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A nursing informatics research agenda for 2008–18: Contextual influences and key components

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A B S T R A C T

The context for nursing informatics research has changed significantly since the National Institute of Nursing Research-funded Nursing Informatics Research Agenda was published in 1993 and the Delphi study of nursing informatics research priorities reported a decade ago. The authors focus on 3 specific aspects of context—genomic health care, shifting research paradigms, and social (Web 2.0) technologies—that must be considered in formulating a nursing informatics research agenda. These influences are illustrated using the significant issue of healthcare associated infections (HAI). A nursing informatics research agenda for 2008–18 must expand users of interest to include interdisciplinary researchers; build upon the knowledge gained in nursing concept representation to address genomic and environmental data; guide the reengineering of nursing practice; harness new technologies to empower patients and their caregivers for collaborative knowledge development; develop user-configurable software approaches that support complex data visualization, analysis, and predictive modeling; facilitate the development of middle-range nursing informatics theories; and encourage innovative evaluation methodologies that attend to human-computer interface factors and organizational context.

The context for nursing informatics research has changed significantly since the National Institute of Nursing Research (NINR)-funded Nursing Informatics Research Agenda was published in 1993¹ and the Delphi study of nursing informatics research priorities reported a decade ago.² Given that context is a core construct of nursing's meta-paradigm and, consequently, that of nursing informatics,³ the authors' premise is that a nursing informatics research agenda must reflect changes in context

while affirming commitment to the core meta-paradigm constructs of patient, health, and nursing. Although there are many contextual changes of relevance to the practice of nursing informatics including economics, consumerism, emerging diseases, workforce shortages, models of care delivery, and globalization,⁴ in this article, the authors focus on 3 specific aspects of context—genomic health care, shifting research paradigms, and social (Web 2.0) technologies—that must be acknowledged in

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formulating a nursing informatics research agenda. These influences are illustrated using the significant issue of healthcare-associated infections (HAI). Lastly, the authors suggest key components of a nursing informatics research agenda for the next decade.

Background

Genomic Health Care

The initial draft of the Human Genome Project in 2001⁵ heralded the age of genomic health care in which evolving understandings of genetic contributions to human health are being applied to the prevention, diagnosis, monitoring and treatment of diseases with “the ultimate promise of revolutionizing the diagnosis and treatment of many illnesses.”⁶ Subsequently, Collins and colleagues⁷ articulated a framework for genomics research and scholarship comprising 3 themes: Genomes to Biology, Genomes to Health, and Genomes to Society.

Based on the understanding that health outcomes are the result of multiple determinants, a recent Institute of Medicine report,⁸ highlighted the need to examine the complex interactions among genes, behavior, and the social environment. The Committee called for the creation of new data sets to inform interdisciplinary and translational research—these data sets would include variables related to biological and genetic measures, but also social and behavioral variables. Goal 3 of the National Library of Medicine’s (NLM) Long Range Plan for 2006–2016⁹—Integrated biomedical, clinical, and public health information systems that promote scientific discovery and speed the translation of research into practice—is aligned to meet the need for new data sets and has 3 associated recommendations: (1) Develop linked databases for discovering relationships between clinical data, genetic information, and environmental factors; (2) Promote development of Next Generation electronic health records to facilitate patient-centric care, clinical research, and public health; and (3) Promote development and use of advanced electronic representation of biomedical knowledge in conjunction with electronic health records.

The role of domain experts in characterizing the phenotypic data to be integrated with genomic and environmental data is paramount. In the context of infectious diseases, Petri et al contend that “the most sophisticated of genetic and epidemiological tools are useless when applied to a poorly defined phenotype.”¹⁰ A similar argument has been posited for the role of nursing by a number of authors who point out the importance of nursing’s specialized knowledge base, which includes integration of biobehavioral and environmental concepts, to genomic health care and to the design of tools that support the organization and

application of genomic data for practice, education, research, and policy-making.^{11–14} In addition, several authors suggest that incorporation of genomics into nursing research is necessary to assure that nursing practice is based on scientific evidence.^{14,15} Nurse researchers have integrated genomics into their programs of research and reports illustrate application of genetics in many clinical areas, including cardiovascular disease, schizophrenia, and child health.^{16–18} Also of relevance and consistent with nursing’s focus on human responses, Read et al¹⁹ developed and validated the Psychological Adaptation to Genetic Information Scale.

A number of societal concerns accompany the promise of genomic health care and must be addressed if the promise is to be achieved.^{14,20} Of most relevance to informing a nursing informatics research agenda are those related to: fairness in the use of genetic information; privacy and confidentiality of genetic information; psychological impact and stigmatization due genetic differences; use of genetic information in reproductive decision-making; education of clinicians, researchers, patients, and the general public in genetic capabilities, scientific limitations, and social risks; and uncertainties associated with gene tests for susceptibilities and complex conditions (eg, obesity) linked to multiple genes and gene-environment interactions.²⁰

A nursing informatics research agenda must support integration and use of genomic data for nursing care and for nursing research.

Shifting Research Paradigms

The manner in which research is conducted is changing dramatically. One major driver is the National Institutes of Health (NIH) Roadmap for Medical Research which articulates the importance of interdisciplinary and translational research.^{21,22} In addition, partially motivated by the Medicare Prescription Drug Improvement and Modernization Act of 2003 and Agency for Healthcare Research and Quality (AHRQ) initiatives, there is a movement toward study designs that test clinical and policy innovations in real world settings with an emphasis on effectiveness or comparative effectiveness as a complement to efficacy testing through randomized, controlled trials (RCTs).²³ Thirdly, there is increased attention at the federal level toward building the science of dissemination and implementation in the service of public health.²⁴

The Roadmap comprises 3 major programs (New Pathways to Discovery, Research Teams of the Future, and Re-engineering the Clinical Research Enterprise).^{21,22} Individual and institutional awards (eg, Clinical and Translational Science Awards) are aimed at accelerating fundamental discovery and translating that knowledge into effective prevention strategies and new treatments. Translational research is broadly defined within the Roadmap and includes the traditional notions of applying discoveries from laboratory and preclinical studies to the development of human

studies (bench-to-bedside and back), but also translation of findings of human studies into best practices and policies toward the goal of improved health. In discussing challenges associated with these 2 types of translation, the Institute of Medicine's Clinical Research Roundtable described the former as T1 and the latter as T2.²⁵ Woolf suggests that calling both T1 and T2 translational research is confusing and also contends that "adequate investment in T2 research is vital to fully salvage investments in T1 research."²⁶

Competence in interdisciplinary research is a prerequisite for both T1 and T2 translational studies since information-sharing and communication among researchers from varied backgrounds is vital across all stages of the research process. The Roadmap defines interdisciplinary research as that which "integrates the analytical strengths of two or more often disparate scientific disciplines to solve a given biological problem." Based on a systematic literature review, interviews and field tests conducted through Roadmap planning center funding, a team of researchers (including SB and EL) from the fields of biomedical informatics, dentistry, economics, epidemiology, medicine, nursing, physiology, and public health, proposed an expanded definition: "Interdisciplinary research is any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process."²⁷ Subsequently, a validated set of competencies based upon this definition was published.²⁸

Increased availability of electronic data, improved computational power, and development of sophisticated analytic techniques along with concerns regarding the limited external validity of RCTs^{29,30} have motivated the application of practice-based research designs and increased attention to the science of dissemination and implementation (eg, 2007 NIH Conference on Building the Science of Dissemination and Implementation in the Service of Public Health).²⁴ Whether experimental, quasi-experimental, or observational (ie, incorporate the natural variation in data from routine clinical practice), these designs share in common an emphasis on effectiveness in real world settings and use of data generated routinely from those settings as compared to efficacy testing under controlled conditions. The following examples depict these principles.

In terms of experimental design, Glynn et al used data from existing information systems to inform design decisions in a cluster-randomized trial.³¹ Data about how many patients are seen by more than one clinician in a practice or how many clinicians cross multiple practices allow the research team to weigh the advantages and disadvantages of particular design strategies—for example, whether randomization in a study of a new protocol for management of deep vein thrombosis should occur at the patient, clinician, or

practice level. Behavioral researchers³² have specified the need for and key characteristics of practical behavioral trials that are conducted across settings; include heterogeneous patients; and address multiple outcomes, patient preferences, and algorithms for intervention tailoring.

Quasi-experimental designs such as "designed delays" without random assignment, in which a clinical or policy intervention is rolled out to multiple sites at planned intervals, have also been advocated and offer several advantages.³³ As in wait-list design, the control group eventually receives the intervention and, secondly, the timing may be tied to delays that are naturally occurring in the real world.

Horn and colleagues have delineated the steps of an observational research methodology for comparative effectiveness research, which they call practice-based evidence for clinical practice improvement (PBE-CPI), and have implemented it across multiple topic areas and settings.^{34,35} Practice-based evidence for clinical practice improvement is characterized by 7 features: (1) consideration of all interventions to determine the relative contribution of each, (2) general rather than specific hypotheses, (3) maximizing external validity by limiting sample inclusion or exclusion criteria, (4) robust measures of severity of illness and functional status for characterization of patients, (5) statistical control of patient differences through measures such as risk-adjustment, (6) essential role of transdisciplinary clinical practice team through all phases of the research, and (7) transparency.³⁴

Beyond comparative effectiveness research, there is a need to build the science of dissemination and implementation so that practices found to be more effective in real-world settings are adopted. A number of theoretical models have been proposed and are being tested in multiple settings. As compared to models of research utilization and evidence-based practice, which are primarily clinician-oriented (eg, the Stetler model³⁶), these models emphasize organizational and community aspects. The Reach, Efficacy/Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework and its associated metrics have primarily been applied to self-management interventions.^{30,37,38} The Veteran Affairs Medical Center Quality Enhancement Research Initiative (QUERI) approach has been implemented for a variety of clinical conditions (eg, colorectal cancer).³⁹ The Availability, Responsiveness, and Continuity (ARC) Organizational and Community Intervention Model⁴⁰ has provided the theoretical basis for adoption of new strategies or technologies in mental health services at the organization and community level.

These trends in the conduct of research portend challenges and opportunities that should be considered in a nursing informatics research agenda.

Social (Web 2.0) Technologies

Web 2.0 has been conceptualized as "a knowledge-oriented environment where human interactions

generate content that is published, managed, and used through network applications in a service-oriented architecture.”⁴¹ Web 2.0 encompasses technologies such as blogs, wikis, podcasts, Really Simple Syndication (RSS) feeds, social software (eg, Facebook and MySpace social networking sites), and web application programming interfaces (Table 1). Web 2.0 is in its infancy in health care, but it offers several features of relevance to patients and clinicians.^{42,43} Through Wiki software, content development occurs collectively among members of a community—the largest example being Wikipedia—and while enhancing collaboration, this collective creation also challenges traditional notions of expertise and intellectual property. In addition to user-controlled content development and distribution, Web 2.0 platforms (eg, iGoogle) support user configuration of interfaces in ways that match their mental models or needs and sharing or repurposing of the created resources (eg, a calculator widget might be incorporated into many different types of Web pages). RSS supports syndication, aggregation, and notification of data from multiple sources (eg, journals, newspapers, blogs) as a single feed into a user interface (eg, Web page, iPod) through a subscription process. Social networking sites facilitate the building of communities among those who share interests or activities (identified through tagged profiles) and typically enable communication via multiple channels such as chat, messaging, email, video, voice chat, file sharing, blogging, and discussion groups.

In championing platforms and applications that support collaborative approaches in science, the authors⁴⁴ of “Wikinomics: How Mass Collaboration Changes Everything” use the aforementioned Human Genome Project as an example of massive, distributed public-private collaborations that resulted in GenBank[®], an annotated collection of all publicly available DNA sequences.⁴⁵ Moreover, the authors note that the

Human Genome Project represents for science “a watershed moment, when a number of pharmaceutical firms abandoned their proprietary human genome projects to back open collaborations” and, subsequently, accelerated innovation by challenging the traditional notions of how research is conducted.

Web 2.0 principles, platforms, and technologies will not only dramatically change the manner in which research studies are designed, conducted, and disseminated, but also offer the foundation for innovative intervention strategies. Shneiderman calls for new kinds of science, which he calls Science 2.0, and notes that “advancing Science 2.0 will require a shift in priorities to promote integrative thinking that combine computer science know-how with social science sensitivity.”⁴⁶

HAI Example

This example is available in the online version of this article at the Nursing Outlook Website: www.nursingoutlook.org.

Key Components of a Nursing Informatics Research Agenda for 2008–18

Reflective of the contemporary needs in nursing practice and the existing information and communication infrastructure (ie, before widespread access to the World Wide Web), the recommended priorities for nursing informatics research for 1992–1996 documented a focus on nursing data, information, and knowledge, most often in isolation from other types of data. The 29 recommended priorities were organized into 7 categories: (1) using data, information,

Table 1 – Web 2.0 Terms and Definitions

Term	Wikipedia Definition ⁴¹
Blog (weblog)	A website where entries are made in journal style and displayed in a reverse chronological order.
Podcast	A multimedia file that is subscription based (paid or unpaid) and distributed over the Internet using syndication feeds, for playback on mobile devices and personal computers.
RSS (really simple syndication)	A family of web feed formats. A web feed is a data format used for serving users frequently updated content. Content distributors syndicate a web feed, thereby allowing users to subscribe to it. Making a collection of web feeds accessible in one spot is known as aggregation.
Social software	Application that enables people to rendezvous, connect or collaborate through computer-mediated communication and to form online communities.
Web widget	A third party item that can be embedded in a web page (eg, calendar)
Wiki	A wiki is a type of Web site that allows the visitors themselves to easily add, remove, and otherwise edit and change some available content, sometimes without the need for registration. This ease of interaction and operation makes a wiki an effective tool for collaborative authoring. The term wiki also can refer to the collaborative software itself (wiki engine) that facilitates the operation of such a Web site, or to certain specific wiki sites, including the computer science site (an original wiki), WikiWikiWeb, and on-line encyclopedias such as Wikipedia.

and knowledge to deliver and manage patient care (n = 6); (2) defining and describing data and information for patient care (n = 7); (3) acquiring and delivering knowledge from and for patient care (n = 3); (4) investigating new technologies to create tools for patient care (n = 7); (5) applying patient care ergonomics to the patient-nurse-machine interaction (n = 2); (6) integrating systems for integrating better patient care (n = 3); and (7) evaluating the effects of nursing information systems (n = 1). Because of closely related priorities across categories, the priorities are collapsed and re-organized in Table 2. User needs of interest were primarily those of nurses, but, consistent with nursing's meta-paradigm, the information and decision-making needs of patients and families were also identified in several recommendations. Priorities also included the evaluation of the effects of technology on the nurses' psychophysiological comfort and functioning (ie, human-computer interaction) and on the nurses' relationships with patients and other health professionals. Another aspect of human-computer interaction mentioned, but not named as such, was the notion of flexible systems tailored to user knowledge and expertise. In addition, although not explicitly defined as practice-based research, development of clinical databases to generate knowledge about linkages among structure, processes, and outcomes was identified as a methodological priority to examine effectiveness, quality of

care, costs, and productivity for guidance of practice and policy. The resulting National Institutes of Health Program Announcement (PA-95-10), Enhancing Clinical Care Through Informatics, which was co-sponsored by NINR and NLM, focused primarily on nursing clinical data, processes and outcomes of care, and clinical decision-making.

The 1998 priorities identified through an electronic Delphi survey of nursing informatics experts and nurse researchers reinforced the 1993 priorities and reflected evolving consumerism in healthcare and changes in telecommunication infrastructure and technologies including the emergence of the World Wide Web. Research aimed at patients as direct users of technology, including consumer health informatics applications, was ranked in the survey as 6th of 10 priorities by nurse researchers and 10th by nursing informatics experts. The focus on patients as technology users is consistent with the changing definition of nursing informatics which, in 2002, acknowledged the role of nursing informatics in supporting patient decision-making: "Nursing informatics facilitates the integration of data, information, and knowledge to support patients, nurses, and other providers in their decision making in all roles and settings."⁴⁷

The research guideposts delineated in a white paper by the American Medical Informatics Association Nursing Informatics Working Group affirmed

Table 2 – Summary of Priorities from NINR Expert Panel (1993) and Delphi Survey (1998)

Priority Areas	1993	1998
User Needs		
Identification of users' (nurses, patients, families) information needs	■	■
Nature and processes of clinical decision making and skill development	■	
Match information technologies to nursing work patterns	■	
Capture, Representation and Storage of Data, Information, and Knowledge		
Develop, validate, and formalize nursing language terms, taxonomies, and classifications	■	■
Interdigitate nursing language schemes with larger standards initiatives	■	
Design and management of nursing information databases for use in patient management, clinical records, and research	■	■
Develop and test clinical data storage schemes that optimize single-recording, multiple use in nursing	■	
Develop alternative modes of conceptualizing, operationalizing, quantifying, and representing nursing information for incorporation into future information systems	■	
Demonstrate connectivity architecture for capture and storage of patient care information across settings	■	
Informatics Support for Nursing and Healthcare Practice		
Technology development including decision support systems to support nursing practice (integrates human-computer interaction)	■	■
Use of telecommunications technology for nursing practice		■
Professional practice issues (eg, competencies, confidentiality)		■
Informatics Support for Patients/Families/Consumers		
Patients' use of information technology	■	■
Consumer health informatics		■
Informatics Support for Practice-based Knowledge Generation		
Develop systems to build clinical databases to generate and analyze knowledge linkages among resource consumption (structure), care processes (including nursing diagnoses and interventions), and outcomes to guide practice and policy	■	
Design and Evaluation Methodologies		
Develop evaluation methodologies for studying system use and impact on nursing decision making, nursing practice, and if possible, patient outcomes	■	
Systems modeling and evaluation	■	■

important targets for nursing informatics research: assessing and improving health care and health outcomes, reducing health disparities in health care for minorities, building data infrastructure to support quality assessments and improvement, and protecting patient privacy and security.⁴

A nursing informatics research agenda must be based upon an understanding of the construct of nursing informatics intervention or solution. In contrast to clinical interventions, nursing informatics is accomplished through the development and application of information structures, information processes, and information and communication technologies. This is clearly delineated not only in the American Nurses Association's definition of nursing informatics,⁴⁷ but also in Effken's informatics research organizing model,³ which was based upon the American Academy of Nursing's model for quality health outcomes⁴⁸ and integrates nursing's meta-paradigm constructs (environment, patient, health, nursing [in this instance, nursing informatics]).

In the following paragraphs, the authors suggest key components of a nursing informatics research agenda for the next decade (2008–18) organized by the categories from Table 2.

User Information Needs

Genomic health care and the well-recognized interaction between environmental and genetic factors require a broadening of the types of information required to meet the health-related information, decision-making, and skill-building needs of nurses, patients, and families. Characterized as a “data tsunami” in the NLM's strategic plan,⁹ volumes of data will require not only computational intervention, but also human intervention to convert data into usable information and knowledge. Additionally, the nursing informatics agenda should more directly focus on meeting the information needs of interdisciplinary researchers along the continuum from discovery through implementation in practice with a particular emphasis on the development and use of information structures, processes, and technologies (eg, collaborative tools such as wikis) to reduce T2 translation roadblocks.

Acquisition, Representation, and Storage of Data, Information, and Knowledge

In the last 15 years, significant progress has been made in the acquisition, representation, and storage of nursing information, knowledge and data (nursing diagnoses, interventions, and outcomes),^{49–55} and in the integration of nursing concept representations with broader healthcare terminologies.^{56–60} Given the expanded breadth of user information needs, research that enables the acquisition, representation, and storage of genomic and environmental data in a manner that supports visualization and analysis in

conjunction with patient and nursing data is also needed. Determinations will need to be made about when integration should occur at the data storage level, the visualization level, or the analytic level.

Informatics Support for Nursing and Healthcare Practice

The majority of 1993 recommendations focused on the informatics support for nursing practice, but in nursing, as in the broader healthcare environment, the impact of information systems on care practices and patient outcomes has not yet been realized. In his essay entitled “Strategic Action in Health Information Technology: Why the Obvious has Taken So Long,” Shortliffe notes that the barriers to adoption are not primarily technical; they relate to the biomedical culture, making the business case, and structural barriers such as inadequate investment in information technology.⁶¹ In nursing, the significant efforts regarding concept representation described in the prior section provide an essential building block for supporting nursing practice.^{62,63} At this juncture, nursing informatics research is urgently needed to guide the re-engineering of nursing practice within the context of interdisciplinary care teams through application of information technology to create what Brennan et al have called technology-enabled practice.⁶⁴ It is vital that the research be based upon a theoretical model or framework to begin to address the dearth of middle-range nursing informatics theories (an exception is Staggers and Parks' nurse computer interaction framework⁶⁵) to complement abstract models and frameworks such as those proposed by Graves and Corcoran,⁶⁶ Turley,⁶⁷ Effken³ and Alexander.⁶⁸ These middle-range theories are needed to predict which information structures, processes, and technologies are likely to achieve the desired results and to build the science of nursing informatics.

Informatics Support for Patients/Consumers and Families

For several decades, the development and evaluation of multi-faceted informatics interventions for patients/consumers and families using a nursing perspective has been the target of several nursing informatics programs of research in a variety of settings.^{69–71} The types of technologies used have changed in concert with the evolution of technology in general. However, beyond the technologies that comprise it, Web 2.0 as a concept encourages broad sharing of contextualized data and information and collaborative knowledge creation in a manner that changes traditional definitions of expertise and facilitates access to the expertise of patients/consumers and caregivers in unimagined ways. Thus, nursing informatics research agenda should include a focus on developing and applying informatics strategies

enabled by Web 2.0 and future technologies to empower patients and their caregivers for collaborative knowledge development particularly related to self-management in chronic care, symptom management, and end-of-life care—key areas of interest to nursing and to the NINR.⁷² Nursing informatics research should not be constrained by current conceptualizations of patient/consumer-oriented applications such as portals, personal health records, and continuity of care records, but rather strive for modular development of structures and processes that support specific functions (eg, tailoring algorithm, consumer vocabulary, message library, risk assessment and communication) that can be accessed through a variety of applications and technology platforms.

Informatics Support for Practice-based Knowledge Generation

One of the 1993 NINR Expert Panel¹ priorities addressed the foundational and methodological support for practice-based research more than a decade prior to its emergence as a significant approach to measuring comparative effectiveness. As distinct from practice-based clinical research or health services research perspectives, which focus on applying a variety of analytic techniques to examine linkages among various structure, process, and outcome data elements to guide practice and/or policy, the focus of informatics research is on developing the information structures (eg, re-usable concept representations, tailored templates for data acquisition), processes (eg, data mining algorithms, natural language processing), and technologies (eg, interfaces to data marts) that support knowledge generation from practice. Knowledge discovery in databases requires domain expertise as well as informatics expertise and has been a focus of several nursing informatics researchers.⁷³⁻⁷⁵ Given the volume, breadth and variety of data available for knowledge discovery, there is a tremendous need for the development of user-configurable software approaches that support complex data visualization, analysis, and predictive modeling.

Design and Evaluation Methodologies

Both 1993 and 1998 priorities emphasized evaluation of impact on practice and outcomes. As a strategy for maximizing what is learned, Stead et al proposed a broader conceptualization of evaluation across stages of the system development life cycle and accentuated the need to match evaluation method to stage of development.^{76,77} Nursing informatics research reflects a panoply of evaluation methods from qualitative methods to randomized, controlled trials.⁷⁸⁻⁸² Although there has been relatively more attention to human-computer interface aspects in nursing informatics research^{80,83} than in other domain areas, more research is needed in order to manage the

impending “data tsunami” and to take advantage of the user-configurability of Web 2.0 platforms. As nursing informatics innovations move from efficacy to effectiveness evaluations, practice-based research designs such as those described earlier in this article warrant consideration as evaluation methodologies because of the importance of factors such as organizational context, “dose” of informatics intervention, and patient variables (eg, severity of illness) on outcomes.

Conclusions

The underlying nursing informatics principles of the 1993 and 1998 priorities for nursing informatics research continue to be relevant. The contextual influences described in this article and illustrated through the HAI example suggest that a nursing informatics agenda for 2008–18 must expand users of interest to include interdisciplinary researchers; build upon the knowledge gained in nursing concept representation to address genomic and environmental data; guide the reengineering of nursing practice; harness new technologies to empower patients and their caregivers for collaborative knowledge development; develop user-configurable software approaches that support complex data visualization, analysis, and predictive modeling; facilitate the development of middle-range nursing informatics theories; and encourage innovative evaluation methodologies that attend to human-computer interface factors and organizational context.

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The HAI example, including Table 3, is available in the online version of this article at the *Nursing Outlook* Website: www.nursingoutlook.org.

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Hai Example

The following example illustrates application of key principles from the contextual influences described in the previous section to the topic of HAI. The major premise of the example is that research and practice are inextricably connected and will motivate similar challenges and opportunities from a nursing informatics research agenda perspective. A second premise is that health outcomes cannot be understood nor improved without practice-based research. Consequently, the authors have chosen to present the example from the practice-based research view.

The Problem

HAI are a major source of morbidity and mortality and increase hospital costs despite the fact that they are often preventable. More than 70% of the bacteria that cause HAI are resistant to at least one of the drugs most commonly used to treat them. Nearly 90,000 of the patients acquiring a HAI annually are estimated to die. This ranks HAI as the fifth leading cause of death in acute care hospitals.⁸⁴ With regard to genomics and environmental influences: environmental and biologic risk factors for many HAIs have been identified. For example, patients who have been previously hospitalized or in a long-term care setting, who have received antibiotics in the past, have conditions that compromise the immune system (eg, cancer, HIV, severe diabetes, renal failure), or are homeless or injecting drug users are more likely to develop HAI. Frequently occurring genetic polymorphisms influence susceptibility to inflammation and infection.¹⁰ While genomics is in its infancy, it is likely that genetic predispositions to certain types of infection interact with environmental influences to increase or decrease the risk of a given patient developing an infection while hospitalized. This suggests the need for genomic and environmental data as well as clinical and administrative data for a program of practice-based research focused on prevention and early detection of HAI.

There have been a number of published studies in which researchers have examined the effectiveness of specific infection prevention and control interventions, such as hand hygiene, contact precautions, appropriate use of antibiotics, and routine surveillance for organisms. From these studies with high internal validity much is known about what is efficacious in preventing these serious infections. Additionally, the Healthcare Infection Control Practices Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC) has reviewed and ranked many of these interventions based on the strength of the research design in a series of published practice guidelines (<http://www.cdc.gov/ncidod/dhqp/guidelines.html>). However, the extent of

the effectiveness of these interventions in clinical practice is not clear. There is also a gap in knowledge about how to ensure that patients are receiving the highest quality care that best protects them from HAI. Petri et al argue that “Infections provide a remarkable window into the genetic diversity of humans, and through evolution, are likely to be responsible for a substantial fraction of that diversity.”¹⁰ Consequently, complementary bench-to-bedside and back (T1) studies are also relevant.

To answer these important questions, interdisciplinary comparative effectiveness and translational research (T1 and T2) approaches are needed. Table 3 provides an overview of research aims, design type, team members, data needs, and analytic strategies for 3 practice-based research studies focused on prevention of HAI which are discussed more fully below.

Comparative Effectiveness Approach

In this example, a comparative effectiveness approach, explicitly an observational design based upon Horn’s PBE-CPI principles,³⁴ is used to achieve the first aim. A transdisciplinary team comprising expert clinicians (eg, nurses, physicians, infectious disease specialists, pharmacists, microbiologists, epidemiologists, informaticians, genomics experts, economists, and biostatisticians and/or modelers) collaborates throughout all phases of the research. A variety of Web 2.0 technologies (eg, wikis, blogs, RSS) support the team’s synchronous and asynchronous collaboration processes. Rather than identifying specific a priori hypotheses, multiple infection control and prevention interventions and multiple outcomes (eg, HAI rates, morbidity, mortality, quality of life, cost-effectiveness) are studied concurrently under the umbrella of a general goal. To maximize external validity, patients are robustly characterized through multiple sources of data rather than limiting the sample of relevance through stringent inclusion or exclusion criteria. Moreover, data to create structural variables for description of the settings and data about the extent to which various processes or practices are implemented correctly and at what “dose” are automatically captured in routine practice in a way that they could be re-used for research purposes. Because organizational social context can enhance or cause barriers to adoption of practices to prevent or control HAI, work attitudes, climate, and culture are measured through the Organizational Social Context measurement system⁸⁵ to create an organizational profile. A variety of analytic strategies (eg, knowledge discovery in databases, multivariate regressions, predictive modeling, cost-effectiveness analysis) supported by user-configurable analytic tools are applied at frequent intervals to examine trends and to move from general to specific hypotheses about particular processes or practices.

Implementation Research Approach

Based on the results of the comparative effectiveness research, the transdisciplinary research team augmented by community stakeholders applies a theoretically-based implementation research model, the ARC Organizational and Community Intervention Model,⁴⁰ to design, implement, and evaluate strategies for increasing adoption of effective practices for prevention of HAI. The team uses a combination of qualitative and quantitative strategies to determine who and what needs to change and how those changes should be implemented.³⁹ As a result of this needs assessment in the hospital setting, adoption of best practices is facilitated by providing point-of-use access to relevant guidelines; applying management and motivational strategies to enhance staff willingness and interest in adhering to guidelines; developing staff reminders and other techniques to make it easy to comply; and establishing peer review and monitoring systems to provide feedback to staff on their own practices and links to outcomes (in this case, rates of HAI). Given the influence of prior antibiotic use on the development of HAI, a community-level campaign is directed at reducing inappropriate antibiotic use. This includes tailored health communication for those at most risk for antibiotic misuse and Web 2.0 portal strategies that support peer-education, support, and communication among community members about issues of HAI and antimicrobial resistance.

T1 Translational Research

The third aspect of this example illustrates cycles of translation from bench-to-bedside and back. A laboratory team of molecular geneticists and chemists discover a strain of staphylococcus common in the community, which has developed biologic characteristics that increase its virulence and transmissibility (eg, toxin formation, ability to adhere to mucosal surfaces, increased resistance to antimicrobial agents, acquisition of a new enzyme). This strain is particularly prevalent in individuals with identifiable high risk profiles and in certain communities. Persons infected with this particular strain are at considerably higher risk of long term sequelae and death. Because of an

increasing prevalence of this strain, alert systems to clinicians and infection control staff are developed and tested to allow rapid identification of those individuals who have the risk profile (phenotypic and environmental characteristics) associated with this staphylococcal strain. Since these patients are identified rapidly based on their admission risk profile and this information is communicated in real time to staff using electronic surveillance systems, special contact precautions and antibiotic prescribing patterns can then be initiated at the time of hospital admission. In addition, data are used to improve the risk profile itself.

However, because this strain cannot be differentiated by standard techniques in the clinical laboratory, the identification of at-risk individuals is based solely on epidemiologic evidence and resources are wasted because many patients are placed in isolation at admission because of their risk profile when they are not, in fact, infected with the virulent strain. Hence, clinicians identify the need for research to develop a screening test that rapidly and cost effectively confirms the presence of this strain. The research and development staff of a pharmaceutical firm work closely with infectious disease clinicians and infection control nurses, geneticists, molecular epidemiologists, and microbiology laboratory personnel to develop and field test a rapid diagnostic test which has a high sensitivity and specificity to differentiate this specific strain of staphylococcus.

The examples reflect the contextual influences of genomic health care, shifting research paradigms, and Web 2.0 technologies on HAI. However, the same influences are relevant to other clinical domains of interest to nursing. The examples serve to explicate a set of needs or “use cases” that can potentially be solved through nursing informatics research. Common across the research studies delineated in Table 3 are the need for: (1) representing a variety of concepts (eg, patient phenotypic and genotypic data, nursing data, organizational data, and environmental data) in a manner that supports re-use for a multitude of purposes; (2) tools for complex data visualization, analysis, and modeling; and (3) methods for efficient and effective communication among transdisciplinary team members. In the following paragraphs, the authors discuss how prior nursing informatics research priorities inform a Nursing Informatics Research Agenda for the next decade and discuss the key components of such an agenda.

Table 3 – Overview of Study Components for HAI Example

Aim	Research Design	Team Members	Data Needs	Data Analytic Strategies
1. Determine the effectiveness of various aspects of the CDC guidelines at decreasing HAI rates in everyday clinical settings.	Comparative effectiveness: PBE-CPI	Clinicians (nurses, epidemiologists, microbiologists, pharmacists) Genomics expert Informaticians Biostatisticians/ Modelers Economists Organizational/ systems researchers	Structure variables of setting (eg, hospital size, type) and organizational social context (ie, culture, climate, and work attitudes) Patient variables (eg, clinical variables, risk factors related to sociodemographics, environment, genomics) Process variables (eg, the extent that various components of the guidelines have been implemented) Outcomes (eg, HAI rates, morbidity, mortality, quality of life and costs)	Knowledge Discovery in Databases (KDD) data mining techniques Multivariable regressions Predictive modeling Qualitative/observational analysis of sites implementing best practices with low HAI rates Cost-effectiveness analyses
2. Develop, implement and evaluate strategies to increase the adoption of the effective practices.	Translational (T2): ARC Model	As above, with the addition of community stakeholders, experts in communication and social marketing	As above, with the addition of key informant qualitative data	Thematic analysis of qualitative data Inferential statistics Econometrics
3a. Identify biologic characteristics of a microbial strain of staphylococcus that increase its virulence.	Translational (T1)	As above, with the addition of molecular geneticists, chemists, pharmaceutical researchers	As above, with the addition of microbial variables: (ie, genetics and biologic and chemical characteristics of staphylococci)	As above, with the addition of basic microbial genetic and chemical analyses and pharmaceutical techniques
3b. Develop screening technique to rapidly and cost effectively identify patients carrying this strain.				