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Evidence-Based Staffing: Potential Roles for Informatics

EXECUTIVE SUMMARY

- ▶ Over the last 15 years, evidence has been accumulating relating higher levels of nurse staffing in both quantity and experience to lower rates of adverse patient outcomes. Consequently, to promote quality patient outcomes efficiently, making staffing decisions based in evidence is of increasing importance. However, there is still limited data to help decide how to effectively allocate scarce nurse resources in practice.
- ▶ Existing principles, frameworks, and guidelines provide a foundation for nurse staffing decisions but face poor adoption. To determine optimal nurse staffing practices and provide evidence-based recommendations for policy, and integration into operations, comprehensive data are necessary.
- ▶ Information technology can assist nurse staffing decisions. Four informatics processes that may support evidence-based nurse staffing are described: (a) Data acquisition from multiple data sources, (b) Representation of data in a way it can be re-used for multiple purposes, (c) Sophisticated data processing and mining, and (d) Presentation of data in standardized and user-configurable ways.

DELIVERY OF NURSING CARE IN hospitals may be heading to the “perfect storm.” The phrase “perfect storm” refers to the simultaneous occurrence of events, which individually would be far less significant; but, these forces in combination are much more powerful. In the delivery of quality care, the events converging for the storm include a nursing shortage that is predicted to worsen, an increase in volume and acuity of patients, and rising health care costs. Therefore, understanding how to provide high-quality nursing care efficiently and making staffing decisions based in evidence is of increasing importance. An element that may help us navigate through the perfect storm is the increased use of health care information technolo-

gy in hospitals. The purposes of this article are to briefly review evidence related to nurse staffing and patient outcomes; provide an overview of current methods used to inform nurse staffing; and, discuss potential informatics solutions that could support evidence-based nurse staffing decisions.

Patient Outcomes and Nurse Staffing

Over the last 15 years, evidence has been accumulating relating higher levels of nurse staffing (both in quantity and experience) to lower rates of adverse patient outcomes. To synthesize this evidence, we developed two tables. In both tables, we limited the evidence to those investigations conducted in U.S. hospitals and published since

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Table 1.
Studies Examining Nurse Staffing and Patient Outcomes at Hospital Level

Study	Design	Sample	Staffing Variables	Data
Aiken et al. (2002)	CSA	168 Pennsylvania hospitals in 1998	RN staffing	RN self-report
al Haider & Wan (1991)	CSA	239 hospitals in 1984	Skill mix	AHA
Cho et al. (2003)	CSA	232 California hospitals 1997	RN hour/patient day	OSHPD
Kovner & Gergen (1998)	CSA	589 hospitals in 1993	RN FTE/patient days	AHA
Kovner et al. (2002)	CSA	528 to 570 hospitals from 1990-1996	RN FTE/patient days LPN FTE/ patient days	AHA
Lichtig et al. (1999)	CSA	126 to 131 New York hospitals; 295 to 352 California hospitals in 1992 and 1994	RN hours/patient adjusted day Skill mix	Cost reports
Mark et al. (2004)	L	422 hospitals from 1990-1995	RN FTE/patient days LPN FTE/ patient days	AHA
Needleman et al. (2002)	CSA	799 hospital in 1997 across 11 states	RN hours/patient days Skill mix	State reports
Schultz et al. (1998)	CSA	373 California hospitals with acute myocardial infarction patients in 1992	RN hours/patient days	OSHPD
Unruh (2003)	L	211 Pennsylvania hospitals from 1991-1997	Licensed FTE/adjusted patient days Skill mix	AHA
Unruh & Fottler (2006)	L	162 to 205 Pennsylvania hospitals 1994-2001	Adjusted RN FTE/ patient days	AHA, MediQual

NOTE: AHA=American Hospital Association, CSA=cross-sectional analysis, FTE=full-time equivalent, L=longitudinal, LPN=licensed professional nurse, OSHPD=Office of Statewide Health Planning and Development, RN=registered nurse.

1990. Table 1 summarizes 11 relevant studies assessing nurse staffing and patient outcomes at the hospital level. The sample sizes in these studies ranged from 162 hospitals in one state to 799 hospitals in 11 states. Researchers mainly used public use files to estimate staffing and patient outcomes were measured using patient discharge abstracts.

There are a number of limitations in this literature. This body of research focused on hospital-level staffing rather than unit-specific staffing. Variations in the demand for nursing care due to different types of patients was only minimally considered as follows: (a) Unruh and Fottler (2006) examined the effect of adjusting patient-to-nurse ratios by patient's length of stay as a proxy for nursing demands, and (b) Needleman et al. (2002) measured nursing

casemix using nursing intensity weights to adjust for nursing demands.

Another group of researchers has examined data at the unit level (see Table 2). While these researchers used more precise measures of nurse staffing, usually the data were collected directly, which generally resulted in smaller sample sizes. The exceptions were Donaldson et al. (2005) and Dunton, Gajewski, Taunton, and Moore (2004) who used large databases. The outcome measures chosen were uniquely defined for each study. Only Blegen and Vaughn (1998) controlled for patients' needs for nursing care using a patient acuity classification scale.

To help bring clarity to this body of research, a meta-analysis was conducted recently (Kane, Shamliyan, Mueller, Duval, &

Wilt, 2007). Pooling data from 28 studies, the investigators found that higher levels of RN staffing were associated with lower hospital-related mortality in intensive care unit (ICU) patients (odds ratio [OR], 0.91; 95% confidence interval [CI], 0.86-0.96), in surgical patients (OR, 0.84; 95% CI, 0.80-0.89), and in medical patients (OR, 0.94; 95% CI, 0.94-0.95). An increase by one RN per patient day in an ICU was associated with a decreased likelihood of hospital-acquired pneumonia (OR, 0.70; 95% CI, 0.56-0.88), unplanned extubation (OR, 0.49; 95% CI, 0.36-0.67), respiratory failure (OR, 0.40; 95% CI, 0.27-0.59), and cardiac arrest (OR, 0.72; 95% CI, 0.62-0.84); and in surgical patients an increase by one RN per patient day was associated with a lower risk of failure to rescue (OR, 0.84; 95% CI, 0.79-0.90). Additionally,

Table 2.
Studies Examining Nurse Staffing and Patient Outcomes at Unit Level

Study	Design	Sample	Staffing Variables
Blegen et al. (1998)	CSA	42 units in 1 hospital	Total nursing hours/patient day, skill mix
Blegen & Vaugh (1998)	CSA	39 units in 11 hospitals	Total nursing hours/patient day, skill mix
Donaldson et al. (2005)	L	200 medical surgical units in California	Total nursing hours/patient day, Total RN hours/patient day, skill mix
Dunton et al. (2004)	CSA	1751 units in 45 states	Total nursing hours/patient day, Total nursing hours/patient day below knot*, percent registered nurses
Mark et al. (2003)	CSA	124 medical surgical units	Skill mix
Sovie & Jawad (2001)	CSA	29 medical surgical units	Total nursing hours/patient day, skill mix
Stone et al. (2007)	CSA	51 intensive care units in 31 hospitals	Total nursing hours/patient day, overtime

NOTE: CSA=cross sectional analysis, L=longitudinal, *=knot is a statistical analysis allowing for non-linear approach.

they noted that use of non-permanent staff increases the patient risk for health care associated infections (Kane et al., 2007).

Despite the variations and limitations of research methods, it is now recognized by many that there is a preponderance of evidence establishing the relationship between staffing and quality patient outcomes (International Council of Nurses, 2006; Institute of Medicine, 2004; Robert et al., 2000). However, the data lack precision to help determine actual levels or mix of staffing that is optimal for any given setting (Clarke, 2005) and there are still limited data to inform managers and administrators on how to allocate scarce nurse resources efficiently.

Current Methods of Informing Nurse Staffing

In Canada, methods used to determine staffing were explored as part of a national research project that included various stakeholders (Hall et al., 2006). Comprehensive frameworks, patient-to-nurse ratios, workload measurement systems, and “gut instinct” were reported as factors influencing decisions on nurse staffing (Hall et al., 2006). Most likely, methods to determine nurse staffing are similar across

developed countries (Hall et al., 2006; Rafferty et al., 2007; Rischbieth, 2006). Each of the formal methods as well as other tools to inform staffing found in the literature are discussed below.

Frameworks. The American Nurses Association (ANA) established guidelines on what should be incorporated in optimal systems that inform staffing decisions (ANA, 1999). The ANA recommends that staffing decisions consider patient characteristics, intensity of nursing care, context of the unit (e.g., geographic dispersion of patients, size and layout of individual patient rooms, arrangement of entire patient care unit, technology) and expertise of the staff.

The Nursing Management Minimum Data Set (NMMDS) was established to meet nurse administrators’ needs for capturing specific data (Huber, Schumacher, & Delaney, 1997; Simpson, 1997). Through an expert consensus process, 17 data elements were identified and categorized into three areas: nursing environment, nurse resources, and financial resources. The goal of NMMDS is to provide a framework for capturing consistent data for unit-level decision making, providing a system for internal organizational benchmarking, creating the oppor-

tunity for external organizational benchmarking, and establishing a methodology for continuum of care evaluation (Huber et al., 1997).

Similarly, the Canadian Nurses Association developed an evaluation framework to determine the impact of nursing staff mix decisions (Canadian Nurses Association, 2005). The principles guiding the framework include (a) client, nurse, and system outcomes are central to the evaluation of nursing staff mix decisions; (b) evaluation of the impact of nursing staff mix decisions is complex and requires a systematic and comprehensive approach using all of the components of this framework; (c) recognition and respect for the value and contribution of each regulated nursing group; and (d) applicable to all sectors and client populations. While these frameworks are comprehensive and identify key factors linked to staffing effectiveness, they have not been easy to operationalize in every day management decisions.

Patient-to-nurse ratios. In 1999, the California State government regulated minimum patient-to-nurse ratios in acute care general, special, and psychiatric hospitals and forbade hospitals to assign unlicensed staff to provide nursing

care ("California Statutes," 1999). Patient-to-nurse ratios are also negotiated in many settings by unions. Supporters of the minimum patient-to-nurse ratios argue based on the evidence presented earlier that increased proportion of care provided by RNs was associated with better quality (Donaldson et al., 2005). Critics argue that ratios are static measures that assume that nursing demands of all patients are the same and not supported by evidence (Clarke, 2005; Kane et al., 2007; Upenieks, Kotlerman, Akhavan, Esser, & Ngo, 2007).

While ratios take into account selected factors, such as numbers of licensed nurses, they do not consider other relevant factors, such as patient characteristics, and nursing demands for admission/discharge (Center for the Health Professions University of California, 2000; Clarke, 2005). Furthermore, nursing demands vary depending on a patient's needs (Graf, Millar, Feilteau, Coakley, & Erickson, 2003). The use of patient-to-nurse ratios to inform staffing is insufficient.

Workload management systems/Patient classification systems. Patient acuity systems consider the intensity of patient care (Urbanowicz, 1999). Patient acuity ratings categorize patients into different groups based on the assessment of the patients' care demands (Harper & McCully, 2007). There are enormous numbers of different patient classification systems available (Walts & Kapadia, 1996). The majority of these may be categorized into two types: (a) acuity systems based on time-motion studies, and (b) care checklist with assigned acuity ratings (Harper & McCully, 2007; Urbanowicz, 1999; Van Slyck & Johnson, 2001). The time-motion model is task-oriented and does not measure indirect nursing care or the environmental demands (e.g., interruptions in nursing work smoothness) (Montgomery, 2006). A care checklist consists of

a nurse checking off patient care needs with predetermined point values and then the points are tabulated for each patient.

Although patient acuity systems are used widely for nurse staffing, few studies on reliability and validity of the acuity systems have been published (Harper & McCully, 2007). In general, patient acuity rating systems assist nurse administrators in making decisions on nurse staffing by providing nursing workload data. On the other hand, it is not sufficient to use patient acuity alone. Other factors, which are not reflected in the acuity system, were recommended to be considered as components of nursing workload estimates, such as nurse features (e.g., nurses' clinical abilities, mental stress) and indirect care (e.g., documentation, transporting patients, and communication with health care team members) (Harper & McCully, 2007; Spence et al., 2006; Upenieks et al., 2007).

Other workload management systems that include indirect care have been developed for specific patient populations, such as the Therapeutic Intervention Scoring System and the Chinese Nursing Intervention in Intensive Care Unit instrument, both of which were developed to measure nurse workload in ICUs (Chou, Wu, Chang, & Stone, 2007; Cullen, Civetta, & Briggs, 1974). However, completing all data elements needed for these systems is time consuming and the need for computerized versions has been identified.

In summary, comprehensive data are necessary to determine optimal nurse staffing practices and provide evidence-based recommendations for policy, staffing models, and integration into operations (Bolton et al., 2001; Spence et al., 2006). Staffing decisions that lack consideration of all relevant factors, such as nurse experience/education level, fatigue factors, patient condition, skills, and competencies may result in potential

adverse events and poor patient outcomes (Joint Commission on Accreditation of Healthcare Organizations, 2002; Mumolie, Lichtig, & Knauf, 2007; Rischbieth, 2006). Moving toward proactive evidence-based staffing is challenging.

Informatics Solutions Supporting Evidence-Based Nurse Staffing

Information technology can help deal with the issues and challenges addressed here and promote new solutions to support evidence-based nurse staffing. Four informatics processes relevant to nurse staffing decisions will be described: (a) Data acquisition from multiple data sources, (b) Representation of data in a way it can be re-used for multiple purposes, (c) Sophisticated data processing and mining, and (d) Presentation of data in standardized and user-configurable ways. How each of these informatics strategies is being used or can be used to inform staffing decisions as well challenges and barriers to their development and adoption are discussed.

Data acquisition from multiple data sources. Currently and increasingly, data are captured electronically from a number of sources that could be used to inform staffing decisions. Many hospitals track the flow of patients in terms of admissions, discharges, and transfers electronically. Also, technology is available to support the use of staff members' identification badges as locators through infrared signals. Patients and beds can also be identified through radio frequency identification or bar-coding technology. Together with the call light system, these technologies have the potential to capture the time a patient requests care, the time the call is answered and assigned, the time the call is canceled by a nurse entering the room as well as the call type. Bar-code technology is also increasingly being used in the administration of medication as are electronic health record sys-

tems for nursing documentation. All of these data have the potential to capture nurse workload and demand for nursing care as well as potential delays in providing care.

Electronic systems are available to monitor quality and safety indicators, many of which may be nursing sensitive. An example is a Fall-Injury Risk Assessment instrument (Currie, Mellino, Cimino, & Bakken, 2004), which was then automated with tailored safety measures based upon risk scores and sub-sequentially deployed in three information systems. Relationships among risk scores, patient safety measures, and falls and falls-related injuries are assessed continuously.

Furthermore, in addition to patient data, the profiles of available nurses in terms of qualifications and competencies may be housed in a local or Web-based electronic data source. A number of commercial products are available in this area (BidShift, 2007; Brown, 2007; Fortin & Douglas, 2006).

Taken together, these comprehensive data may capture real-time the need for nursing services, the supply of qualified nurses available, and the quality of the care being given in any specific setting. These are the necessary components identified to inform staffing. However, having these data synthesized into meaningful reports is challenging. This is especially true given the proprietary nature of many of these systems, and the lack of data integration among systems (e.g., in a clinical data repository or data warehouse) in many organizations.

Representation of data in a way that it can be re-used for multiple purposes. Most clinical and administrative data, including that related to nursing, are not currently represented in a manner that optimally supports computer processing and re-use. Using a standardized terminology may help capture nursing concepts from EHR systems since it repre-

sents them in a standardized and consistent way (Hardiker, Bakken, Casey, & Hoy, 2002). Collaboration between the International Council of Nurses and the International Medical Informatics Association-Nursing Informatics Working Group resulted in the development of an international standard for models of nursing diagnoses and nursing actions (International Standards Organization, 2003). These models have been used to integrate ANA-recognized terminologies (e.g., Nursing Interventions Classification, Clinical Care Classification) into SNOMED CT, the reference terminology for the United States, and allows mapping among the nursing terminologies (Iowa Intervention Project, 1993; Saba, 2004; SNOMED International, 2006; Warren et al., 2003). In addition, use of such models may support data mining for a variety of purposes including informing staffing decisions (Bakken, Hyun, Friedman, & Johnson, 2005).

Use of a standardized terminology alone is not sufficient to support computer processing and data re-use (Hardiker et al., 2002). To achieve this purpose, data such as nursing interventions must be formally represented in a manner suitable for computer processing. The Health Level 7 Clinical Document Architecture (HL7 CDA) is a standard that specifies the structure and semantics of clinical documents and enables exchange across and within organizations (Dolin et al., 2001). The HL7 CDA specifies the content of document headers (information about the document; e.g., the document ID, the document title, the author, etc.), as well as the body (information conveyed in the document; e.g., section title, section text, subsections, etc.), using eXtensible Markup Language (XML) (Dolin et al., 1999; W3C, 2005) to identify and label information. Using XML and HL7 CDA makes electronic documents both machine processable and human

readable; thus, these data can be processed electronically and retrieved by clinicians. The markup can be applied at a very fine level of detail, identifying clinical facts embedded in phrases and sentences, such as symptoms, diagnoses, medications, and procedures (Dolin et al., 2001). Using this standardized format, clinical information can be coded at the time of data entering, saving time and money and providing timely information for clinicians and researchers (Paterson, Shepherd, Wang, Watters, & Zitner, 2002). The HL7 CDA is potentially relevant to evidence-based staffing because sometimes the context of a document section is required to gain understanding.

As health care information sharing/exchange becomes increasingly important, the representation of the information in formal ways that supports re-use becomes more significant (Committee on Data Standards for Patient Safety, 2003). Nursing researchers who are experts in informatics have made efforts to integrate nursing data and information into comprehensive data standards to support data sharing and re-use across health care organizations (Bakken et al., 2005; Danko et al., 2003; Goossen et al., 2004; Moss, Coenen, & Mills, 2003; van Grunsven, Bindels, Coenen, & de Bel, 2006). Unfortunately, in the past, there has been little interaction between those developing nursing workload systems and nursing informaticians.

Sophisticated data processing and mining. Sophisticated data processing and mining methods are being developed that can be applied to support evidence-based staffing decisions. Knowledge discovery in databases may be conducted using a number of approaches including both statistical methods and natural language processing (NLP). A number of nurse researchers have applied statistical methods for knowledge

discovery in large databases for purposes such as predicting pre-term birth (Goodwin, VanDyne, Lin, & Talbert, 2003), predicting admission from long-term care into acute care (Abbott, Quirolgico, Manchand, Canfield, & Adya, 1998), and examining relationships among the elements of the Nursing Minimum Data Set (Delaney, Ruiz, Clarke, & Srinivasan, 2000). Natural language processing is a tool for capturing clinical information from free text data and encoding the information in a manner that allows computer processing for purposes such as event detection, decision support, and data aggregation. Previous researchers demonstrated that NLP is an effective method of accurately interpreting clinical notes in several domains; e.g., real-time detection of community-acquired pneumonia (Fizman & Haug, 2000) and detection of adverse events in outpatient visit notes (Honigman, 2001). In nursing, Hyun, Johnson, and Bakken (in press) used an NLP system to examine what terms of relevance to patient safety and quality of care could be extracted from oncology nursing narratives.

A number of investigators are combining data mining with sophisticated computational modeling to turn data into actionable information. For example, Stone and colleagues (2007) (R21HS017423, Principal Investigator: Patricia Stone) are testing the applicability of queuing theory to inform staffing decisions. Effken and colleagues have used OrgAhead, a theoretically based computational modeling program developed at Carnegie Mellon University, to simulate nursing units and to allow hypothesis testing about potential nursing unit changes on patient outcomes (Effken et al., 2003, 2005). Much of the data needed for these models are already being electronically captured and increasingly more data will be captured as information systems become more common in health care organizations.

Therefore, these projects are very timely.

Presentation of data in standardized and user-configurable ways. Increasingly, decision support systems are being used for evidence-based management decisions in health care. Three evaluation studies of specific electronic decision support systems for nurse managers were found in the literature (Graf et al., 2003; Junttila et al., 2007; Ruland & Ravn, 2003). However, all of these reports came from single sites. Two of the systems were developed in Europe and are not publicly available (Junttila et al., 2007; Ruland & Ravn, 2003). One application was limited in that data required entry by the nurse manager (versus self-populating) (Ruland & Ravn, 2003). Another system was developed using a data warehouse model, which uses existing multiple data points in information systems including payroll and patient characteristics (Junttila et al., 2007). This approach enables re-use of available data and avoids redundant data entry. Participants that piloted this system indicated that effective uses required firm knowledge about both clinical nursing management and information technology. A limitation to the system was the lack of outcome measures to identify quality of care.

Using operational data for benchmarking purposes is not a new innovation; however, providing automated processes of using these operational report data for creating dashboards is innovative and increasingly significant. These dashboards can combine indicators of clinical outcomes and resource utilization. For example, Web-based real-time dashboards for benchmarking strategic operational data such as nurse staffing needs for the current patient mix, quality indicators, as well as credentialing requirements are possible. There are several positive discussions of the use of dashboards in the nursing

literature (Donaldson et al., 2005; Egan, 2006). Dashboards should help managers meet "SMART" goals, that is the requirements of the presented data for benchmarking and operations should be specific, measurable, achievable, realistic, and timely (Alberti & Durand-Zaleski, 2007).

Web-based staffing and scheduling systems are recent innovations being promoted to increase communication among managers and staff nurses about scheduling needs and availability and willingness to work (Brown, 2007; Douglas & Pledger, 2007; Ellerbe, 2007; Fortin & Douglas, 2006; George, 2006; Hayes & Douglas, 2006; Kulma & Springer, 2006). Dashboards and Web-based staffing and scheduling systems are typically implemented using Web 1.0 technologies.

More recent innovations include Web 2.0 approaches and the potential for application is vast. 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" (Wikipedia, 2008). Web 2.0 encompasses technologies such as blogs, wikis, podcasts, Really Simple Syndication (RSS) feeds, social software (e.g., Facebook and MySpace social networking sites), and Web application programming interfaces. Web 2.0 is in its infancy in health care and while more widely recognized for its social networking aspects, Web 2.0 offers several features of relevance to evidence-based staffing. Web 2.0 platforms (e.g., iGoogle) support user configuration of interfaces in ways that match user mental models or needs and sharing or re-purposing of the created resources. For example, two nurse managers may prefer that staffing and outcome data be organized in different ways and can easily drag and drop the data into their preferred view for monitoring and analysis. RSS

supports syndication, aggregation, and notification of data from multiple sources (e.g., journals, reports, blogs) as a single feed into a user interface (e.g., Web page, iPod) through a subscription process. A division director might subscribe to an RSS feed that “publishes” staffing levels on a unit-by-unit basis in comparison to patient admissions and view these data on her cellular telephone or personal digital assistant as she attends to other activities. A chief nurse executive might use a Mashup, a Web 2.0 technology combining a map and a database, to efficiently locate nurses with a particular set of skills to respond to a crisis situation.

Regardless of whether Web 1.0 or Web 2.0 technologies are implemented, it is vital that data are useful in supporting evidence-based staffing decisions and presented in a manner that is timely, easy to comprehend, and actionable.

Conclusions

Staffing decisions that lack consideration of all relevant factors may result in poor patient outcomes. Existing principles, frameworks, and guidelines provide a foundation for nurse staffing but face poor adoption, varying approaches, and are limited by available research. The increasing development and adoption of technology in health care offers the opportunity for increased availability of data to drive operations and the potential to support evidence-based management decisions. While challenges and unforeseen consequences will undoubtedly arise, with diligence we have the opportunity to provide better patient care and improve health outcomes through informed and effective evidence-based nurse staffing with the use of technology innovations. \$

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