parking)? How well maintained is the site? If the site is not well maintained, could it be due to lack of attention to details, insufficient staffing, or tight budgets? Either of these reasons would suggest that the veterinarian's recommendations should be tailored to accommodate these realities. For example, a manager who is very attentive to detail is more likely to follow a complex or detailed treatment protocol. Note that season of the year, current weather, and time of day may influence what is seen at this level and needs to be considered.

1.7.4.3 Circle 3: Evaluation of Inside of the Building and Office

The third circle involves walking through the inside of the building. In this case, the objective is to get a better feel for the overall environment of the pigs, covering all regions of the building. One must walk from one end of the building all the way through to the other side. If one takes too long to walk from one end to the other, it becomes more difficult to identify ventilation differences as one starts to become adapted to the new environment.

Stocking density is also evaluated at this time. It is important to note differences in stocking densities between pens as well as between barns. Lower stocking densities may indicate high mortalities in a particular pen or barn. Recommended stocking densities and the impact of density on health are described in Chapter 5, and expected pig weights based on age and growth rate are described in Chapter 2.

Pig activity and the general health of all pigs in the barn are evaluated at this time. Note that time of day and season impact expected behavior. Winter feeding patterns are most active in the middle of the day, while summer feeding behavior is bimodal with rounds of feeding in the early morning and late evening. Is there coughing, sneezing, or signs of diarrhea? The magnitude of the problem should be quantified. This is easily done by estimating the number of affected pigs in a pen as well as the total number of pigs in the pen. For example, if there are approximately 5 pigs coughing in every pen and there are around 25 pigs per pen, then it would suggest that approximately 20% of

the pigs are affected. On the other hand, if it is found that only one or two pigs are affected in every other pen, then it would suggest the prevalence to be approximately 2–4% of the barn. The quantification of prevalence does not have to be exact, as usually we are more concerned with the size of the magnitude of the problem (60 vs. 10%) rather than knowing the exact prevalence of the clinical sign (8 vs. 12%). Determining general prevalence has three main goals. It allows for the correct perspective on the extent of the problems (i.e. is there currently a disease or welfare issue, or is one imminent?). It helps to differentiate herd problems from individual pig issues, thus helping to determine the correct level of treatment (i.e. whole herd treatment or individual pig treatments). Finally, it provides a baseline for determining the effect of any intervention. This is especially important as although coughing may still be present after 5 days of treatment, the change in prevalence from 25 to 4% is a good indicator of improvement suggesting that further intervention may not be warranted.

1.7.4.4 Circle 4: Evaluation of Individual Pens

The fourth circle is performed by doing an evaluation of individual pens. Based on the third circle, pens identified in the evaluation of the room are selected for further evaluation of the extent of the problem. Veterinarians must get in the pens with pigs. One cannot make a full assessment of the problem by simply walking the alleyway of the barn, as many pig issues will be missed. This is the point in time that feeders and waterers are also checked for proper function.

The overall behavior/attitude within the pen is evaluated by identifying individual pig concerns as well as pen concerns. Differences in sizes of pigs in a pen are again noted at this time. It is especially important to always ask if any type of size sorting (regrouping by size) has occurred as well as knowing the expected age difference for the barn. This is a suitable time to look closely for evidence of diarrhea. Often the diarrhea is first noted by the fecal character that may be present on the floor or walls of the facility, and extra observational time is needed to identify the individual pigs that may be affected. Evaluation of the effective ventilation at the pen level is also important as drafts from the inlets or curtains can impact the pigs in a certain pen, which may not be reflective of the entire barn.

By "nesting" the evaluation of pens in the process of evaluating the room (Circle 3), all pens can be evaluated in the room. As the observer tours the room, each pen is evaluated along the way. This allows for the detection of subtle changes that might be specific to one part of the room and a complete evaluation of all the pigs. Sampling a subset of pens as "representative of the whole room" risks missing early localized changes that are significant. Individual pig issues of concern, especially those related to welfare (severe, chronic, or moribund individuals), should also be identified at this time.

1.7.4.5 Circle 5: Evaluation of Individual Pigs

The fifth and final circle involves a complete evaluation of individual pigs. Pigs are evaluated from head to tail. Anomalies are noted as well as suspected chronicity of issue. Rectal temperatures are taken at this time as a measure of the presence of infectious disease processes and stage of infection (e.g. fever tends to suggest an acute infection). One of the cornerstones of effective disease management is the early detection and intervention of clinically affected pigs. The identification of these pigs is the most important part of that and requires diligent, daily observations of each pig within their environment, as part of the Five Circles evaluation discussed earlier. It is vital that veterinarians can teach the caretakers how to identify and differentiate pigs in the various stages of clinical disease. Individual Pig Care was a management training tool, created by Zoetis, to teach and train caretakers how to do this. A vital piece of this was the classification of pigs into various categories of clinical disease expression, based on how long they had been clinically affected. This video (https://vimeo.com/user111508157/ipcare) provides examples of pigs in various degrees of the clinical expression of disease. Pigs that are classified as "A" pigs are typically the most difficult to find, as they are acutely ill (less than 24 hours) and may only exhibit depression and slight gauntness as the only visible signs of illness. "B" pigs have been affected for 1–2 days and can be characterized by definite weight loss as evidenced by gauntness and the beginning of the visibility of the backbone along with a rougher appearing hair coat. "C" pigs are the most obvious pigs to identify as they have been affected for multiple days and show extreme weight loss and a very prominent backbone. While "C" pigs are much easier to identify for caretakers, they also are less likely to respond to treatment, so it is vital to train them to always be looking for A and B pigs, as treatment success is better the earlier they are identified in the course of clinical disease. "E" pigs are those that need to be humanely euthanized because they show inadequate improvement or have minimal prospect for improvement after 2 days of intensive care, are severely injured or non-ambulatory pigs with an inability to recover, or are immobilized with a body condition score (BCS) of 1.

For breeding herd examinations, the body condition of females should be evaluated periodically. When making recommendations for feed or feeding changes, the stage in the reproductive cycle must be considered. Females entering the farrowing house should be in their best body condition (target BCS of 3), while gilts exiting the farrowing

house (end of lactation) will have lower BCSs. Feed changes are best executed by making small changes (0.5–1.0 kg) in the daily feed allotments. Recently, a sow caliper device has been created and used to measure BCS and to make feed adjustments, as it is a more reliable measurement of sow body condition than subjective visual scoring alone (Knauer and Baitinger 2015) more objectively.

This is also a suitable time to identify individual pigs requiring treatment as well as acutely infected animals that would be useful for diagnostic sample collection. Animals appropriate for euthanasia, necropsy, and tissue collection are also identified at this time.

1.8 Selecting Pigs from a Population for Diagnostic Testing

When selecting pigs for antemortem or postmortem diagnostic sample collection, there are several important points to consider:

1. Animals must be selected that truly represent the major clinical signs of concern in the herd.
2. Animals should be in the early stages of the disease process. The selection of acute cases will increase the probability that the primary causative agent and compatible lesion are identified.
3. An animal that has received no antimicrobials or therapy is usually preferred for identifying primary causes of disease. When investigating treatment failures, an animal that has been treated may be preferable.

If it is determined that antemortem sampling is not adequate and if the mortality available on the farm for postmortem examination does not fit the ideal criteria listed above, the practitioner may choose to euthanize a pig for the purpose of postmortem examination and diagnostic testing. The practitioner should consider that an animal's life will be sacrificed for the good of the herd, and the three selection criteria listed above should be utilized in determining the appropriate pigs.

The number of animals selected for necropsy and tissue sample collection depends on the objective. Generally, animals that are found dead are necropsied first. Mortalities are necropsied until a pattern of disease process is apparent, which suggests the primary herd disease issue rather than unrelated individual animal afflictions. Based on necropsy findings and clinical evaluation, representative live animals are euthanized for fresh tissue sample collection. The number of animals euthanized depends on the individual case presentation and necropsy findings in the euthanized pig. When considering multifactorial etiologies, it is important to remember that not all animals in the herd will have all pathogens present at any one time point. This suggests that in a large herd, it may be necessary to euthanize sufficient animals to completely represent the full range of clinical and pathological findings and to identify the multiple, interacting disease agents. In other cases where there may be only one primary pathogen of concern, one or two euthanized pigs may be sufficient to answer the diagnostic question. The goal is to sacrifice the least number of animals yet maximize the diagnostic value for the benefit of the rest of the herd, thereby benefitting the current group as well as future groups. Live-animal (antemortem) sampling is commonly done. For some pathogens (e.g. influenza A virus via nasal swabs or oral fluids), simply finding the agent in the herd is all that may be necessary. In other cases, finding a common, endemic potential pathogen of interest (e.g. porcine circovirus type 2 [PCV2]) must be in association with compatible lesions to support the role of such an agent in the current clinical presentation.

1.9 Prioritizing Diagnostics

In simple terms, and above all else, a proper diagnostic investigation must begin with one or more well-defined questions or specific objectives that establish reasons for testing and that guide selection of an appropriate diagnostic process. These factors help guide the selection of an appropriate pathway in the diagnostic process, based on the diagnostic question and reason for testing, which will ultimately guide the diagnostic investigation (for more on this topic, see Chapter 8, especially Figure 8.6). All subsequent aspects of the investigation, including animal selection, selection of sample types, the number of samples required, and the selection of particular diagnostic tests with estimates of their diagnostic sensitivity and specificity, are dependent upon the clinical context and specific questions raised.

A diagnosis is synthesized by the swine veterinarian from all manner of diagnostic tests that help discover both proximate causes (the infectious agents or specific insult types associated with lesions or disease states, derived from answering diagnostic questions) and ultimate causes (risk factors leading to disease expression, derived from building case histories). Both causes are important for deriving appropriate interventions. Three objectives of veterinary diagnostic medicine are to (1) ascertain proximate and ultimate causes associated with a given disease or disorder of an animal or population of animals, (2) describe the pathogen status of a population and whether it is changing or static, or (3) declare as free from disease or pathogens for interstate or international movement. These form the basis

for creating appropriate and well-defined diagnostic questions that are the essential and necessary first step prior to initiating a diagnostic investigation. These concepts are needed for purposeful integration of the collected evidence and establishing causality.

1.10 Process to Arrive at a Definitive Diagnosis

The veterinarian should have a working list of differential diagnosis based on the history and signalment that have been collected after visiting with site personnel and a review of the records. The site visit is the crucial next step to verify the history and signalment received and look for things that may have been missed in terms of the behavior of the animals and the environment they are living in. It is best to use the Five Circles methodology for the site visit as was outlined earlier in this chapter. The goal is to confirm the clinical signs that were reported, the severity of the clinical signs, and the duration of these signs as well. This is also the time to look for any other clinical signs that may have not been reported or any other area of concern that may have been missed by the caretakers and not reported.

While conducting the individual animal evaluation, it is important to notice acutely affected animals that are good representations of the clinical signs of concern in the population. It is useful to mark several of them throughout the barn in an effort of defining a small population from which to select potential necropsy and diagnostic specimens.

When the on-site evaluation is finished, it is time to begin the necropsy process. If available, performing necropsies on already dead animals is of no additional lost cost to the pig owners and may provide some discernment on the differential diagnosis list based upon the gross pathology noted, provided that the dead pigs are recently deceased and in relatively good condition. It is important to be thorough and to have a systematic process of performing necropsies so that nothing is missed or overlooked. During the necropsy, close attention to any alterations from normal (lesions) that may be associated with pathological changes is critical to note. Classification by body system is useful. When necropsying dead pigs, carcass decomposition and postmortem artifact may resemble meaningful lesions. Refer to Chapter 7 for more details on the necropsy process.

After completion of the necropsies on dead pigs, use the findings and go back to the differential diagnosis list. The combination of signalment, history, live pig observations, response to treatment, and necropsy results should be used to reprioritize the initial and establish the final differential diagnosis list based on all the information acquired. You will now use this prioritized and ranked list to form your diagnostic questions to answer.

Figure 8.6 can be used to help work through the diagnostic questions surrounding the prioritized differential diagnosis list. The main premise is that if the confirmation of the differential is going to change the intended intervention plan. If the answer is no, then it is important to question the value of spending the money on the diagnostic tests, unless there are other purposes, such as an epidemiological investigation, or if the status of the site impacts management of nearby units.

Once the pathogen is identified that requires diagnostic confirmation, the next step is to seek what kind of assay(s) to use in order to confirm the diagnosis. The choices are antigen, antibody, lesion, or lesion-based assay (fluorescence in situ hybridization (FISH) and immunohistochemistry (IHC)) or some combination of these. Which of these tests to use will depend upon a variety of factors, such as time since exposure, pathophysiology of the disease, prior vaccination and medications, and it is expected to be present in the substrate or tissue where it is found. There is no universally best or preferred diagnostic test, and often, several tests in parallel provide stronger evidence for a cause of disease. Figure 1.6 describes the diagnostic assays expected to be effective in various clinical scenarios, and Chapter 8 addresses this topic in more detail.

One additional step is to decide if determination of the disease or infection status of the population or individual animals is important. For population-based diagnostics, it may be necessary to have a working knowledge of the estimated prevalence in the population and utilize epidemiological tools to determine the sample size necessary to successfully determine the status. This is especially true as the population-based test samples animals individually. With the sensitivity of polymerase chain reaction testing and more population-based sampling methodologies (e.g. oral fluids), it may not be quite as important to determine exactly how many animals to sample, as these strategies sample many more samples than necessary to find positives in low-prevalence situations. If diagnosis is needed at the individual level, then collection of the appropriate tissues can take place.

The superior choice for the collection of tissue-based diagnostic samples will be from untreated animals that are displaying clinical signs that are representative of the entire group. Select two to three of these animals and euthanize them to collect the appropriate tissues to answer the diagnostic question and either rule in or rule out the pathogens on the differential list. The best candidates are going to be animals that are in the acute phase of the clinical signs that are part of the chief complaint. It is going to take a financial commitment from the owners to allow these pigs to be

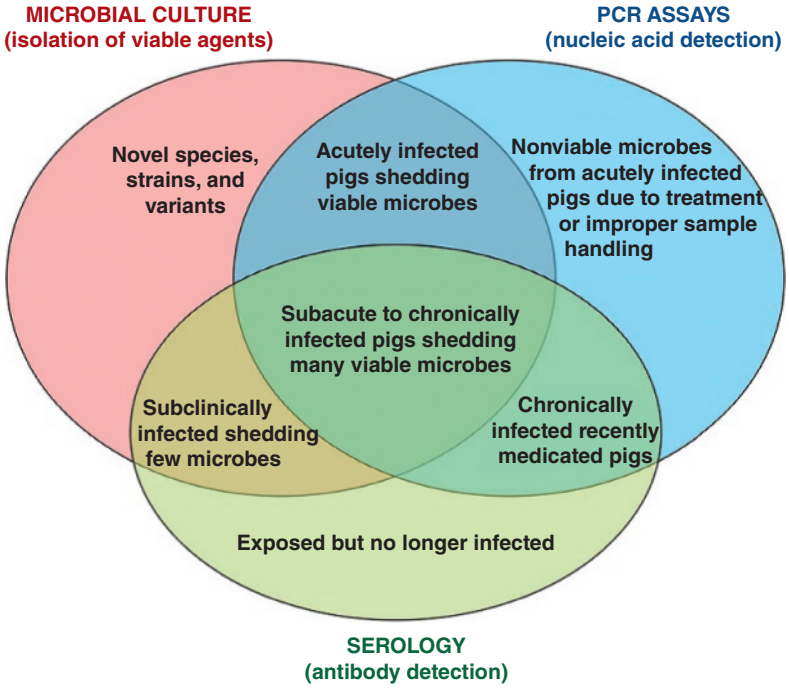


Figure 1.6 Diagnostic assays expected to be effective in various clinical scenarios.

sacrificed, as they are also likely to be in good condition with a good likelihood of recovery if treated properly. The owners may prefer that animals are selected that have been treated and not responding to those that are in the cull pen. These animals are not the optimal diagnostic samples, as they may be more advanced in the progression of their disease, which may not be conducive for the detection of the offending agents, and previous treatments can mask bacterial pathogens.

1.10.1 Sufficient Cause Versus Necessary Cause

It is important to distinguish between "sufficient" and "necessary" causes of disease. In an epidemiological sense, "necessary" causes must be present for disease to occur every time. In some situations, but not all, a "necessary" cause alone may be all that is required to cause disease. However, in some situations, a necessary cause alone may not be enough to cause disease, and additional factors may be required. "Sufficient" cause refers to the set of conditions that will cause disease. There may be several different "sufficient" causes or combinations of factors capable of causing a particular disease. For example, to have porcine circovirus–associated disease, it is necessary to be infected with PCV2. However, not all pigs infected with PCV2 virus become diseased. So, infection alone is a necessary but not sufficient cause of clinical disease due to PCV2. There are several pathogens in swine that also exist as normal (or expected) components of the animal's microbiome but produce disease when they gain virulence factors or gain access to a normally protected environment within the pig that they are routinely excluded from. One that is frequently encountered is disease due to *Streptococcus suis* (see Chapter 57 for more information). The location of the sample that leads to a positive diagnostic test impacts the evidentiary value of the organism's contribution to the disease state. A *S. suis* isolate cultured from a nasal swab may or may not be a contributor to disease. However, a *S. suis* isolated from a diseased pericardium is much more likely to be a contributor to the disease and should be considered a pathogen. Understanding sufficient and necessary causes for a particular disease helps to prioritize and focus interventions in an efficient manner. When a necessary cause exists, targeting it may be the most effective approach.

1.11 Interventions

Interventions can be presented in a multilayered approach. As the veterinarian is investigating the initial complaint and developing a list of differentials, they should also be generating some short-term intervention options while awaiting diagnostic results. Owners, managers, and caretakers will have expectations to begin an intervention after the visit or consultation. The type of intervention depends upon the potential pathogen(s) that are at the top of the

differential list. Frequently, the immediate intervention may be pharmacological in nature in terms of selecting the appropriate antibiotic based on clinical signs, herd history, and clinical experience or providing supportive care during a viral infection. It may also be adjustments to the environmental conditions (e.g. ventilation) if there is an error discovered during the investigation. After diagnostic results begin to come back in, this will clarify the differential list and may result in an adjustment in the short-term intervention plan as well as begin to clarify the intermediate and long-term plan if the problem affects multiple sites and begins to reveal a chronic or systemic problem that needs to be addressed. Interventions can also be layered if they attack the problem by addressing multiple inputs from the five production inputs (nutrition, environment, disease, genetics, and management) model as was discussed earlier in this chapter. An example of this might be when dealing with cases of enterotoxigenic F18 *E. coli*. The short-term intervention might be selecting the appropriate antibiotic to inject affected pigs demonstrating clinical signs as well as utilizing the appropriate water-soluble medication when the individual treatments exceed a certain threshold. Intermediate term interventions might be dietary adjustments to the feeding program, such as adjusting the fiber and crude protein levels in post weaning diets to help combat the *E. coli* infections. Longer term interventions might include the investigation of utilizing different genetic sire lines that have more resistance to F18 infections.

The current standard for determining a treatment objective in the context of antimicrobial therapy is a diagnosis that includes bacterial culture and identification accompanied with antimicrobial sensitivity testing of that isolate. In swine cases, this isolation should be the consequence of a complete diagnostic investigation that confirms lesions consistent with the pathogen are present in appropriate tissues. Furthermore, the case needs to be representative of the primary problem in the target swine population. It is often necessary to confirm culture and sensitivity data for several representative cases in a specific population, as pathogens are not necessarily a homogenous species or even a genus in a swine population. Several pathogenic bacteria can coexist with nonpathogenic strains of the same genus and species in the pigs, such as the case with intestinal *E. coli*.

When culture and sensitivity confirmation is not available or the urgency of intervention on behalf of swine welfare requires initiating therapy before results are available, several sources of information are available to supplement empirical treatment. Veterinarians have the capability, with some diagnostic laboratory cooperation, to maintain antimicrobial sensitivity summaries for their clients or practice region compiled from a series of diagnostic cases. Several diagnostic laboratories summarize the percentage of isolates that are susceptible to selected antimicrobials on a routine basis. These summaries are generally available online and may represent a more current and broad view of microbial susceptibilities than even randomized, controlled trials using single isolates. The same accumulation of sources of objective and subjective evidence for a disease cause or environmental impact would occur as outlined here for a bacterial example.

In working through the diagnostic process, most often it is initiated with a complaint from the client or caretakers. This may come in the form of overt clinical signs (e.g. coughing, diarrhea, lameness) or more subclinical in nature (slow growth, low born alive, poor feed conversion).

1.12 Reporting and Communication

Once interventions have been identified and prioritized, it is critical to provide this information to the end user (client, caretaker, owner, etc.) in a concise and clear manner. The intended audience will influence the form of the communication that the information may come in. In the past, a farm report or client letter was a very helpful tool in making sure the correct information was being communicated, since in many cases, the client was the owner and the caretaker. In some cases, there are several levels of management that the veterinarian will need to communicate with. For those with caretaking responsibilities, it is important to quickly get the short-term intervention plan communicated, first verbally and then followed up with their preferred written form of communication, whether that is by text, email, or in writing. Written communication and instructions will minimize miscommunications. Those communications should be concise and should include a prioritized list (bullet points) with only two or three top interventions. Personal experience suggests that providing too many recommendations allows for the caretakers to lose focus. They may select only recommendations that are desired or easiest to implement. When communicating at the owner or senior management level, the communication may be slightly different, depending upon the desires of those clients. It's important to establish their wishes and desires on communication early on in the relationship. Communication here is going to be more of an overview summary of the findings along with short-, medium-, and long-term recommendations. Veterinarians with a valid, Veterinarian-Client-Patient Relationship (VCPR) with the site must maintain records that document visits, diagnosis, treatment, and medications prescribed. They must also be knowledgeable of the local/state/federal guidelines in terms of what constitutes

medical records. One question that veterinarians struggle with is how to share the diagnostic information that they get back from the diagnostic labs. One approach is to forward on the diagnostic reports that are received from the diagnostic labs or allow permission to view them. The advantage is the transparency and speed of the flow of diagnostic information back to the clients and their caretakers. The potential downside is that they can lack diagnostic interpretation and some results may be over- or under-interpreted, leading to confusion and additional time explaining extraneous test results. Another method is to allow the veterinarian to communicate all the results coming from the diagnostic lab. This allows for some interpretation from the veterinarian but can be slower to get to the clients and doesn't allow for full transparency as well. This is another discussion to have with the clients at the beginning of the relationship to have a clear, defined communication plan from the beginning.

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