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Novel disease surveillance systems to support regional disease control in swine

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An information infrastructure is an essential tool for any enterprise in the 21st century

~ Detmer and Gillings (2003)[1]

Times are changing, and the best thing to do is adapt to the advances in technology.

~ Vipin Gupta, security analyst, Sandia National Laboratories

Introduction

A quarter of a century ago, medical leaders were proclaiming victory against human infectious diseases and US Surgeon General William H. Stewart announced that 'it is time to close the book on infectious diseases'. Subsequently, over 30 new human pathogens have been identified and declarations about the inevitability of a new 'global pandemic' have become a staple of the news media. This heightened awareness of the threat of emerging infectious diseases, accentuated by the spectre of bioterrorism, 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, such as the National Health Infrastructure Initiative (NHII) in the USA.[1] The field of disease surveillance is changing dramatically beyond the traditional model of notifiable diseases, and 'biosurveillance' is becoming recognized as a distinct discipline lying at the intersection of epidemiology, medicine (human and veterinary), microbiology, computer science, statistics, artificial intelligence, and system engineering.[2] Similarly, there are strong pressures to improve the efficiency of veterinary surveillance activities,[3-5] and there are a number of innovative projects now in development or implementation.[6-10]

We have also seen the pendulum of perception swing regarding the importance of swine infectious diseases. From the mid-80s to mid 90s, there was much discussion among veterinarians about disease 'not being important'. In 1993, Dr. Hank Harris, an eminent swine disease researcher, stated 'knowledge of disease agents per se will continue to be of lesser importance to the profitability of pig farms'.[11] Certainly, at that time there were large inefficiencies in US swine productivity that were unrelated to disease, as well as optimistic expectations of the benefits that multisite systems would deliver for swine health. Subsequently, many of these 'non-disease' inefficiencies have been addressed and disease arguably remains the most unpredictable and challenging factor that affects swine producers. As our experience with PRRS approaches the end of a second dismal decade, we stare into the face of a potentially severe epidemic of PCV2 associated diseases. Further, we wonder if the lability of influenza viruses will come to really bite our pigs or employees, and accept that Pandora's biological box promises more unpleasant surprises in the future. General epidemiologic descriptors of patterns of disease occurring in populations are summarized in **Table 1**. Although the exotic and emerging disease categories capture much attention owing to perception of high risk, it is the endemic and hyperendemic diseases the exact the greatest toll on the industry.

Because of risk perceptions, public resources for animal disease control have been devoted predominantly to diseases of perceived importance to public health or international trade (e.g., rabies, TB, brucellosis, BSE, 'foreign animal diseases), and future public funding to support control of endemic swine diseases is extremely unlikely (other than for research). Therefore the burden of management of costly hyperendemic problems such as PRRS sits squarely in the lap of industry and the veterinarians who serve it. Although history suggests that we can anticipate the emergence of a significant new swine health problem every 5 to 10 years, there is little existing structure to deal with this contingency.

The capacity for some swine pathogens, most notably PRRS, to spread locally among farms despite significant investments in biosecurity is the most problematic issue in swine health management today. Veterinarians know they have the means to eliminate PRRS virus from a given farm, but the risk of reinfection remains high even with the best current practices of biosecurity. This has led to a consensus among US swine veterinarians that more coordinated, or 'regional', approaches must be taken to combat PRRS and some other emerging viral diseases of swine. In 2005 this culminated in the AASV position statement on PRRS eradication which promotes collaborative PRRS eradication efforts at the local, regional, and national levels.[12]

Table 1: Phases of disease progression in populations[A]

Exotic (foreign)	Novel/emerging	Epidemic	Endemic	Hyperendemic
Description				
Disease (agent) does not occur within a specific geographic entity (usually country or defined region)	Disease occurs at increasing rates due to: • Spread of a novel agent • Recognition of an existing disease that has gone undetected • Influence of other component causes	Disease occurs at rates greatly exceeding expected or historic rates	Disease occurs in a predictable manner without major fluctuations in rates	Disease persists in population at a very high rate
Examples				
FMD	Circovirus associated diseases		*S. suis*	PRRS
Hog cholera			*H. parasuis*	Swine influenza *Mycoplasma hyopneumoniae*

[A]Also sporadic – occurring unpredictably at low incidence

We describe two complementary initiatives to develop improved disease surveillance capabilities to underpin disease control efforts in the swine industry. The fundamental rationale for these initiatives is that technological advances in relevant disciplines provide opportunities for innovation in surveillance that can enhance the capacity of the industry to combat its most pressing disease challenges in a more efficient manner.

Innovations in animal disease surveillance

A number of our competitors have already established infrastructure and relationships to strengthen their capacity to address infectious disease problems. The Danish swine industry has invested significantly in personnel and programs targeting industry disease issues.[13] The avian industries in Minnesota, recognizing that efficient communication about disease problems is fundamental to effective regional control, are taking cooperative approaches to address major disease concerns (avian pneumovirus; avian influenza) in their industries.[14]

Despite the fact that veterinary practitioners work at the frontline of disease problems in food animals, their collective efforts have been largely ignored as a source of epidemiologic intelligence. Consolidation of food animal production (and veterinary services) together with advances in information technology have increased the feasibility of recruiting veterinarians for disease surveillance. Pioneering efforts to obtain animal disease data from practicing veterinarians have been initiated with dairy cattle veterinarians in New Zealand[6] and beef veterinarians in Kansas.[7] Both employ palm held computers for field data capture; integrate data into centralized databases; analyze disease trends; and enable practicing veterinarians to access summary data by location. A web-based syndromic surveillance system for cattle producers in remote parts of Australia has also recently been established.[8] The Multi-Hazard Threat Database (MHTD) project of the North Carolina Department of Agriculture and Consumer Services is designed to minimize the impact from any disaster or disease on agriculture in that state. MHTD integrates information systems of numerous federal, state and local agencies to offer extensive, real-time information in the event of an emergency, natural disaster or bioterrorism event. While primarily designed to support emergency responses, it also provides decision support for veterinarians by enabling web access to real time maps of endemic disease status (currently PRRS and TGE) represents a significant step forwards in integrating veterinary clinical and government regulatory activities. North of the border, the Alberta Veterinary Surveillance Network is designed to enable veterinarians to share livestock health and disease information via the Internet.[9] This system provides both detection and warning functions, and information about unusual disease problems can be rapidly disseminated among participating veterinarians through the website.

These examples are by no means comprehensive but serve to illustrate the level of current effort being applied to capture the benefits of modern technologies to enhance regional approaches to disease control.[4] The objectives and features of these initiatives vary considerably but all share the common realization that the advances in modern technologies applicable to animal health management are greatly underexploited. Inevitably, there remain numerous issues to address with respect to ownership and confidentiality of data, the sensitivity and specificity of clinical diagnoses, and the value (vs. cost) of the information obtained. Importantly, to capture the full benefits of available 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. Pilot regional control projects led Dr. Bob Morrison have focused on such practical issues to advance coordinated local efforts to control PRRS in two Minnesota counties. These include establishing more accurate information about the locations of pigs in the areas, regular testing of participating farms, and promoting the sharing of farm disease status amongst the producers involved.[15]

Geographical information systems (GIS)

Regional disease control, by definition, has a geographic perspective, and mapping of affected farms has always been the bedrock of coordinated disease control programs. Logically, advances in the discipline of geography should empower our efforts in controlling disease, and recent years have seen an exponential increase in the sophistication of GIS and of analytical methods to exploit them. Modern GIS systems (specialized databases and software for visualizing and analyzing geographical features and patterns) can greatly facilitate epidemic management.[16-18] Georeferenced data are vital for monitoring the progress of disease control programs and also enable predictive modeling of the likely effects of different control options.[19, 20] In some countries (e.g., New Zealand, Switzerland) comprehensive national farm databases have been in operation for many years, and GIS is viewed to have broad potential in the poultry industry.[21, 22] Rapid advancement of techniques for temporospatial analysis has greatly advanced the ability to understand patterns of disease in populations. Outside the context of emergency response preparedness in government agencies, these technologies are currently underexploited by the US swine industry.

Embarking on any regional disease control effort without fully exploiting current GIS technology is a recipe for inefficiency if not failure. However, capturing maximum benefit from these rapidly advancing technologies will depend on effective communication and teamwork among practitioners, producers, academia and relevant public agencies. A major focus of our current work (funded jointly by the MPB, National Pork Board, and University of Minnesota) is to establish a web-based GIS capability through which veterinarians can readily visualize and exchange information about regional disease patterns. An essential factor in any disease control effort is knowledge of where animals are. In a preliminary study funded by the MPB, we compared existing MN state databases on swine farm locations with both the NASS census data for the state and for Rice County data where we had field-verified farm locations. This analysis indicated considerable discrepancies among sources, and in both cases significant variance from the other data sources (unpublished data). For either state agency or industry initiatives to control swine diseases at a regional scale, farm locations need to be accurately known. Every swine producer and veterinarian can contribute to build our capacity to combat swine disease by ensuring farms are registered under National Animal Identification System (http://animalid.aphis.usda.gov/nais/subjects/premises_id/index.shtml) and by promoting and adopting the 'Swine ID Plan' developed by the industry.

Identification of needs

The technological demands for real-time (or near real time) surveillance and analysis of regional patterns of animal disease can no longer be viewed as a constraint on our efforts to implement such systems. The pioneering efforts cited above are understandably diverse as they have been designed for various industries and locations. Through interactions with leading swine practitioners in Minnesota we identified two core features to be most desirable for supporting regional swine health management:

1 A web-based GIS enabling authorized parties to exchange information on herd status for selected diseases (primarily PRRS) through an interactive mapping system.

2 A system for detection of atypical or emerging syndromes to facilitate rapid recognition of unusual disease events.

For the first approach, a customized database was designed in Microsoft SQL server to enable web-based data entry remotely by veterinarians using the internet. Interactive mapping capability was established using ArcIMS/Arc SDE (ESRI). Key features of the system are:

- Use of public data that is either freely available data (high resolution aerial photography) or has restricted availability (swine farm locations) as a platform for mapping.
- Password protected access to authorized veterinarians enabling them to edit specific farm location, disease, and other attributes (limited to a single veterinarian per farm)

- Ability to view all farm data of an organization (e.g. company, practice) limited to organization members
- Ability to interactively visualize all swine farm locations in the state, and disease status for all participating farms in the database.
- Ability to add new disease entities including clinical or laboratory observations pertinent to case definitions.

The ArcIMS and database system is currently in the phase of pilot testing. The utility of the system will be a function of participation rate. Although the technical challenges are significant, the sociological barriers to participation (concerns of confidentiality, privacy, and potential litigation) present the most significant barriers to successful implementation of the system.

The second component (focused on detecting the emergence of novel or atypical syndromes) is still under design but embodies three essential differences from the ArcIMS based system. Firstly, it is oriented more towards syndromic surveillance rather than specific diseases. Secondly, it will employ a much lower scale of geographic resolution (counts of syndromic events mapped by county), and therefore has inherently lower levels of concern about confidentiality. Thirdly, as the key objective is to detect broader trends in incidence over time (rather than farm specific data on health), its utility is less dependent upon participation rate and could be achieved with a relatively small group of sentinel participants.

PRRS/PMWS

Conclusions

The feasibility of controlling disease on a regional scale is constrained by a number of factors that can be biological, technological, managerial, financial, or sociological in nature. While there has been abundant research of PRRS and other agents at a biological level, there has been disproportionately less investment in other constraining factors. Our approaches to managing swine disease at a regional scale are not keeping pace with the technological opportunities. Integration of near real-time clinical disease surveillance with GIS and advanced tools for temporo-spatial analysis of disease can deliver epidemiologic intelligence that far exceeds existing capability. We are working to close this gap and develop appropriate infrastructure 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. This should bolster decision making capabilities in many individual herd situations, as well as providing an essential platform for more comprehensive disease control efforts.

It is difficult to imagine that the industry can efficiently implement coordinated disease control efforts without technological tools of the types that we are developing. The question is whether we are ready for what technology can provide us. The full exploitation of these tools in the short term is likely to be impeded by other constraints, particularly sociological factors (e.g., concerns about privacy, confidentiality, and the threat of litigation). However, the implementation of these systems in itself may be a catalyst for sociological change in the industry and recognition that the collective benefits of effective information sharing on major disease problems in the long term will greatly outweigh these more individual concerns. Progress will be largely dependent on the ability of the key parties (industry, veterinary profession, universities, public agencies) to establish functional working relationships.[23] There is much to be nervous about, in the same way that many are nervous about the ready access that anybody with Internet access has to geographic information through Google Earth.[24] The following quotation reflects an optimistic view that we need to carry forward:

When we reach out and engage with knowledgeable people, the concern tends to subside. A lot of good things come out of making information available.

~ John Hanke, Google Earth

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