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New approaches for swine disease surveillance

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'Nothing in the world of living things is permanently fixed'
Hans Zinnser: 'Rats, Lice and History' (1935)

'Between the extremes of panic and complacency lies the solid ground of vigilance'
Margaret Chan, WHO, July 2, 2009

Population health - A moving target

Plague and pestilence wreaked havoc through biblical and medieval times, and their lingering threat now sustains a genre of fear mongering paperbacks. Nonetheless, progress in public health and medicine during the 20th century lured even the most learned into blind optimism about man's power to tame nature:

- 'One can think of the middle of the 20th century as the end of one of the most important social revolutions in history - the virtual elimination of the infectious disease as a significant factor in social life' (Sir Macfarlane Burnet, Nobel laureate in medicine, 1962)
- 'It is time to close the book on infectious diseases and declare the war on pestilence won' (William Stewart, US Surgeon General, 1960s)
- 'There are no new diseases to be discovered' (Lewis Thomas, Dean of Yale Medical School, 1976).

Emerging diseases are 'diseases that have newly appeared in a population, or are rapidly increasing in incidence or geographic range'.[1] Since those premature declarations of victory, more than 30 infectious diseases of humans have been recognized. Likewise, regular emergence of diseases in animals and plants instructs us that disease patterns in populations are dynamic and unpredictable. Despite profound understanding of infectious disease agents and mechanisms of disease in individual hosts, understanding of what drives disease patterns at higher levels of aggregation (herds, regions, nations, global), and over longer timeframes, remains rudimentary.[2,3] Swine veterinarians have had our share of 'teachable moments', including two severe viral pandemics (PRRS and PCV2); the regional epidemic of zoonotic Nipah virus in Malaysia in 1998; worldwide detection of asymptomatic Hepatitis E infection; a sporadic event of a zoonotic paramyxovirus (Menangle virus) in Australia; the human epidemic of virulent *Streptococcus suis* type 2 disease in China in 2005; MRSA ST398 colonization of pigs and farm workers; and last but not least, pandemic H1N1 influenza in 2009. These events varied enormously in impacts on human health, swine health, commerce and perceptions. At one extreme, PRRS and PCV2 as host specific viruses devastated swine health globally but posed no zoonotic risk. At the other extreme, H1N1 (2009) pandemic influenza has spread quickly among people across the globe, with no epidemiologic role of swine populations and virtually no impact on pig health. By usual definitions of emerging disease, the H1N1 (2009) influenza is hardly (at time of writing) an emerging disease of swine.[1] However, it certainly is an 'emerging disease issue', as defined by the Swine Futures Project: "any sudden, negative economic impact related to the appearance of a disease which could have a direct impact upon productivity, presents a real or perceived risk to public health, or present a real or perceived risk to a foreign country which imports from the United States".[4] The swine industry has felt the blows from both realities and perceptions of emerging diseases, and the uncertainty that shrouds these incidents. Perhaps the sole certainty attached to any emerging disease issue in pigs is that a chorus of industry opponents will promptly and stridently proclaim 'industrial farming' to be the unequivocal root cause of the problem.

Industrialization of swine production and disease emergence - What have we done?

The extensive changes witnessed in swine production systems in the USA over the last 20 years have influenced disease patterns. Many of these changes [e.g., all-in/all-out (AIAO) management; multiple site production] were specifically instituted with the goal of improving herd health (Table 1).[4,5] Key components likely to influence disease rates include herd size, population structure and dynamics; sources and health status of incoming stock; area density of pigs and other species; biosecurity practices; group sizes and animal density; replacement practices in breeding herds; pig flow (e.g., AIAO vs. continuous flow); housing systems; ventilation systems and air quality; sources, quality and delivery systems of feed and water; hygiene and effluent management; nutritional programs; weaning age; and specific health interventions (e.g., vaccines).

Advances in swine health management have reduced the impact of important swine health problems. For example,

Table 1: Some strategies used to improve swine health in developed countries

Change	Health related rationale
Confinement on concrete	Protection from environmental extremes and predators Reduction in some parasites Species segregation
Specific Pathogen Free (SPF) systems	Sources of breeding stock free of some several host specific pathogens
Pyramidal breeding stock production	Multiply sources of SPF pigs to expand availability of high health replacement stock
Early weaning	Reduction of sow-to-piglet transmission of pathogens
AIAO management	Reduce group to group transmission of pathogens
Multiple site production	Segregation of age groups Facilitation of AIAO pig flow
Enhanced biosecurity	Reduce risk of pathogen introduction

swine dysentery and sarcoptic mange were once widespread problems that are now rarely encountered in commercial herds in the US. *Trichinella spiralis, Toxoplasma gondii* and *Taenia solium* are foodborne hazards of global importance that have been either eliminated or substantially reduced in modern systems. In most developed countries, evolution of production systems has occurred in concert with considerable industry concentration and specialization. Traditional farms typically reared multiple species, usually with little attention to biosecurity. Today, most commercial swine farms do not rear other animal species; house larger numbers of animals; have less variability in animal age and immunity (e.g. specialized nursery and finishing sites); use AIAO management at room, barn or site level; pay more attention to biosecurity; use more specialized labor; and maintain stricter segregation of pigs by age-group and source.

Isolation and segregation of groups of pigs is reliant on transport, and modern US production involves considerable pig movement that facilitates dissemination of agents across wide geographic areas. The state of Minnesota receives approximately 10,000 pigs per day from over 30 states and Canada. Systems devised to improve individual herd health have, due to pig movement, augmented the potential risk and rate of regional disease spread. This is a particular concern for infectious agents that can overcome standard biosecurity barriers to spread locally among farms, most notably PRRS, *Mycoplasma hyopneumoniae* and other agents for which long distance aerosol transmission can occur.[7] Approaches to meet this challenge include air filtration of farms and cooperative efforts to control disease at a regional level.[8,9]

Production systems will continue to evolve and deliver both benefits and sometimes unintended negative consequences. Pandora's Box of evolution will continue to spring new surprises with novel agents, and advances in diagnostics will bring previously unknown agents to light. This scenario has long been in place, and I believe the net results of our efforts until now have been positive. Productivity in swine production in developed countries has increased markedly without substantial negative events for human health, but with continual challenges in maintaining pig health. Developing countries remain the hot spots for emergence of novel zoonotic diseases arising from interspecies contact. In contrast, developed countries have predominantly witnessed the emergence of novel animal diseases characterized by high virulence in individual species but which appear to be relatively host specific (e.g., PRRS, PCVD, turkey poult enteritis syndrome, among others). The progressive replacement of labor by capital (i.e., less direct human contact per animal produced); specialization of enterprises (reduced rates of interspecies contact); and larger herd sizes (increased intraspecies transmission) together may make intensive systems of animal production more likely to be troubled by emerging diseases that are host-specific than by novel agents arising from interspecies transmission. However generalizations are dangerous, and both Nipah virus emergence and avian influenza risk have been linked to large 'industrial' production systems in Asia.[10,11]

Responses and responsibilities

In the one opportunity I had to hear Al Leman speak at a conference (at this meeting in 1991), he bemoaned the collective failure of the US swine industry, government and others to mount any effective response to 'Mystery Swine Disease' (now PRRS) in the aftermath of its recognition as a novel syndrome in 1987. For foreign animal diseases, and other regulated diseases, roles and responsibilities of government veterinarians and others in response to disease outbreaks are relatively well defined. However, when disease events fall outside the regulatory umbrella, roles and responsibilities are less certain. It is not uncommon for veterinarians to be confronted by unusual clinical presentations that raise concerns about potentially novel infectious diseases. The vast majority are 'red herrings' that may result from anomalies of population immunity, or unusual environmental events, but do not herald propagated epidemics. For example, an unusual occurrence of neurological disease in pigs in Minnesota in 2005 was ultimately confirmed to be caused by porcine teschovirus 1 and was reported in the US annual report to the OIE.[12] However, the case involved several months of uncertainty related to the diagnosis and potential implications of the outbreak.[13] Just what is the 'right' response to such events is a really tough call that can really only be assessed retrospectively - but we have to act prospectively. If agents are highly transmissible, the bugs are likely to win regardless of response efforts. Considerable resources have been devoted to improve global pandemic preparedness due to the H5N1 avian influenza scare. However, within days of the recognition of H1N1 influenza in California and Mexico, the WHO declared that containment of the outbreak was not feasible and recommended against closing borders or restrictions on international travel – the horse had bolted! In other scenarios, for example Nipah virus in Malaysia, early detection with rapid deployment of traditional control methods (movement restrictions and depopulation) can be successful even when epidemiologic understanding is minimal.[14] Timid or delayed responses may lead to lost opportunities for controlling a nascent epidemic. Conversely, aggressive responses entail significant costs that may not be warranted in mild or self-limiting outbreaks. However, the question of what is the right reaction is a moot point if essential infrastructure for diagnostics, communication and coordination is not in place. Improved infrastructure and capability broadens the range of options that may be feasible when an outbreak or unusual disease event occurs.

In response to Al's charge of collective failure with PRRS, what would have been needed back in 1987 to extinguish the nascent PRRS epidemic, and who should/could have driven it? Twenty years on, are we now better positioned in terms of infrastructure and decision making? Our major disease challenges are hyperendemic pathogens that transmit locally among farms in hog dense areas, and occasional novel syndromes for which epidemiologic knowledge is sparse or absent. In the absence of a perceived public health risk, the days of obtaining public resources (other than authority) for supporting swine disease control are probably behind us and the veterinary profession and industry need to explore new approaches for coordinated management of these challenges. The fiasco of the National Animal Identification System indicates that government initiatives lacking universal industry support have a troubled future, and that different meat industries (or industry segments) may have conflicting views on how to move forward regarding response capability and the value of traceability. When I arrived in Minnesota in 2003 to take up the Leman Chair, there was growing recognition that regional approaches to disease control will be necessary to address our more difficult problems. A focus of my efforts has been to assess the potential for capturing technological advances in other fields (particularly electronic communications and geographical information systems) to underpin the deployment for more powerful tools for managing swine diseases at a regional level, and for exchange of spatial disease information among swine veterinarians.

The surveillance revolution

Mounting angst about emerging diseases, bioterrorism and agroterrorism has coincided with an era of phenomenal advancement in information technology (IT), medical informatics and communications. Many countries are pursuing initiatives to improve healthcare through the use of IT, and disease surveillance is evolving rapidly beyond the traditional model of notifiable diseases. 'Biosurveillance' is now recognized as a distinct discipline incorporating epidemiology, medicine, microbiology, computer science, statistics, artificial intelligence, and system engineering.[15] In our modern world, the desired scope of surveillance activities is increasingly national or global rather than local, and it is recognized that more powerful communications and information technologies empower surveillance capabilities even in low-capacity settings.[16, 17] Concurrently, there are strong pressures to improve the efficiency of veterinary surveillance activities,[18-20] and increasing calls for integration of human and animal disease surveillance.[21]

Disease surveillance is a management information tool, where disease events in defined populations are recorded to inform decision makers (e.g. producers, veterinarians; industry; government agencies). Although practicing veterinarians are the frontline of response to emerging health problems in food animals, they remain an underutilized resource for epidemiologic intelligence.[19] However, consolidation of food animal production (and its veterinary services) have increased the potential for harnessing the efforts of veterinary clinicians for purposes of disease surveillance, and a number of pioneering projects have been initiated.[22–27] In all cases, these efforts are underpinned by advances in communications that assist data capture and analysis but details vary according the goals of each program. For example, the BOSSS system for cattle disease surveillance in remote areas of Australia obtains data provided by cattlemen via the internet and includes on-line support to assist diagnostic efforts. All these initiatives face common issues including data ownership and confidentiality, as well as the sensitivity, specificity, and value (vs. cost) of the data that can be obtained. Another common issue is that such systems, which are reliant on data capture at farm level, tend to be 'top down' designs and producers and veterinarians may have little motivation or reward for participation. It is widely accepted that technological barriers to development of real-time information sharing are negligible. The challenges for swine veterinarians are to understand the possibilities and to decide what information they need, and what they and their clients are willing to share.

Geography matters

Anybody who uses MapQuest, a GPS system reading satellite signals to navigate the roads, or has a kid playing with Google Earth should appreciate the power of the technological revolution in Geographical Information Systems (GIS) and communications technology. However, the uptake of these tools in the field of animal health has been relatively slow. By definition, regional disease control plays out in a geographic context and mapping of affected farms is the bedrock of coordinated control programs. Logically, advances in the discipline of geography should empower efforts to control animal disease. Modern GIS systems can greatly facilitate epidemic management,[28, 29] and better techniques for temporospatial analysis have advanced the ability to understand patterns of disease in populations.[30] Increasingly, there is a trend towards integration of spatial information into animal health information systems that underpin decision making related to disease control.[31,32] Such 'spatial decision-support systems' integrate GIS with customized databases and provide a range of functions for visualization and analysis of data. The potential applications are vast and we are essentially limited by our imaginations. The current priority for integrating GIS into swine veterinary activities in the USA is to develop systems that deliver effective decision support to practicing veterinarians seeking to control hyperendemic viral diseases such as PRRS.

Swine disease surveillance in Minnesota – The first steps

The long term objective of this work has been to establish web-based GIS capability through which veterinarians can readily visualize and exchange information about regional disease patterns. Minnesota has some attributes that make it an attractive location for attempting such an initiative: it is a major swine producing state; the industry has consolidated considerably the last decade; and specialist veterinary services in a small number of practices and companies have oversight of a considerable proportion of production in the state. These swine specialists are progressive and computer literate, and some practices had independently started to use GIS software to map area spread of PRRS among their clients' farms. Collective frustration in controlling PRRS over many years also provides motivation and acceptance to innovations in surveillance and information sharing. Through a series of meetings with leading swine veterinarians to discuss perspectives on developing new systems for PRRS surveillance, two functions were identified as most desirable for supporting regional swine health management:

- A web-based GIS enabling authorized parties to exchange information on herd details for selected diseases (primarily PRRS) through an interactive mapping system.
- A system for detection of atypical or emerging syndromes to facilitate rapid recognition of unusual disease events.

But where are the pigs? At the outset it was anticipated that the NAIS system would ultimately provide a useable farm database that would underpin development of these tools. But here in 2009 it still remains a challenge to know reliably where swine farms are located in Minnesota, and NAIS appears to be progressively debilitated. In 2005 we evaluated public sources of data from entities that maintain spatial data on MN swine farms independently, and for different purposes. Although the total numbers of swine sites (aggregated at the county level) were significantly correlated among datasets, analysis of spatial clustering patterns demonstrated considerable regional biases among the datasets.[33] In two counties with recent field verified data of farm locations, we could quantify inaccuracies in records of individual farm locations. This analysis indicated rates of omitted or erroneous farm sites, and positional inaccuracies of farms limit the utility of the data for analytic purposes or for disease control efforts.[33] At the date of writing, this has not been resolved, and there is little reason to believe that the situation is much better in most states. The lack of a comprehensive and reliable database on farm locations may prove the biggest obstacle to exploiting technologies to support regional disease control – we need to know where the farms are! One opportunity for overcoming this may result from packers requiring PQA plus status including locations to enable traceback of pigs. Meanwhile, through the MN PRRS eradication task force we are collaborating with companies and veterinarians who have provided data on over 1500 known farm locations, and can also reference swine farm locations registered by the Minnesota Board of Animal Health.

Unlike our underwhelming progress with farm locations, progress in GIS technology is overwhelming. Initially the scope of our first efforts was the state of Minnesota, and the focus was PRRS. The prototype system included a customized database (Microsoft SQL Server 2000) enabling web-based data entry via the internet coupled to a web-based mapping tool (ESRI -ArcIMS/Arc SDE). Initial features included

- Use of public data that were either freely available data (high resolution aerial photography) or had restricted availability (BAH swine farm locations) as a platform for mapping.
- Password protected access for authorized users
- Ability to interactively visualize all swine farm locations in the database via the internet, including aerial photography
- Ability to view drop down lists of client/enterprise farms with direct links to interactive maps for each farm
- Ability (limited to a single individual per farm) to edit specific farm data including location, disease, and other attributes
- Ability to view (but not edit) all farm data related to an organization (e.g., company or practice) limited to authorized organization members
- A 'range' report that displays a list of farms (with selected details) within a chosen radius of the farm of interest

Swine disease surveillance in Minnesota – The slow march

The release of Google Earth, with its amazing global visualization tools, opened the door to a whole new set of possibilities. The valid criticism that pigs and disease do not stop and start at the Minnesota border can now be more readily addressed. Furthermore, beyond PRRS myopia, the current system has been made flexible to enable recording and mapping of multiple diseases, both known and unknown, thereby providing a potential tool for use with both endemic and emerging problems. With GIS and programming expertise from David Wray and Brandon Peele in North Carolina, we redesigned the prototype tool using ArcGIS Server (ESRI) that enables an interface with Google Earth. In addition to removing the geographic limitation to MN (now global visualization potential), the ability to export data confidentially from the application to Google Earth offered new options for parsing farm information into confidential (accessible only to an individual or organization) and shared (visible to all authorized users). A more powerful viewer provides several automated functions enabling users to measure distance between locations, query the database on selected attributes, and rapidly access shared information in a geographical area of interest, etc. These features will be displayed at the conference.

Conclusions and future path

Integration of near real-time clinical disease surveillance with GIS and advanced tools for temporospatial analysis of disease can deliver epidemiologic intelligence that far exceeds existing capability. There is enormous potential for establishing systems that will provide better understanding of regional patterns of disease transmission, location-related risks for local spread, and enhanced detection and tracking of both familiar diseases and emerging disease syndromes. The pace of technological change far exceeds that of sociological change, so the question is whether we are ready for what technology can provide us. The uptake of such tools in industry will be a function of the benefits that they confer to veterinarians and producers in managing common disease problems, balanced against costs and the historic and understandable reluctance of producers to share information about disease status. To capture the full benefits from developing technologies, some cultural change will be required in both the industry and veterinary profession with respect to sharing rather than protecting animal disease information. This is already recognized by our competitors in the poultry industry. The progressive nature of MN veterinarians and producers, the collaborative vehicle of the PRRS Eradication Task Force, and the exploratory application of the system itself should all contribute momentum towards more efficient and collaborative disease control.

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