Infrastructure for Quality of Care

JAMIA

Review ■

Informatics: Essential Infrastructure for Quality Assessment and Improvement in Nursing

SUZANNE BAKKEN HENRY, RN, DNSc

Abstract In recent decades there have been major advances in the creation and implementation of information technologies and in the development of measures of health care quality. The premise of this article is that informatics provides essential infrastructure for quality assessment and improvement in nursing. In this context, the term quality assessment and improvement comprises both short-term processes such as continuous quality improvement (CQI) and long-term outcomes management. This premise is supported by 1) presentation of a historical perspective on quality assessment and improvement; 2) delineation of the types of data required for quality assessment and improvement; and 3) description of the current and potential uses of information technology in the acquisition, storage, transformation, and presentation of quality data, information, and knowledge.

■ *J Am Med Informatics Assoc.* 1995;2:169–182.

In recent decades there have been major advances in the creation and implementation of information technologies and in the development of measures of health care quality. Yet the following words, spoken by Florence Nightingale in 1863, may be uttered by the nurse manager of the 1990s preparing a quarterly quality assurance report for an impending site visit by an accreditation agency:

In attempting to arrive at the truth, I have applied everywhere for information, but in scarcely an instance have I been able to obtain hospital records fit for any purpose of comparison. If they could be obtained they would enable us to decide many other questions besides the one alluded to. They would show the subscribers how their money was being spent, what good was really being done with it, or whether the money was not doing mischief rather than good.¹

Affiliation of the author: School of Nursing, University of California, San Francisco, San Francisco, CA.

Presented in part at Informatics: The Infrastructure for Quality Assessment and Improvement in Nursing, Austin, Texas, June 22–25, 1994.

Correspondence and reprints: Suzanne Bakken Henry, RN, DNSc, Box 0608, School of Nursing, University of California, San Francisco, San Francisco, CA 94143-0608. e-mail: sbhenry@itsa.ucsf.edu

Received for publication: 12/05/94; accepted for publication: 12/22/94.

Unfortunately, in most health care organizations today, these words are more likely to inspire empathy rather than nostalgia.

The premise of this article is that informatics provides essential infrastructure for quality assessment and improvement in nursing. In this context, the term quality assessment and improvement comprises both short-term processes such as continuous quality improvement (CQI) and long-term outcomes management. The evidence for this premise is reviewed

Table 1 ■

Important Societal Forces That Have Influenced Quality Assessment and Improvement in the United States since the Beginning of the Twentieth Century

1910–1959		1980s	
Nursing	First minimum standard for nursing in U.S. hospitals (1946) ³ Study conducted to establish criteria of quality nursing care (1954) ⁴	Nursing	Unit-based quality assurance is predominant, as evidenced by the release of the Marker Model for Quality Assurance and JCAHO Monitoring and Evaluation Process ^{27–32}
Health care	Access to and financing of care, rather than quality of care, are major issues ² Flexner report about quality of medical education (1910) ²		Development and dissemination of specialty practice standards ³⁰ Publication of list of nursing-sensitive patient outcomes ³³
Regulatory	Minimum standard by American College of Surgeons (1918) ⁵ JCAH formed as official accrediting body for U.S. hospitals (1952) ⁵	Health care	Seminal studies highlight variation in practice and the poor quality of evidence related to appropriateness of medical treatments ³⁴ Development of multidimensional outcome measures such as the Medical Outcome Study Short Form General Health Survey ^{35,36} CQI/TQM principles appear in the literature and early innovators begin incorporating them into quality assurance programs ^{37–39}
Business/industry	Hawthorne experiments demonstrate the complexity of work and worker/manager relationships, leading to subsequent research on motivation ⁶ Deming advises Japan on CQI post-world War II ⁷	Regulatory	Implementation of diagnostic-related groups as the basis of prospective reimbursement for Medicare recipients ² JCAHO publishes the <i>Agenda for Change</i> to institute its clinical indicator program that increases emphasis on outcomes of care ^{31,32} Passage of the Omnibus Budget Reconciliation Act leads to the formation of the Agency for Health Care Policy and Research ⁴⁰ Pilot testing of the Uniform Clinical Data Set as a method of examining quality of care ⁴¹ CQI/TQM processes widely implemented ⁷
1960s			
Nursing	Development of the Phaneuf retrospective process audit, which was subsequently published in the 1970s ^{8,9} Attempts to systematically link the process and outcomes of nursing care ¹⁰ Examination of criterion measures in nursing ¹¹		
Health care	Publication of classic articles by Donabedian on the differences among structure, process, and outcomes ^{12–15}	Business/industry	
Regulatory	Enactment of Medicare and Medicaid accompanied by government regulations for utilization review of the cost and quality of services ¹⁵ JCAH requirements focused on structure elements ¹⁵	Nursing	Movement away from primary care nursing as a predominant care delivery model as a result of work redesign in health care organizations ⁴² Revised ANA <i>Standards of Clinical Nursing Practice</i> delineates outcome identification and evaluation of the quality and effectiveness of nursing care as important components of nursing practice ⁴³ ANA Database Steering Committee focuses on development and implementation of a Unified Nursing Language System and incorporation of nursing-specific data elements in federal databases used to examine cost and quality of care ⁴⁴ Seminal work on the development of nursing-sensitive outcome measures ^{45–47}
Business/industry	Traditional hierarchical bureaucratic structures predominate ⁶ Worker motivation is the primary method for improving product quality, with cognitive theorists and behaviorists providing competing strategies ⁶	Health care	Shift from fee for service to managed care as a reimbursement mechanism ^{48,49} Development and dissemination of <i>Clinical Practice Guidelines</i> by the AHCPR ^{50–54} Implementation of strategies to decrease variation in practice, such as clinical algorithms, practice guidelines, and critical pathways ^{55–58} Publication of comparative outcomes via health care "report cards" ^{59,60} Publication of reports about the computer-based patient record and regional health networks reflect increasing need for sharing of electronic data ^{61,62} Adaptation of CQI/TQM principles for the clinical environment ⁶³
1970s		1990s	
Nursing	Publication of the ANA <i>Standards of Nursing Practice</i> ¹⁶ Publication of the ANA Model of Quality Assurance in Nursing ¹⁵ Research on quality of nursing care focused on the development of measures examining the process of care (i.e., QUALPACS, Rush-Medicus) ^{17–22}	Regulatory	CQI and information management principles incorporated into JCAHO standards ⁶⁴
Health care	Retrospective chart review is the predominant method for assessing quality ¹⁵ Beginning work on small area practice variation reported ²³ Early work on measurement of health status dimensions published ²⁴	Business/industry	Reengineering emerges as a major approach to economic survival and quality improvement ^{6,65}
Regulatory	Establishment of Professional Standards Review Organizations (PSROs) to examine care provided for persons in federally funded programs ² JCAH increased emphasis on quality assurance with establishment of the Peer Evaluation Program ²		
Business/industry	"Quality guru" Phillip Crosby publishes <i>Quality is Free</i> , which becomes an international best-seller ²⁵ Adoption of CQI principles by a few organizations ²⁶		

through the 1) presentation of a historical perspective on quality assessment and improvement; 2) delineation of the types of data required for quality assessment and improvement; and 3) description of the current and potential uses of information technology in the acquisition, storage, transformation, and presentation of quality data, information, and knowledge.

Historical Perspective on Quality Assessment and Improvement

Societal Influences

Bull identified five societal forces influencing quality assurance: 1) consumer demands and needs; 2) government legislation; 3) third-party payers; 4) professional accountability and organizations or accrediting bodies; and 5) technology.² Table 1 summarizes important societal forces related to nursing, health care, regulatory bodies, and business/industry that have influenced quality assessment and improvement in the United States since the beginning of the twentieth century.²⁻⁶⁵ Many of these forces are not unique to the United States, but rather serve as examples. Five trends are of particular importance to the topic of informatics as infrastructure for quality assessment and improvement. First, the emphasis of quality assessment has shifted from structure or the capacity to provide quality care to examination of the linkages between the processes and outcomes of care. Second, the government has become a predominant third-party payer for health care and has exerted increasing influence on the utilization of health care services and the assessment of quality of care. Third, there has been an increased focus on professional accountability for costs and quality of health care, evidenced by the development of standards of care and practice guidelines by professional bodies. Fourth, quality has emerged as a phenomenon to be controlled, managed, and continuously improved upon, rather than reviewed retrospectively. Finally, the conceptualization of quality outcomes has shifted from mortality and morbidity to a multidimensional construct with resultant complexity in measurement. This multidimensionality is illustrated in Table 2, which compares six representative published lists of health care outcomes.^{24,33,36,47,66,67}

The Current Environment

In the current environment of health care reform and managed care, health care organizations are faced with increasing demands for information about the quality and cost of health care services for internal quality management and for external reporting to

regulatory agencies (e.g., Joint Commission on Accreditation of Health Care Organizations [JCAHO]), governmental bodies (e.g., Health Care Financing Administration), research organizations (e.g., University Hospital Consortium), and third-party payers (e.g., Health Plan Employer Data and Information Set [HEDIS]).^{59,60,64,68} In addition, consumer forces are driving the movement toward benchmarking and comparative health care "report cards." Manual abstraction of these types of data in large volumes from paper-based systems is neither cost-effective nor feasible.⁶⁹

The importance of information management to the functioning of a health care organization has been recognized by the JCAHO, which has recently formulated information management standards and measurement criteria to be included in the accreditation process.⁶⁴ While not dependent on information technology, the ease with which the standards are met can be facilitated by an information system.

Table 2 ■

Comparison of Outcome Dimensions as Listed by Six Authors

Dimension	Author					
	1	2	3	4	5	6
Mortality/death		x	x			
Disease			x			
Adverse events		x				
Decline in health status	x					
Utilization of services					x	
Physical functioning	x			x		
Physiologic status					x	
Role—physical				x		
Disability/inadequate recovery		x	x			
Prolongation of medical problem		x				
Functional status					x	
Self-care ability						x
Ambulation						x
Home functioning/maintenance					x	
Mental health	x			x		
Role—mental				x		
Psychological distress						x
Psychosocial status					x	
Social functioning				x		
Behavior					x	
Pain/discomfort	x		x			
Symptom control					x	
Quality of life		x			x	
Health perceptions	x			x		
Satisfaction			x		x	
Knowledge					x	
Safety					x	
Family strain					x	
Goal attainment					x	
Resolution of nursing diagnosis					x	

1 = Brook²⁴; 2 = Lohr⁶⁶; 3 = Lohr⁶⁷; 4 = Stewart³⁶; 5 = Marek³³; 6 = Holzemer.⁴⁷

National Initiatives for Electronic Sharing of Health Care Information

The 1991 report from the Institute of Medicine about the computer-based patient record (CPR) presented a vision for a national infrastructure aimed at "improving the care of both individual patients and populations and, concurrently, to reduce waste through continuous quality improvement."⁶¹ Efforts toward achievement of the CPR are being facilitated by both the private and the public sectors through the Computer-based Patient Record Institute.⁶¹ In addition, both the National Library of Medicine and the Agency for Health Care Policy and Research (AHCPR) are funding research focused on the advancement of electronic medical records. The AHCPR is primarily charged with the enhancement of the quality, appropriateness, and effectiveness of health care services through a broad program of scientific research and information dissemination.⁴⁰ Among the activities of the agency is data development specifically focused on the identification, evaluation, and expansion of existing databases to support research on patient outcomes.

With the emergence of entities focused on the public release of data from large databases, the Institute of Medicine Committee on Regional Health Data Networks has released recommendations regarding the use of patient-specific and aggregated health care data.⁶² These recommendations focus on the accuracy and completeness of the data and on advocacy for widespread data use and release while protecting individual confidentiality and privacy through the enactment of federal legislation. The American Nurses Association (ANA) through the ANA Database Steering Committee is working to ensure the inclusion of data elements relevant to nursing care in regional health databases.⁴⁴

The complexity of the current health care environment and increasing demands for information about the quality of care have highlighted the need for informatics as infrastructure for quality assessment and improvement. The remainder of this article delineates the types of data required for quality assessment and improvement and describes the manner in which information technology can be used to acquire, store, transform, and present data, information, and knowledge related to quality assessment and improvement.

Types of Data

The role of informatics as essential infrastructure for quality assessment and improvement in nursing is reviewed using the framework for design character-

Table 3 ■

Examples of Patient-specific Data, Agency-specific Data, and Domain Information and Knowledge for Quality Assessment and Improvement

Patient-specific data

Demographics (date of birth,*† gender,*† race and ethnicity,*† source of admission,† payer*†)
Problems (nursing diagnoses,* medical diagnoses,† symptoms, reasons for the health care encounter)
Severity of illness score (APACHE III, Medis Groups, Computerized Severity Index)
Individual preferences or utility assessments
Interventions (nursing interventions,* medical interventions, procedures,† laboratory tests, treatments)
Nursing care intensity*
Primary provider identifiers (MD, RN*)
Outcomes* (functional status, quality of life, mortality,*† morbidity, health service utilization, cost, satisfaction with care, resolution of nursing diagnoses, disposition*†)

Agency-specific data

Medicare case mix‡
Occupancy‡
Nursing resources‡
Budget‡
Locally developed or agency-specific practice parameters and guidelines
Average intensity of medical and nursing care‡
Utilization patterns
Raw and risk-adjusted patient outcome measures (e.g., mortality, length of stay, functional status, complication rates, patient satisfaction‡)
Provider satisfaction‡
Achievement of accrediting body standards

Domain information and knowledge

Bibliographic databases
Standards of care, practice guidelines, regulations from federal agencies, professional organizations, and accreditation bodies
Electronic patient advising and consultation systems
Comparative databases

*Data element in Nursing Minimum Data Set.⁷¹

†Data element in Uniform Hospital Discharge Data Set.³

‡Data element in Nursing Management Minimum Data Set.⁷²

istics of a nursing information system provided by the National Commission on Nursing Implementation Project (NCNIP) Task Force on Nursing Information Systems.⁷⁰ The framework includes three categories of information required to support professional nursing practice. Because the evaluation of the quality and effectiveness of nursing practice is a standard of professional nursing performance,⁴³ the framework is appropriate for examining quality assessment and improvement data in nursing. *Patient-specific data* are those data about a particular patient that are acquired from a variety of data sources. *Agency-specific data* are those data relevant to the specific organization under whose auspices the health care is provided. *Domain information and knowledge* are specific to the discipline of nursing or to other related health care disciplines. Examples of each category of information are given in Table 3.^{3,71,72}

Patient-specific Data

As shown in Table 3, a variety of patient-specific data are required for quality assessment and improvement purposes depending on the specific purpose of the study. Some of these data are atomic, i.e., elemental, precise data captured at the source in the course of clinical care.⁷⁰ Other data, such as severity of illness scores⁷³⁻⁸¹ or nursing care intensity,⁸² are derived from atomic-level data. Figure 1 provides examples of the manner in which atomic-level, patient-specific data can be abstracted, aggregated, and summarized using a clinical information system in order to meet a variety of information needs.⁷⁰

These data include inputs to the care process, processes of care, and outcome measures. Structure or input has traditionally been defined as the capacity to provide quality care, including facilities, equipment, and provider qualifications.¹²⁻¹⁴ However, more recently, the conceptualization of structure or input has been broadened to include other inputs to the care process, including patient-specific variables such as demographics, severity of illness, problems, and utility assessments, to facilitate comparisons of risk-

adjusted outcomes.^{83,84} Process variables comprise interventions and intensity of intervention measures. While outcome measurement still includes mortality, other measures related to the end result of care in terms of health and satisfaction are essential due to the multidimensional nature of quality.^{24,33,36,66,67}

Some data are specific to nursing (e.g., nursing diagnoses, nursing interventions, and nursing care intensity), while others relate to the total health care encounter. When examining the quality and effectiveness of nursing care, it is vital to include variables such as severity of illness score or medical diagnosis to statistically control for the underlying medical condition of a patient.

In his discussion of a framework for the transition from nursing records to a nursing information system, Turley notes that the storage of the transaction log (what the nurse does when) is not likely to add to the understanding of a patient's condition and problems. He states, "Alone, transaction logs do not reflect the evolvement of patient status, condition resolution, or expected long-term outcomes. All those lost data represent the forfeiture of documented

Figure 1 Examples of uses for atomic-level patient data collected once but used many times. Reprinted with permission from *Next-Generation Nursing Information Systems*, ©1993, American Nurses Association, Washington, DC.

nursing knowledge and will critically effect the development of decision support components of any nursing information system."⁸⁵ This statement is consistent with the recommendation found in the Institute of Medicine's report about the CPR that identifies the documentation of the logical basis for all diagnoses or conclusions and the clinical rationale for decisions about the management of a patient's care as an essential attribute of CPR systems.⁶¹ The collection of appropriate, patient-specific data is vital to quality assessment and can also facilitate the design of decision support strategies to improve the quality of care.⁸⁶

Agency-specific Data

There are a variety of agency-specific data relevant to quality assessment and improvement. These fall into the areas of practice parameters or guidelines, operational data, and financial data. Examples of data or information in the category of practice parameters include standards of care,⁴³ standardized nursing care plans,⁸⁷ multidisciplinary critical paths,^{55,56} locally developed practice guidelines,^{57,58} standardized protocols, and procedures.²⁷ This type of information can be used to analyze variation in practice when linked with patient-specific or provider-specific data and also has the potential to serve as an intervention to decrease variation in practice.

Operational data are also extremely important. Types of data that are potentially relevant to quality assessment and improvement include measures of utilization and workload. For example, information about the pattern of utilization of the operating room would be useful to a CQI team charged with improving work flow in the surgical suite. Workload information, such as that provided by a patient classification system, can provide useful process data to be combined with outcome data for comparison of outcomes among units.⁸⁸

The reengineering literature is replete with examples of the importance of sharing financial data with decision makers at all levels, and numerous authors have described information technology as an "enabler" in the reengineering process.^{6,65} A number of different types of financial data are relevant in the quality assessment and improvement process, e.g., the costs of particular supplies, medications, and procedures. Other data of vital importance in the current environment of increasing capitation are the average costs of care for specific groups of patients.

Domain Information and Knowledge

Access to four types of domain information and knowledge sources is required to support the quality

assessment and improvement process. First, there must be point-of-care access to the bibliographic literature from electronic sources such as MEDLINE, the Cumulative Index of Nursing and Allied Health Literature (CINAHL), and SEDBASE.⁸⁹ The second type of domain information and knowledge source useful in the quality assessment and improvement process is non-agency-specific parameters such as the AHCPR clinical practice guidelines⁵⁰⁻⁵⁴ and standards of care from professional health care organizations.⁴³ Third, consulting systems for patient-specific advice, such as QMR, Iliad, or COMMES, have an emerging role in the process.⁹⁰⁻⁹² Fourth, comparative databases have the potential to play an important role in terms of benchmarking as a quality improvement strategy.⁶⁴ These comprise regional and national databases, databases of regulatory agencies such as JCAHO, and public and proprietary databases maintained primarily for research and health policy purposes.^{59,60,64,67}

Information Technology

The NCNIP framework delineates four types of information system processes that relate to the three categories of information.⁷⁰ *Data acquisition* is the set of methods by which data become available to the information system, e.g., from data entry by the nurse or from a medical device. *Data storage* includes the methods, programs, and structures used to organize data for subsequent use (e.g., type of database and indexes to search the database). *Data transformation* or processing comprises the methods by which stored data or information is "acted upon" according to the needs of the end user (e.g., calculations or searches for matches with system rules). *Presentation* encompasses the forms in which information is delivered to the end user after processing (e.g., charts, graphs, or multimedia).

The processes of acquiring, storing, transforming, and presenting quality assessment and improvement information are described in the following sections. The major emphasis is on transformation or processing because the other information processes are common across applications and all processes are familiar to the audience of this journal. Finally, selected examples of quality improvement facilitated by integrated information systems are described.

Acquiring

The three major strategies for acquiring quality assessment and improvement data for storage, processing, and presenting in an information system are data entry by a member of the health care team or

by the patient, transfer of data from a medical device to an information system, and sharing of data among computer-based systems.

Patient-specific data such as patient assessments and history collected by the provider at the point of care can be entered into the information system via a number of interface devices, such as the keyboard, trackball, mouse, touch screen, or light pen. While not yet widely implemented, pen-based and voice recognition interfaces are being studied by a number of investigators.⁶¹ Although strides are being made in the development of clinical workstations, for the near future, dictation and transcription by clerical or data entry personnel may continue as a predominant method or an alternative method of data entry for admission history and physical examination in some institutions.⁹³

In addition, with increasing emphasis on the patient as a decision partner, several researchers have demonstrated the efficacy of using innovative information technology to assess patient preferences regarding treatments and treatment outcomes. Of particular interest is the work of Kasper et al.⁹⁴ using computer-assisted interactive video in the selection of treatment for benign prostatic hypertrophy and the investigation by Goldstein et al.⁹⁵ utilizing a multimedia-based utility assessment approach to gather health state data for decision analysis and cost-effectiveness analysis.

Quality assessment and improvement data can also be acquired from medical devices such as ventilators, intravenous pumps, urimeters, and pulse oximeters.^{96,97} This acquisition has been hampered by the lack of a standard for electronic data exchange between the devices and the information system, necessitating custom programming.⁹⁷ However, a recent effort by the Institute of Electrical and Electronic Engineers entitled the Medical Information Bus Standard is aimed at "the development of a hardware and software communication standard that would allow 'plug and play' connection of medical devices to data monitoring and data management systems"⁹⁷ and thus would enhance electronic data exchange. This proposal is currently under review for adoption as a standard.

Quality assessment and improvement data are frequently acquired from a variety of information systems (e.g., pharmacy, laboratory, financial, and radiology), as well as from systems supporting the documentation and retrieval of clinical care information. These systems are likely to have varying degrees of integration. Domain information and knowledge are frequently acquired through access to

external databases and knowledge bases and, for the most part, are not integrated into point-of-care information systems. Such linkages, however, have been identified as an essential attribute of the evolving CPR.⁶¹ Regardless of the type of quality process or outcome being examined, it is clear that the data are likely to be acquired from numerous sources via a variety of interfaces.

Storing

The principles for storage of data, information, and knowledge, whether patient-specific, agency-specific, or domain-specific, are the same. Regardless of the acquisition strategy, most data should be stored using accepted vocabularies, dictionaries, and lexicons to enhance single-entry, multiple use and with extensive indexing of stored contents to facilitate retrieval, review, and update.⁷⁰

Standardized vocabularies or classification schemes designed specifically for nursing include the North American Nursing Diagnosis Association (NANDA) Taxonomy 1,^{98,99} the Nursing Interventions Classification,¹⁰⁰⁻¹⁰² the Home Health Care Classification System,^{103,104} and the Omaha Community Health System.¹⁰⁵⁻¹⁰⁷ Investigators have also demonstrated the feasibility of using terminologies not specifically designed for nursing, such as the Current Procedural Terminology (CPT) codes^{108,109} and SNOMED International,¹¹⁰ to represent some types of nursing concepts.¹¹¹

Other efforts have been aimed at the design of standardized minimum data sets related to nursing management rather than the description of patient problems, interventions, and outcomes. The Nursing Practice Personnel Data Set is designed to collect data at the individual nurse level for six categories of data elements: demographics, professional education, position, practice, organizational training, and recruitment/retention.¹¹² The 18 data element Nursing Management Minimum Data Set, on the other hand, is focused on data at the nursing unit and institution levels clustered into four dimensions: structure/process/resources, outcomes, personnel, and relational database links.⁷² Nursing unit variables include, for example, method of care delivery, average intensity of nursing care, and nursing resources. Examples of institution-level data elements are Medicare case mix, staff mix, revenues, and achievement of accrediting body standards.

Several national initiatives are aimed at unifying the vocabularies used in computer-based systems to facilitate transfer of data, information, and knowledge among systems. The National Library of Medicine

has funded a project entitled the Unified Medical Language System, which is focused on the establishment of a conceptual link between the user's information needs and information sources, including biomedical literature, clinical records, databases, knowledge bases, and dictionaries of information resources.^{113,114} Other efforts include the work of the American National Standards Institute Healthcare Informatics Standards Planning Panel in coordinating the work groups for health care data interchange.¹¹⁵ The ANA, at the national level,⁴⁴ and the International Council of Nursing, at the international level,¹¹⁶ are pursuing the establishment of a family of taxonomies of problems, interventions, and outcomes within the framework of a Unified Nursing Language System.

While standardized vocabularies do not yet exist for all data relevant to quality assessment and improvement, the standardization is essential for comparative studies across organizations, communities, or regions. In addition, the storage in a standardized format and the extensive indexing of quality data will facilitate the development and sharing of computer-based quality improvement interventions such as knowledge-based clinical decision support systems. These strategies, however, must be complemented by electronic data interchange standards and standardized instruments to measure health care outcomes.

Transforming

The major impact of informatics on the quality assessment and improvement process is in the transforming or processing of data, information, and knowledge. Although numerous instances exist, the transformation process is illustrated by the examples of aggregation of atomic-level data, concurrent monitoring, and linkages among structure, process, and outcome variables.

Aggregation of atomic-level data

The use of information technology to automatically abstract atomic-level data collected as part of the clinical care process and to transform these data into individual scores or aggregate rates for groups of patients is a vital contribution to the quality assessment and improvement process in nursing, and in health care as a whole. Two prime examples of this are the abstraction of data to generate severity of illness scores and for aggregation to provide quality and utilization data to external sources.

Severity of illness. Severity of illness measures are classification or scoring systems that transform selected patient-specific data into determinations of

prognosis and treatment. Although there are differences among systems, potential uses of severity of illness scores for quality assessment and improvement purposes include the calculation of risk-adjusted outcome based on severity of illness, cost-benefit analyses related to allocation of resources, and prediction of appropriate levels of nurse staffing.⁷³⁻⁸²

An excellent example is provided by Shabot and associates, who have demonstrated the efficacy of automatic extraction of patient-specific data and calculation of intensity-intervention scores from a computerized surgical intensive care unit (ICU) flow-sheet.⁸² The data included 14 physiologic variables from the Simplified Acute Physiology Score¹¹⁷ (SAPS), 31 indicators of nursing interventions, and APACHE II chronic health and surgical indicators. These scores were validated by correlations with ICU mortality, length of stay, manual severity of illness scores, and subjective classifications of patients to levels of care. These scores have been used to guide appropriate use of ICU resources, to provide information about nurse staffing ratios, and to normalize (by adjusting for severity of illness) data used for research and operational purposes.⁸²

HEDIS 2.0. HEDIS 2.0^{59,60} is a core set of performance measures developed to respond to the need of employers as purchasers of health care services to determine the value purchased by the health care dollar. HEDIS is used to illustrate the type of request that can be responded to by the processing and aggregation of patient-specific data (Table 4). While there are no nursing-specific HEDIS indicators, nurses, along with other members of the multidisciplinary health care team, are contributors to the outcomes measured. In addition to the performance measures listed in Table 4, which relate specifically to quality, access and patient satisfaction, and membership and utilization, HEDIS includes 14 performance measures related to finance and descriptive information about health plan management and activities. Health care organizations are barraged with similar requests for a broad variety of data from numerous external sources. The provision of these types of data in a timely manner is essential to survival in today's economic climate.

Concurrent monitoring

Concurrent monitoring applies agency-specific data or domain information and knowledge to patient-specific data. In relation to quality assessment and improvement, this is most frequently operationalized as electronic alerts and reminders that identify potential "quality" problems and may include sugges-

Table 4 ■

Health Plan Employer Data and Information Set (HEDIS) 2.0 Performance Indicators Related to Quality, Access and Patient Satisfaction, and Membership and Utilization*

Quality

- Preventive medicine
 - Childhood immunization
 - Cholesterol screening
 - Mammography screening
 - Cervical screening
- Prenatal care
 - Low birth weight
 - Prenatal care in first trimester
- Acute and chronic diseases
 - Asthma inpatient admission rate
 - Diabetic retinal exam
- Mental health
 - Ambulatory follow-up after hospitalization or major affective disorders

Access and patient satisfaction

- Access
 - Percentages of members aged 23–39 years and 40–64 years with plan visits in previous three years
 - Number and percent of primary care physicians accepting new patients
 - Provision of plan access standards for various types of visits and telephone responses
- Member satisfaction
 - Percent of members who are “satisfied” with the plan
 - Provision of plan satisfaction surveys

Membership and utilization

- Membership—enrollment/disenrollment
- High occurrence/high cost—frequencies and average costs of nine DRG categories and frequencies of seven selected procedures
- Inpatient utilization (general hospital/acute care)—medicine/surgery, maternity, and newborns
- Ambulatory care utilization—outpatient visits, emergency room visits, and ambulatory surgery/procedures
- Inpatient utilization (nonacute care)—stays in nursing homes, rehabilitation facilities, hospices, transitional facilities, and respite facilities
- Maternity—vaginal births, cesarean sections, optional reporting of vaginal births after cesarean sections
- Newborns—well and complex newborns differentiated by length of stay
- Mental health—treatment on the basis of inpatient, day/night, and outpatient location, and readmission rate for major affective disorders
- Chemical dependency—treatment on the basis of inpatient, day/night, and outpatient location, and readmission rate for chemical dependency
- Outpatient drug utilization—average cost and number of prescriptions per member

DRG = diagnosis-related group.

*HEDIS 2.0 also includes 14 measures of financial performance and descriptive information about health plan management and activities, such as provider recredentialing and utilization review activities.^{59,60}

tions for the appropriate treatments or preventive strategies.

Identification of patients “at risk.” Blaufuss and Tinker described the implementation of a computer-

based falls alert in the HELP system.¹¹⁸ Using the alert designed by expert clinicians, the decision logic within the system is applied to current and past information to identify a patient at high risk for fall. The user is then guided by the system during the selection of appropriate interventions.

Prompting to enhance compliance with standards of care. A similar strategy utilizing different information technology was described by Graves et al.^{86,119} Atomic-level data are documented using an intelligent graphic user interface and structured text entries on a mobile, pen-based patient assessment tool. The nurses are prompted for the essential data to be collected based on standards of care. The data are stored in a database and have been used for a medical decision support system to diagnose delirium in the elderly. Plans exist to link this database with other databases and decision support systems.

Surveillance for potential adverse events. Patient-specific data have also been used to trigger other types of alerts, such as those related to potential adverse drug events. A number of studies have been conducted to assess the impact of a computerized surveillance program within the HELP information system on the prevention of adverse drug events and the detection of the effects of adverse drug events.^{120–122} Potential adverse drug events were automatically identified through monitoring of multiple sources, including sudden medication stop orders, antidote ordering, and abnormal laboratory values, and then were reviewed and verified by a pharmacist. The studies demonstrated the superiority of the automated system over the traditional approaches to adverse event detection. Because nursing has a major role in the detection and management of adverse drug events, sign and symptom data collected as part of routine nursing care may also serve as an additional data source.

Linkage of structure, process, and outcome

Informatics has the capacity to provide the infrastructure to link structure, process, and outcome variables from numerous data sources. In addition, the use of information technology can assist in strategies to handle measurement issues associated with the relationships among the variables.

Development of infrastructure. Two current nursing projects are focusing on the development of a computer-based infrastructure for the linkage of problems, interventions, and outcomes. Ozbolt et al. are developing a clinical database for nursing research in collaboration with the University Hospital Consortium.^{66,123} Nursing-specific data elements to be

added to the demographic and medical diagnostic and therapeutic information include nursing diagnosis/patient problem, outcome of nursing diagnosis, nursing intervention, frequency of nursing intervention, stop date and time of nursing intervention, principal nursing care unit, other nursing care units, patient's average nursing acuity score, and average staffing level of the principal unit during the hospitalization.

Initial plans for the incorporation of a 14-item outcome measure, adapted from the Quality Audit Marker,⁴⁷ across the continuum of care in a large health maintenance organization (HMO) have been described by Lush.⁸⁸ The three-dimension (functional status, health care engagement, and mental and social well-being) outcome measure will be linked with data from the nursing utilization database and complementary outcome data such as length of stay, complication rate, and member satisfaction that are already collected as part of the HMO's outcomes management program.

Measurement issues in linking structure, process, and outcome. It is difficult to determine the relationships among the dimensions of structure, process, and outcome simultaneously because there is considerable variation in each dimension. Informatics provides support for strategies to control or minimize variation in one aspect while examining the relationships among the dimensions. For example, risk-adjusted outcome models provide control for structure or input variables in order to do comparisons of risk-adjusted outcomes across providers, units, or organizations.^{83,124} Information technology is essential in the capture and processing of the relevant variables in the model. Informatics is also an enabling technology in the delivery of strategies to minimize variation in practice or care process (e.g., standardized care plans,¹²⁵ clinical practice guidelines,⁵⁰⁻⁵⁴ and critical paths,¹²⁶⁻¹²⁸ as well as concurrent monitoring to identify variances). One of the great issues in the measurement and interpretation of outcomes data is the lack of population-based norms.¹²⁹ Although significant efforts have already begun in some clinical populations,⁸⁰ information technology has the potential to facilitate the development of population-based norms for standardized outcome measures by the acquisition, storage, and aggregation of these types of data in regional databases.

Presenting

The manner in which quality assessment and improvement data are presented is dependent on the primary purpose of the presentation and on the degree of integration with patient-specific data. CQI

tools for presenting information, such as Pareto diagrams, cause-and-effect diagrams, and flowcharts, can be easily created using simple computer programs.^{130,131} These types of CQI tools, whether computer-based or not, are useful for problem identification and retrospective analyses in the quality improvement process. However, these data are likely to have little impact on an individual's current care process.

There are numerous examples of using computer technology to facilitate access to information, such as policies and procedures, that has the potential to improve the delivery of care. Document-handling technologies such as hypertext are suited to the presentation of textual data such as policies and procedures.⁷⁰ In addition, the use of multimedia technology to visualize the steps of a particular procedure has the potential to decrease the variation in the application of the procedure. Zielstorff et al. implemented an online system in the critical care unit for providing computer-based access to synthesized expert knowledge in the area of troubleshooting pulmonary artery catheter waveforms.¹³² The system evaluation is focused on the system's impact on knowledge and decision making, as well as user satisfaction. Additional implementations are planned in the areas of prevention and management of pressure ulcers and in the management of patients on ventilators.

It is likely that the major impact of informatics as infrastructure for quality assessment and improvement will be the use of informatics to monitor and improve care while the patient is still receiving care (i.e., concurrent monitoring and presentation of information in the form of alerts or reminders).¹³³ Alerts, reminders, and other types of notifications are a type of presentation format that can be integrated in a clinical information system (e.g., notifying the provider who is collecting assessment data that a patient meets the criteria for a clinical practice guideline aimed at preventing pressure ulcers, or reminders aimed at improving pediatric immunization rates).

Selected Examples

Systems integration remains a major challenge in most health care organizations,³ thereby limiting the potential for utilizing informatics to facilitate the quality assessment and improvement process. Several studies have demonstrated the impact of systems connectivity or systems integration on quality assessment and improvement. The following examples illustrate the potential of information systems in three specific areas related to quality assessment and improvement: 1) provision of comparative data, 2) de-

tection of adverse drug events, and 3) implementation of a computer-assisted management protocol.

Shea et al. recently reported the results of a randomized clinical trial in which more than 14,000 patients were assigned to an intervention group (informational physician message) or to a control group.¹³⁴ Data from the medical records coding system were linked with the clinical information system to provide the physician with a patient's length of stay and the mean length of stay for a patient's provisional diagnosis-related group (DRG) at the time the physician was reviewing test results. After adjustment for covariates, the mean length of stay in the intervention group was significantly shorter than that in the control group.

Another example is provided by the adverse drug event surveillance program within the HELP information system.¹²⁰⁻¹²² During the 36,653 admissions over the 18-month period of one study, 631 adverse drug events were identified by the automated system and only nine were identified by traditional detection methods.¹²¹ Another study reported that the timely surveillance of adverse drug events combined with physician notification significantly reduced the number of severe adverse drug events.¹²² These studies required an integrated clinical information system to facilitate multiple source detection of adverse drug events.

Disease-specific care guidelines were implemented via a computer-assisted management protocol (CAMP) in a prospective, randomized study.¹³⁵ Guidelines for diabetic care were individualized based on patient-specific data in the electronic patient record. Although there was no significant difference between the control and experimental groups prior to the intervention, the providers who received the CAMP had a significantly greater median level of compliance with the guideline than did the providers who did not receive the CAMP.

Conclusions

Demands for information about the quality of care provided are increasing. This article provides evidence to support the premise that informatics is essential infrastructure for quality assessment and improvement. While some technologic challenges remain, the primary challenge to nursing is the acquisition of knowledge and skills necessary to meet the demands for information related to the quality of nursing care. Knowledge and skills are needed to 1) define the information management requirements for quality assessment and improvement; 2) participate

in patient-centered, multidisciplinary quality assessment and improvement efforts; 3) utilize data collected by other disciplines as a complement to nursing-specific data for the conduct of studies examining the impact of nursing care; and 4) use the appropriate information technologies to document and support quality assessment and improvement in nursing.

The author thanks colleagues who have influenced her thinking related to informatics and quality of care: William L. Holzemer, RN, PhD, FAAN; Leslie A. Lenert, MD, MS; Blackford Middleton, MD, MS, MPH; Rebecca Partridge, RN, PhD; and Cheryl A. Reilly, RN, MS.

References ■

1. Nightingale F. Notes on Hospitals. London: Longman, Green, Longman, Roberts, & Green, 1863.
2. Bull MJ. Quality assurance: its origins, transformations, and prospects. In: Meisenheimer CG, ed. Quality Assurance: A Complete Guide to Effective Programs. Rockville, MD: Aspen, 1985.
3. Henry SB, Partridge R, Lenert LA, Middleton BF. Linking process and outcome with an integrated clinical information system. *Proc HIMSS 93*. 1993;2:58-79.
4. Lang NM, Clinton JF. Assessment of quality of nursing care. In: Werley HH, Fitzpatrick JJ, eds. Annual Review of Nursing Research. New York: Springer, 1984:135-63.
5. American College of Surgeons. Manual of Hospital Standardization: History, Development and Progress of Hospital Standardization: Detailed Explanation of the Minimum Requirements. 1938.
6. Boyett JH, Conn HP. Workplace 2000. New York: Plume, 1991.
7. Deming WE. Out of the Crisis. Cambridge, MA: MIT-CAES, 1986.
8. Phaneuf MC. What the audit is and what it is not. In: Phaneuf MC, ed. The Nursing Audit: Self-regulation in Nursing Practice. New York: Appleton-Century-Crofts, 1976:31-4.
9. Phaneuf MC. The audit instrument. In: Phaneuf MC, ed. The Nursing Audit: Self-regulation in Nursing Practice. New York: Appleton-Century-Crofts, 1976:35-49.
10. Aydelotte MK, Tener ME. An Investigation of the Relation between Nursing Activity and Patient Welfare. Iowa City, IA: University of Iowa, 1960.
11. Abdellah FG. Criterion measures in nursing. *Nurs Res*. 1961;10:21-6.
12. Donabedian A. Explorations in Quality Assessment and Monitoring: The Definition of Quality and Approaches to Its Assessment. Ann Arbor, MI: Health Administration Press, 1980.
13. Donabedian A. Institutional and professional responsibilities in quality assurance. *Qual Assur Health Care*. 1989;1:3-11.
14. Donabedian A. Medical care appraisal: quality and utilization. In: A Guide to Medical Health Care Administration, vol. 2. New York: American Public Health Association, 1969.
15. Lang NM, Clinton JF. Quality assurance: the idea and its development in the United States. In: Willis LD, Linwood ME, eds. Measuring the Quality of Care. Edinburgh: Churchill Livingstone, 1984:69-88.
16. American Nurses Association. Standards of Nursing Practice. Kansas City, MO: American Nurses Association, 1973.
17. Hegyvary ST, Haussman RKD. Correlates of the quality of

- nursing care. *J Nurs Adm.* 1976;6(2):22-7.
18. Hegyvary ST, Haussman RKD. Nursing professional review. *J Nurs Adm.* 1976;6(9):12-6.
19. Hegyvary ST, Haussman RKD. Monitoring nursing care quality. *J Nurs Adm.* 1976;6(9):3-9.
20. Hegyvary ST, Haussman RKD. The relationship of nursing process and patient outcomes. *J Nurs Adm.* 1976;6(9):18-21.
21. Wandelt M. The Slater nursing competencies rating scale and the quality patient care scale. In: Phaneuf MC, ed. *The Nursing Audit: Self-regulation in Nursing Practice*. New York: Appleton-Century-Crofts, 1976:145-53.
22. Ventura MR. Correlation between the quality patient care scale and the Phaneuf audit. *Int J Nurs Stud.* 1980;17:155-62.
23. Rettig R. History, development, and importance to nursing of outcomes research. *J Nurs Qual Assur.* 1991;5(2):13-7.
24. Brook RH. Overview of adult health status measures fielded in Rands health insurance study. *Med Care.* 1979;17:1-131.
25. Crosby PB. *Quality is Free*. New York: New American Library, 1979.
26. Juran JM. *Jurans Quality Control Handbook*, ed. 4. New York: McGraw-Hill, 1988.
27. Marker CG. The Marker umbrella model for quality assurance: monitoring and evaluating professional practice. *J Nurs Qual Assur.* 1987;1(3):52-63.
28. Marker CG. The Marker model: a hierarchy for nursing standards. *J Nurs Qual Assur.* 1987;1(2):7-20.
29. Marker CG. Total quality management and the Marker Management System 1988, Part I: an overview. *Aspen's Advisor Nurse Executives.* 1991;7(3):5-8.
30. Maibusch RM, ed. *Nursing Quality Assurance: A Unit-based Approach*. Rockville, MD: Aspen Publications, 1984:3-28.
31. Joint Commission for Accreditation of Health Care Organizations. Chicago, IL. Overview of the Joint Commission's "Agenda for Change." 1987.
32. Joint Commission for Accreditation of Health Care Organizations. Chicago, IL. *Monitoring and Evaluation of the Quality and Appropriateness of Care*. 1987.
33. Marek KD. Outcome measurement in nursing. *J Nurs Qual Assur.* 1989;4:1-9.
34. Eddy DM, Billings J. The quality of medical evidence. *Health Aff (Millwood).* 1988;7:19-32.
35. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form survey (SF-36): 1. Conceptual framework and item selection. *Med Care.* 1992;30(6):473-83.
36. Stewart AL, Hays RD, Ware JE. The M.O.S. Short Form General Health Survey: reliability and validity in a patient population. *Med Care.* 1988;26(7):724-35.
37. Berwick DM. Measuring health care quality. *Pediatr Rev.* 1988;10:11-6.
38. Berwick DM, Godfrey AB, Roessner J. *Curing Health Care: New Strategies for Quality Improvement: A Report on the National Demonstration Project on Quality Improvement in Health Care*. San Francisco, CA: Jossey-Bass, 1991:351-92.
39. Anderson CA, Cassidy B, Rivenburgh P. Implementing continuous quality improvement (CQI) in hospitals: lessons learned from the International Quality Study. *Qual Assur Health Care.* 1991;3:141-6.
40. Agency for Health Care Policy and Research. Report to Congress: Progress on Research on Outcomes of Health Care Services and Procedures. Rockville, MD: U.S. DHHS, 1991. AHCPR Publication no. 91-0004.
41. Uniform Clinical Data Set (UCDS). *J Am Med Records Assoc.* 1991;62:48-51.
42. Lathrop JP. *Restructuring Health Care: The Patient-focused Paradigm*. San Francisco, CA: Jossey-Bass, 1993.
43. American Nurses Association. *Standards of Clinical Nursing Practice*. Kansas City, MO: American Nurses Association, 1991.
44. McCormick KA, Lang N, Zielstorff R, Milholland DK, Saba V, Jacox A. Toward standard classification schemes for nursing language: recommendations of the American Nurses Association Steering Committee on Databases to Support Clinical Nursing Practice. *J Am Med Informatics Assoc.* 1994;1:421-7.
45. Lang NM, Marek KD. The classification of patient outcomes. *J Prof Nurs.* 1990;6:158-63.
46. Lang NM, Marek KD. The policy and politics of patient outcomes. *J Nurs Qual Assur.* 1991;5(2):7-12.
47. Holzemer WL, Henry SB, Stewart A, Janson-Bjerklie S. The HIV quality audit marker (HIV-QAM): an outcome measure of hospitalized AIDS patients. *Qual Life Res.* 1993;2:99-107.
48. Barnsteiner JH, Mohan A, Milberger P. Implementing managed care in a pediatric setting. *AACN Clin Issues.* 1992;3:776-87.
49. Wolford GR, Brown M, McCool BP. Getting to go in managed care. *Health Care Manage Rev.* 1993;18:7-19.
50. Acute Pain Management Guideline Panel. *Acute Pain Management: Operative or Medical Procedures and Trauma. Clinical Practice Guideline*. Rockville, MD: Agency for Health Care Policy and Research, Public Health Service, U.S. DHHS, 1992. AHCPR Publication no. 92-0032.
51. Depression Guideline Panel. *Depression in Primary Care. Clinical Practice Guideline, Number 5*. Rockville, MD: Agency for Health Care Policy and Research, Public Health Service, U.S. DHHS, 1993. AHCPR Publication no. 93-0550.
52. Panel for the Prediction and Prevention of Pressure Ulcers in Adults. *Pressure Ulcers in Adults: Prediction and Prevention. Clinical Practice Guideline, Number 3*. Rockville, MD: Agency for Health Care Policy and Research, Public Health Service, U.S. DHHS, 1992. AHCPR Publication no. 92-0047.
53. Sickle Cell Disease Guideline Panel. *Sickle Cell Disease: Screening, Diagnosis, Management, and Counseling in Newborns and Infants. Clinical Practice Guideline, Number 6*. Rockville, MD: Agency for Health Care Policy and Research, Public Health Service, U.S. DHHS, 1993. AHCPR Publication no. 93-0562.
54. Cataract Management Guideline Panel. *Cataracts in Adults: Management of Functional Impairment. Clinical Practice Guideline, Number 4*. Rockville, MD: Agency for Health Care Policy and Research, Public Health Service, U.S. DHHS, 1993. AHCPR Publication no. 93-0542.
55. Del Tognio-Armanasco V, Hopkin LA, Harter S. *Collaborative Case Management: A Handbook for Development and Implementation*. New York: Springer, 1993.
56. Zander K. Nursing case management: strategic management of cost and quality outcomes. *J Nurs Adm.* 1988;18(5):23-30.
57. Leape LL. Practice guidelines and standards: an overview. *Q Rev Bull.* 1990;16(2):42-9.
58. Aucott JN, Taylor AL, Wright JT, et al. Developing guidelines for local use: algorithms for cost-efficient outpatient management of cardiovascular disorders in a VA medical center. *J Comm J Qual Improv.* 1994;20:17-29.
59. HEDIS 2.0 Executive Summary. Presented at a seminar of the National Committee for Quality Assurance, July 1993, Washington, DC.
60. Corrigan JM, Nielsen DM. Toward the development of uniform reporting standards for managed care organizations: the Health Plan Employer Data and Information Set (Version 2.0). *J Comm J Qual Improv.* 1993;19:566-75.
61. Dick RS, Steen EB. *The Computer-Based Patient Record: An Essential Technology for Health Care*. Washington, DC: Na-

- tional Academy Press, 1991.
62. Donaldson MS, Lohr KN. Health Data in the Information Age: Use, Disclosure, and Privacy. Washington, DC: National Academy Press, 1994.
 63. Schroeder P. Issues and Strategies for Nursing Care Quality. Gaithersburg, MD: Aspen, 1991.
 64. Joint Commission on Accreditation of Healthcare Organizations: 1994 Accreditation Manual for Hospitals. Chicago: Joint Commission on Accreditation of Healthcare Organizations, 1993.
 65. Hammer M, Champy J. Reengineering the Corporation. New York: Harper, 1993.
 66. Institute of Medicine. Health, health care, and quality of care. In: Lohr K, ed. Medicare: A Strategy for Quality Assurance, vol. 1. Washington, DC: National Academy Press, 1990:19-44.
 67. Lohr KN. Outcomes measurement: concepts and questions. *Inquiry*. 1988;25(1):37-50.
 68. Ozbolt JG, Fruchtnicht JN, Hayter JR. Toward data standards for clinical nursing information. *J Am Med Informatics Assoc*. 1994;1:175-85.
 69. Shabot MM, Bjerke HS, LoBue M, et al. Quality assurance and utilization assessment: the major by-products of an intensive care unit clinical information system. In: Shabot MM, Gardner RM, eds. *Decision Support Systems in Critical Care*. New York: Springer-Verlag, 1994:277-84.
 70. Zielstorff RD, Hudgings CI, Grobe SJ, et al. Next-Generation Nursing Information Systems. Washington, DC: American Nurses Publishing, 1993.
 71. Werley HH, Devine EC, Zorn CR. Nursing Minimum Data Set Data Collection Manual. Milwaukee, WI: School of Nursing, University of Wisconsin, 1988.
 72. Huber DG, Delaney C, Crossley J, Mehmert M, Ellerbe S. A nursing management minimum data set. *J Nurs Adm*. 1992;22:35-40.
 73. Iezzoni LI, Ash AS, Cobb JL, Moskowitz MA. Predicting in-hospital mortality: a comparison of severity measurement approaches. *Med Care*. 1992;30:347-59.
 74. Iezzoni LI, Moskowitz MA. A clinical assessment of MedisGroups. *JAMA*. 1988;260(21):3159-63.
 75. Knaus WA, Wagner DP, Lynn J. Short-term mortality predictions for critically ill hospitalized adults: science and ethics. *Science*. 1991;18:389-94.
 76. Knaus WA, Wagner DP, Draper EA, et al. The APACHE III prognostic system: risk prediction of hospital mortality for critically ill hospitalized adults. *Chest*. 1991;100:1619-36.
 77. Knaus WA, Sirio C. Acuity of illness and risk prediction in critically ill adults: the APACHE III intensive care unit management system. In: Shabot M, Gardner R, eds. *Decision Support Systems in Critical Care*. New York: Springer-Verlag, 1994.
 78. Knaus WA, Draper EA, Wagner DP, et al. An evaluation of outcome from intensive care in major medical centers. *Ann Intern Med*. 1986;104:410-8.
 79. Knaus WA, Draper EA, Wagner DP, et al. APACHE II: a severity of disease classification system. *Crit Care Med*. 1985;13:818-29.
 80. Knaus WA, Wagner DP, Zimmerman JE, et al. Variations in mortality and length of stay in intensive care units. *Ann Intern Med*. 1993;118:753-61.
 81. Horn SD, Sharkey PD, Buckle JM, Backofen JE, Averill RF, Horn RA. The relationship between severity of illness and hospital length of stay and mortality. *Med Care*. 1991;29(4):305-17.
 82. Shabot MM, Leyerle BJ, LoBue M. Automatic extraction of intensity-intervention scores from a computerized surgical intensive care unit flowsheet. In: Shabot MM, Gardner RM, eds. *Decision Support Systems in Critical Care*. New York: Springer-Verlag, 1994:266-76.
 83. Blumberg MS. Risk adjusting health care outcomes: a methodologic review. *Med Rev*. 1986;43:351-93.
 84. Brewster AC, Karlin BG, Hyde LA, Jacobs CM, Bradbury RC, Chae Y. Medisgroups: a clinically based approach to classifying hospital patients at admission. *Inquiry*. 1985;22:377-87.
 85. Turley JP. A framework for the transition from nursing records to a nursing information system. *Nurs Outlook*. 1992;40:177-81.
 86. Graves JR, Fehlauer CS, Gillis PA, et al. Mobile pen-based technology as the interface of a clinical information system: a panel presentation. In: *Nursing Informatics: An International Overview for Nursing in a Technological Era*. Amsterdam: Elsevier, 1994:730-3.
 87. Holzemer WL, Henry SB. Computer-supported versus manually generated nursing care plans: a comparison of problems, nursing interventions and AIDS patient outcomes. *Comp Nurs*. 1992;10:19-24.
 88. Lush MT. Developing an infrastructure for outcomes analysis with a nursing utilization database in a health maintenance organization. In: *Proceedings of the Spring Congress of the American Medical Informatics Association*, 1994.
 89. Henry SB. New technologies for multidisciplinary education, Part 1. In: *Proceedings of Drug and Device Induced Disease: Developing a Blueprint for the Future*. Chicago, IL: American Medical Association, 1994.
 90. Miller RA, McNeil MA, Challinor SM, et al. The Internist-1/Quick Medical Reference project: status report. *West J Med*. 1986;145:816-22.
 91. Warner HR Jr, Bouhaddou O. Innovation review: Iliad—a medical diagnostic support system. *Top Health Inf Manage*. 1994;14:51-8.
 92. Evans S. The COMMES nursing consultant system: a practical clinical tool for patient care. In: *Nursing and Computers: Proceedings of the Third International Symposium on Nursing Use of Computers and Information Science*. St. Louis: C.V. Mosby, 1988.
 93. Kohane IS. Getting the data in: three year experience with a pediatric electronic medical record system. In: *Proceedings of the Eighteenth Annual Symposium on Computer Applications in Medical Care*. *J Am Med Informatics Assoc Suppl*. 1994;457-61.
 94. Kasper JF, Mulley AG Jr, Wennberg JE. Developing shared decision-making programs to improve quality of health care. *QRB*. 1992;18(6):183-90.
 95. Goldstein MK, Clarke AE, Michelson D, Garber AM, Bergen MR, Lenert LA. Developing and testing a multimedia presentation of a health state. *Med Decis Making*. 1994;14:336-44.
 96. East TD, Young WH, Gardner RM. Digital electronic communication between ICU ventilators and computers and printers. *Respir Care*. 1992;37:1113-23.
 97. Shabot MM. Standardized acquisition of bedside data: the IEEE P1074 medical information bus. In: Shabot MM, Gardner RM, eds. *Decision Support Systems in Critical Care*. New York: Springer-Verlag, 1994:107-17.
 98. Kim MJ, McFarland G, McFarlane A. A Pocket Guide to Nursing Diagnosis, ed. 4. St. Louis: C. V. Mosby, 1993.
 99. North American Nursing Diagnosis Association. *NANDA Nursing Diagnoses: Definitions and Classification 1992-1993*. Philadelphia: NANDA, 1992.
 100. McCloskey JC, Bulechek GM. *Nursing Intervention Classification*. St. Louis: C.V. Mosby, 1992.

101. Moorhead SA, McCloskey JC, Bulechek GM. Nursing interventions classification: a comparison with the Omaha System and the Home Healthcare Classification. *J Nurs Adm.* 1993;23:23-9.
102. Bulechek GM, McCloskey JC. Nursing interventions: what they are and how to choose them. *Holistic Nurs Practice.* 1989;1(3):36-44.
103. Saba VK. Home health care classification. *Caring Magazine.* 1992;11(4):58-60.
104. Saba VK. The classification of home health care nursing: diagnoses and interventions. *Caring Magazine.* 1992;11:50-6.
105. Martin KS, Scheet NJ. A community health nursing data management model. In: Lun KC, Degoulet P, Piemme TE, Rienhoff O, eds. *MedInfo92.* Geneva: North-Holland, 1992:1036-40.
106. Martin KS, Scheet NJ. *The Omaha System: Applications for Community Health Nursing.* Philadelphia: W. B. Saunders, 1992.
107. Martin KS, Scheet NJ, Stegman MR. Home health clients: characteristics, outcomes of care, and nursing interventions. *Am J Public Health.* 1993;83(12):1730-4.
108. Griffith HM, Robinson KR. Survey of the degree to which critical care nurses are performing Current Procedural Terminology-coded services. *Am J Crit Care.* 1993;1:91-8.
109. Griffith HM, Robinson KR. Current Procedural Terminology (CPT) coded services provided by nurse specialists. *Image J Nurs Sch.* 1993;25:178-86.
110. Cote' RA, Rothwell DJ, Palotay JL, et al. SNOMED International. Northfield, IL: College of American Pathologists, 1993.
111. Henry SB, Holzemer WL, Reilly CA, Campbell KE. Terms used by nurses to describe patient problems: can SNOMED III represent nursing concepts in the patient record? *J Am Med Informatics Assoc.* 1994;1:61-74.
112. De Groot HA, Forsey L, Cleland VS. The Nursing Practice Personnel Data Set: implications for professional practice systems. *J Nurs Adm.* 1992;22:23-8.
113. Humphreys B, Lindberg DAB. Building the unified medical language system. In: *Proceedings of the Thirteenth Annual Symposium on Computer Applications in Medical Care.* Washington, DC: IEEE, Computer Society Press, 1989:475-80.
114. Lindberg DAB, Humphreys BL, McCray AT. The Unified Medical Language System. *Methods Inf Med.* 1993;32:281-91.
115. Work Group on Computerization of Patient Records. *Toward a National Health Care Information Structure. Report of the Work Group on Computerization of Patient Records to the Secretary of the U.S. DHHS.* Washington, DC: Public Health Service, 1993.
116. Clark J, Lang NM. Nursing's next advance: an international classification for nursing practice. *Int Nurs Rev.* 1992;39:109-12.
117. LeGall JR, Lemeshow S, Saulnier F. A new simplified acute physiology score (SAPS II) based on a European/North American multicenter study. *JAMA.* 1993;270:2957-63.
118. Blaufuss J, Tinker A. Computerized falls alert: a new solution to an old problem. In: *Proceedings of the Symposium for Computer Applications in Medical Care,* 1989:69-73.
119. Gillis PA, Booth H, Graves JR, Felauer CS, Soller J. Translating traditional principles of system development into a process for designing clinical information systems. *Int J Technol Assess Health Care.* 1994;10:235-48.
120. Evans RS, Classen DC, Stevens LE, et al. Using a hospital information system to assess the effects of adverse drug events. In: *Proceedings of the Symposium for Computer Applications in Medical Care,* 1994:161-5.
121. Classen DC, Pestonik SL, Evans RS, Burke JP. Computerized surveillance of adverse drug events in hospital patients. *JAMA.* 1991;266:2847-51.
122. Evans RS, Pestonik SL, Classen DC, et al. Prevention of adverse drug events through computerized surveillance. In: *Proceedings of the Symposium for Computer Applications in Medical Care,* 1993:437-41.
123. Ozbolt JG, Graves JR. Clinical nursing informatics: developing tools for knowledge workers. *Nurs Clin North Am.* 1993;28(2):407-25.
124. Iezzoni LI, Ash AS, Cobb JL, Moskowitz MA. Admission MedisGroups score and the cost of hospitalizations. *Med Care.* 1988;26(11):1068-80.
125. Hoy D. *Computer-assisted Nursing Care Planning Systems in the United Kingdom: A Review of the Professional Issues.* Edinburgh: Nursing Division, Scottish Home and Health Department, 1989.
126. Cohen EL, Cesta TG. *Nursing Case Management: From Concept to Evaluation.* St. Louis: C. V. Mosby, 1993.
127. Olivas GS, Del Togno-Armanasco V, Erickson JR, Harter S. Case management: a bottom line care delivery model, Part 1: The concept. *J Nurs Adm.* 1989;19(11):16-20.
128. Olivas GS, Del Togno-Armanasco V, Erickson JR, Harter S. Case management: a bottom line care delivery model, Part 2: Adaptation of the model. *J Nurs Adm.* 1989;19(12):12-7.
129. Greenfield S, Nelson EC. Recent developments and future issues in the use of health status measurements in clinical settings. *Med Care.* 1992;30:MS23-MS41.
130. Relyea DB. The simple power of pareto. *Qual Progress.* 1989;22:38-9.
131. Sarazen JS. The tools of quality, Part II: Cause and effect diagrams. *Qual Progress.* 1990;23:59-62.
132. Zielstorff RD, Barnett GO, Fitzmaurice JB, et al. A decision support system for troubleshooting pulmonary artery catheter waveforms. In: Grobe SJ, Pluyter-Wenting ESP, eds. *Nursing Informatics: An International Overview for Nursing in a Technological Era.* Amsterdam: Elsevier, 1994:362-6.
133. Gardner RM. Computerized data management and decision making in critical care. In: Shabot MM, Gardner RM, eds. *Decision Support Systems in Critical Care.* New York: Springer-Verlag, 1994:212-23.
134. Shea S, Sideli RV, DuMouchel W, Pulver G, Arons RR, Clayton PD. Computer-generated informational messages directed to physicians: effect on length of hospital stay. *J Am Med Informatics Assoc.* 1995;2:58-64.
135. Lobach DF, Hammond WE. Development and evaluation of a computer-assisted management protocol (CAMP): improved compliance with care guidelines for diabetes mellitus. In: *Proceedings of the Eighteenth Annual Symposium on Computer Applications in Medical Care.* *J Am Med Informatics Assoc Suppl.* 1994:787-91.