RESEARCH REPORT
SWINE HEALTH

Title: Linking veterinary diagnostic laboratory submissions and corresponding PEDV test results to spatiotemporal mapping tools: the future of disease management, control and elimination – **NPB13-233.**

Investigator: Rodger Main

Co-Investigators: Jordan Bjustrom-Kraft[1], Bret Crim[1], Erin Lowe[2], Zack Whedbee[3], Enrique Mondaca[2], Kate Mueller[1], Dale Polson[2], and Beatriz Martínez-López[3]

Institution: Iowa State University[1], Boehringer-Ingelheim[2], and University of California-Davis[3].

Date Submitted: January 6, 2016

Collaborating Veterinary Diagnostic Laboratories & Technology Partners: Iowa State University Veterinary Diagnostic Laboratory (Rodger Main), Kansas State University Veterinary Diagnostic Laboratory (Gary Anderson), South Dakota State University Animal Disease Research and Diagnostic Laboratory (Jane Hennings), and the University of Minnesota Veterinary Diagnostic Laboratory (Stephanie Rossow), USDA National Animal Health Laboratory Network (Sarah Tomlinson), and GlobalVetLINK (Michael Russell).

Scientific Abstract:
Managing, monitoring, and maintaining the health status of US swine has become increasingly complex. The continued expanse of today's multisite pig production systems; extensive pig movement within and across broad geographic regions of US and Canada; a growing list of emerging and reemerging diseases of local, regional, and national significance; diagnostic data being derived from any number of veterinarians, veterinary clinics, production systems, and veterinary diagnostic laboratories; and a growing appreciation for the effect that the health status of a region, pig-flow, or production system has on the biological and financial performance of pork production operations have each contributed to a need for improved systems (or intercommunicative networks) capable of effectively collating, managing, summarizing, and securely communicating information pertaining to the health status of swine herds. A primary aim of our highly collaborative efforts has been to develop a broadly applicable and streamlined system for linking veterinary diagnostic laboratory submissions, corresponding test results, attending veterinarian insight, and an interpreted health status of farm sites to an exceptionally capable spatiotemporal disease management tool (Disease BioPortal®, University of California – Davis, http://bioportal.ucdavis.edu/) for use in area-regional, veterinary clinic, or production system specific swine health monitoring and disease control initiatives. Partnering with three different producer groups (pilot participants) enabled access to the premises-specific information and corresponding flow of diagnostic information needed to evaluate and trouble-shoot the performance and functionality of the systems and web-based animal health information management tools being developed. These efforts have led to the development of a suite of complementary methodologies and web-based tools (Animal Health Information Management Network, Figure 1) that will provide producers a new system for monitoring and maintaining the health status of swine farms in their practice, region, or production system over time. While the focus of this animal health information management network development project has initially concentrated on porcine diseases, specifically PEDV, PDCoV, and PRRSV; the tools developed can be readily adapted to and used across any number of pathogens, livestock species, and laboratories in the National Animal Health Laboratory Network. Moving forward, the Iowa State University Department of Veterinary Diagnostic and Production Animal Medicine (in collaboration with the University of California-Davis, participating VDLs, and GlobalVetLINK) plans to continue to

enhance the capabilities of the network and pilot a service whose aim is to support the efforts of veterinarians, veterinary clinics, and/or production systems interested in using this suite of web-based applications to monitor and maintain the health status of swine farms in their practice, region, or production system over time. Additionally, through collaborations with the USDA National Animal Health Laboratory Network and peer veterinary diagnostic laboratories in the National Animal Health Laboratory Network (e.g., Iowa State University Veterinary Diagnostic Laboratory, Kansas State University Veterinary Diagnostic Laboratory, South Dakota State University Animal Disease Research and Diagnostic Laboratory, and the University of Minnesota Veterinary Diagnostic Laboratory); the tools and systems of inter-laboratory connectivity being further developed in the Animal Health Information Management Network were used to establish a web-based dashboard of time and space sensitive graphics in Disease BioPortal® that depict the national and state level trends in case level PEDV and PDCoV PCR test results observed in case submissions made to VDLs and reported to the USDA. These efforts may well represent the first working example in US history whereby aggregate diagnostic data has been electronically captured from all of the VDLs located throughout the US and seamlessly integrated into an interactive web-based summary of national and state level diagnostic trends. Collectively, this suite of novel methods, web-based tools, and systems of inter-laboratory connectivity being advanced and further developed hold promise for helping create a step-wise improvement for both producer group specific and larger-scale (aggregate data) swine health monitoring applications. The continued development and use of the next generation of animal health information management tools (e.g. such as Animal Health Information Management Network described in this report) for routine private enterprise applications are unquestionably necessary to create the systems of connectivity and web-based analytics needed to enhance the US pork industry's overall capabilities and preparedness for managing endemic, emerging, and/or transboundary diseases of high consequence.

Keywords: information, technology, health, management, surveillance, monitoring, network

Introduction:

Streamlined systems that link diagnostic submissions and corresponding test results to spatiotemporal disease management tools are needed to enhance US pork producers' ability to proficiently monitor, manage, control, and/or eliminate endemic diseases of significance across systems and regions, as well as to improve the industry's overall preparedness for emerging and/or transboundary diseases of high consequence. Significant connectivity gaps exist between veterinary diagnostic laboratories' laboratory information management systems (LIMS) and highly capable spatiotemporal disease management tools. Extensive efforts are presently required to ascertain the data needed from the various diagnostic laboratories, veterinary clinics, and production systems to harness the capabilities of these sophisticated regional disease management tools. These gaps in connectivity and limited routine access to user-friendly, highly functional area regional disease management tools that can be used for non-program/private sector disease management applications are hampering US animal agriculture's foreign animal disease preparedness and the US pork industry's ability to capitalize on markedly improved regional disease management technologies. Existing regional health management tools that rely on manually gathering, assembling, and reentering diagnostic information are glaringly inadequate to support the health management needs of the US animal agriculture and the 21st century pork industry.

Objectives:

Objective 1. Animal Health Information Management Network.

The primary objective of this project was to develop a scalable and broadly applicable streamlined system for linking veterinary diagnostic laboratory submissions, corresponding test results, attending veterinarian insight, and an interpreted health status of farm sites to a spatiotemporal disease management tool (Disease BioPortal®, University of California - Davis) for use in area-regional, veterinary clinic, or production system swine health monitoring and control initiatives. While the focus of this development project centered on monitoring porcine diseases, specifically PEDV, PDCoV, and PRRSV; this Animal Health Information Management Network was strategically designed to utilize the same systems of inter-laboratory connectivity and diagnostic data messaging standards used by the USDA National Animal Health Laboratory Network for program disease applications to ensure that these developments can be readily adapted to and used across any number of pathogens, livestock species, and laboratories in the National Animal Health Laboratory Network.

Objective 2. National and State Level Trends in PEDV and PDCoV Diagnostic Results (Web-Based)

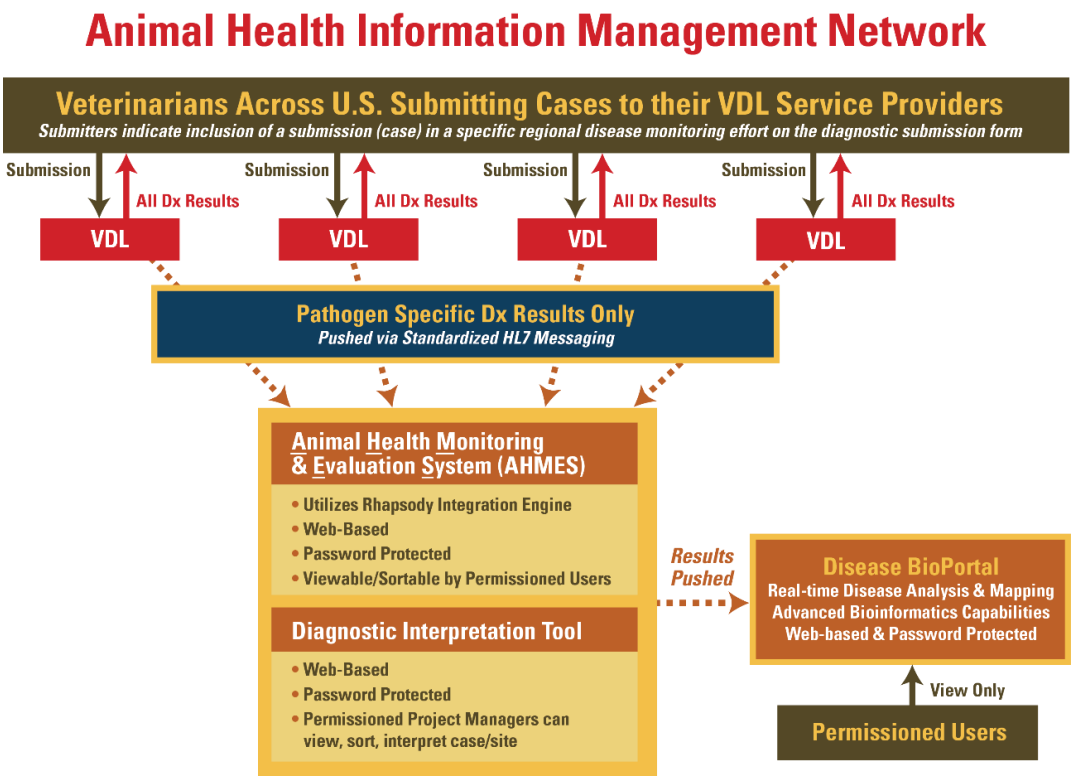
A secondary objective that evolved through the course of this project was to use the tools and systems of inter-laboratory connectivity being established to create a working example where by these web-based tools are used to collate diagnostic data (identified only to the state of origin) from VDLs across the US for aggregate, time, and space diagnostic trend analysis. Thus, through collaborations with the USDA National Animal Health Laboratory Network and the four swine-focused veterinary diagnostic laboratories (Iowa State University Veterinary Diagnostic Laboratory, Kansas State University Veterinary Diagnostic Laboratory, South Dakota State University Animal Disease Research and Diagnostic Laboratory, and the University of Minnesota Veterinary Diagnostic Laboratory); we set forth to create a web-based dashboard of time and space sensitive graphics that depict national and state level trends in case level PEDV and PDCoV PCR test results observed in case submissions made to VDLs and reported to the USDA.

Materials and Methods:

These highly collaborative efforts served to develop an effective disease management tool (Animal Health Information Management Network, see Figure 1) that streamlines veterinary diagnostic laboratory submissions, corresponding test results, attending veterinarian insight, and an interpreted health status of farm sites to a spatiotemporal mapping tool (Disease BioPortal®, University of California - Davis) for use in area regional, veterinary clinic, or production system swine health monitoring and disease control initiatives.

Three pilot projects (a large swine production system; an area regional control (ARC) project with multiple vets, vet clinics, and producers; and a large genetic breeding company with sites in multiple states and using multiple diagnostic laboratories) were established throughout the course of the project period. Pilot project participants enabled access to the premises-specific information and corresponding flow of diagnostic information that were needed to evaluate and trouble-shoot the performance and functionality of the systems and web-based animal health information management tools being developed.

Figure 1: Animal Health Information Management Network

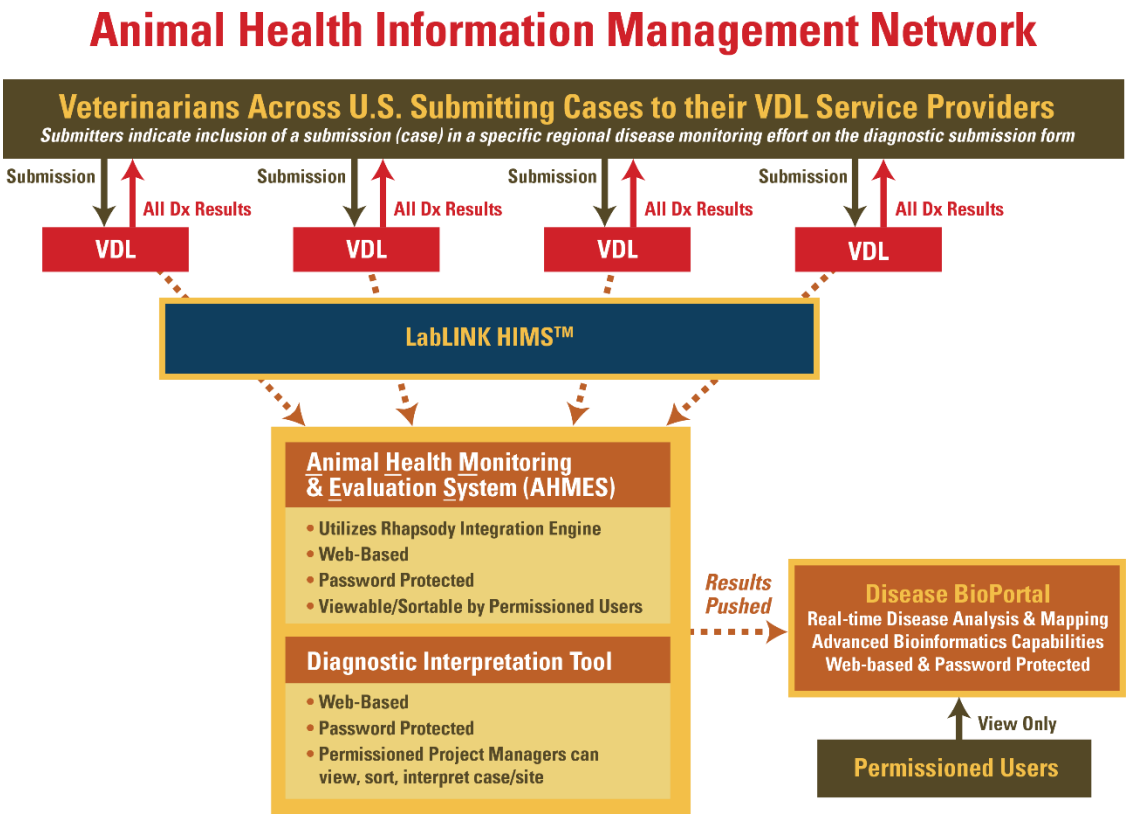


The core functionality of the Animal Health Information Management Network being developed relies upon the incorporation of premises identification numbers (PINs) into VDL records and adopting the use of a universally recognized Health Level Seven® (HL7) message standard when messaging veterinary diagnostic data to third-party database applications. Each of the collaborating VDLs involved in this project (Iowa State University Veterinary Diagnostic Lab, Kansas State University Veterinary Diagnostic Laboratory, South Dakota State University Animal Disease and Research Diagnostic Laboratory, and the University of Minnesota Veterinary Diagnostic Laboratory) established a suite of user-friendly options for VDL clientele to incorporate PINs into VDL records and established the ability to generate and routinely message PEDV and PDCoV PCR diagnostic results using universally recognized HL7 message standards to a third-party database application (USDA, Laboratory Messaging Service) for aggregate analysis and reporting. As indicated earlier, the Animal Health Information Management Network (Figure 1) being developed in this project was intentionally built using the same core principles and standards (i.e., use of PINs and HL7 messaging) as used by the USDA's National Animal Health Laboratory Network to ensure the practices and capabilities established by the disease management tools in this project for private enterprise applications would have a direct carry over benefit toward enhancing the greater state of emergency disease preparedness across the US pork industry.

The Animal Health Information Management Network developed in this project involves participating veterinarians submitting diagnostic cases to their preferred VDL in traditional fashion while including the PIN (to identify site of origin and link the case to those previously submitted from the same site) and an affiliate code (to enable VDLs to share the data appropriately) on the submission form. Pathogen-specific test results are then pushed via HL7 standardized messaging using Rhapsody® integration engine to a novel, web-based database application (Animal Health Management and Evaluation System, AHMES) that has been developed (de-novo) at Iowa State University. AHMES serves to upload premises (farm-site) information; receive diagnostic submission information and test results via HL7 messaging from any number of VDLs in the NAHLN; interpret diagnostic results using a pre-defined, industry accepted set of rules and algorithms; assign an appropriate health status and/or classification to farm sites based upon test results and/or via input from the attending veterinarian; and transmit site information, test results and interpreted health status/classification information to Disease BioPortal® for data summary, visual display, and further bioinformatic analysis. As this project evolved through the learning gained via working with the aforementioned pilot project participants, we recognized the need to be able to accommodate situations in which there is more than one farm-site per given PIN and for health-status

classifications of sites to be able to be updated directly via the attending veterinarian's working knowledge of the site. Thus, AHMES was modified to accommodate these needs and deliver the necessary functionality. Similarly, while receiving diagnostic data from participating submissions via HL7 messages sent directly from the VDLs is the primary and most broadly applicable mechanism for obtaining the diagnostic information from participating VDL submissions into the Animal Health Information Management Network (Figure 1); we recognized the benefits (again, through learnings gained via working with pilot projects) of establishing the capability to receive diagnostic data from LabLINK HIMS™ (a GlobalVetLINK owned web-based application and service that gathers and collates LabLINK HIMS™ client-specific diagnostic information from any number of VDLs into a common web-based reporting tool) into AHMES. Thus, we proceeded in collaboration with GlobalVetLINK to establish connectivity between LabLINK HIMS™ and AHMES as an additional way to incorporate a real-time flow of diagnostic information from any number of VDLs into the Animal Health Information Management Network being developed (See Figure 2).

Figure 2. Connectivity between Lab-Link HIMS® (GlobalVetLINK) and AHMES was established as an additional way to incorporate a real-time flow of diagnostic information from any number of VDLs into the Animal Health Information Management Network.



These highly capable disease management tools were built to enable permissioned users to monitor the health status of farm sites and/or the movement of particular pathogens (or strains) within a given region, production system, or veterinary practice area in near-real-time. Permissioned users only have access (via user-name and password) to the specific web-based reports in which they have been prospectively been permissioned to view. The system is designed for network-designated Project Account Managers (PAM) to work with specific user-groups (clients) to interpret cases, assign health-status classifications, and maintain client-specific premises-level data within AHMES; build client-specific dashboards (e.g. compilations of web-based reports, graphs, maps, charts, and dendrograms) within Disease BioPortal®, and train users on how to navigate and use AHMES and Disease BioPortal®.

In addition to the primary objective of developing a suite of practices and web-based tools for client or user-group specific applications, a collaborative effort was forged with the USDA National Animal Health Laboratory Network and peer VDLs to use some of the tools and systems of inter-laboratory connectivity being advanced in this project to establish a

PEDV and PDCoV dashboard within Disease BioPortal® that depicts national and state level trends in case level PEDV and PDCoV PCR test results observed in case submissions made to VDLs and reported to the USDA.

Results:

Objective 1. Animal Health Information Management Network.

- Established a suite of user-friendly methods (web-based, VDL laboratory information management system specific solutions, and barcode stickers) for VDL clientele to incorporate PINs into their VDL records. As one example of success, the incorporation of PINs in porcine diagnostic records at ISU VDL has increased from less the 5% to greater than 80% over the project period.
- Established mechanism of affiliating diagnostic case submissions with specific area-regional-control projects.
- Developed a novel, scalable, and broadly applicable streamlined system (Animal Health Information Management Network, Figure 1 and 2 above) for linking veterinary diagnostic laboratory submissions, corresponding test results, attending veterinarian insight, and an interpreted health status of farm sites to a spatiotemporal disease management tool (Disease BioPortal®, University of California - Davis) for use in area-regional, veterinary clinic, or production system swine health monitoring and control initiatives.
- Moving forward, the Iowa State University Department of Veterinary Diagnostic and Production Animal Medicine (in collaboration with University of California-Davis, participating VDLs, and GlobalVetLINK) plan to continue to enhance the capabilities of the network and pilot a service whose aim is to support the efforts of veterinarians, veterinary clinics, and/or production systems interested in using the suite of web-based tools and connectivity established (Animal Health Information Management Network, Figures 1 and 2) to monitor and maintain the health status of swine farms in their practice, region, or production system over time.

Objective 2. National and State Level Trends in PEDV and PDCoV Diagnostic Results (Web-Based)

- Established the connectivity necessary to collate and integrate the aggregate (identified only to the state of origin) case level PEDV and PDCoV PCR test results observed in diagnostic submissions made to VDLs throughout the country and reported to the USDA into a user-friendly web-based dashboard in Disease BioPortal® that depicts the PEDV and PDCoV diagnostic trends throughout the US. These efforts may well represent the first time in which aggregate diagnostic data has been electronically captured from all of the VDLs located throughout the US and seamlessly integrated into an interactive web-based summary of national and state level diagnostic trends.

Discussion:

The novel methodologies, web-based tools, and systems of inter-laboratory connectivity developed and advanced in this project represent significant progress in helping further the animal health information management infrastructure and practices that are needed to more proficiently support producer group specific and larger-scale (aggregate data) swine health improvement and monitoring applications. The continued development and use of the next generation of animal health information management tools (e.g. such as Animal Health Information Management Network described in this report) for routine private enterprise applications are unquestionably necessary to create the systems of connectivity and web-based analytics needed to enhance the US pork industry's overall capabilities and preparedness for managing endemic, emerging, and/or transboundary diseases of high consequence.