A nursing information model process for interoperability

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ABSTRACT

The ability to share nursing data across organizations and electronic health records is a key component of improving care coordination and quality outcomes. Currently, substantial organizational and technical barriers limit the ability to share and compare essential patient data that inform nursing care. Nursing leaders at Kaiser Permanente and the U.S. Department of Veterans Affairs collaborated on the development of an evidence-based information model driven by nursing practice to enable data capture, re-use, and sharing between organizations and disparate electronic health records. This article describes a framework with repeatable steps and processes to enable the semantic interoperability of relevant and contextual nursing data. Hospital-acquired pressure ulcer prevention was selected as the prototype nurse-sensitive quality measure to develop and test the model. In a Health 2.0 Developer Challenge program from the Office of the National Coordinator for Health, mobile applications implemented the model to help nurses assess the risk of hospital-acquired pressure ulcers and reduce their severity. The common information model can be applied to other nurse-sensitive measures to enable data standardization supporting patient transitions between care settings, quality reporting, and research.

Key words: Electronic Health Records, Nursing Information Models, Quality Assurance/Health Care, Nursing Research, Nursing documentation

The US Affordable Care Act aimed to transform health care systems to provide higher quality, safer, more affordable, accessible, and patient-centered care.1 Technology and information systems, a necessary foundation for achieving these goals, provide an opportunity to use “big data” from multiple settings to improve outcomes.2 However, this opportunity is unrealized, in part because electronic health record (EHR) systems lack standardization of data and structures to consistently represent patient information and nursing care across care settings.

Standardizing health care data to allow semantic interoperability supporting patient transitions between care settings, quality and safety measurement reporting, and research is an ongoing effort.3–7 Quality indicators related to medical diagnosis and treatment may align with clinical and billing codified data, but many nursing-sensitive quality indicators remain in nonstandardized data formats not easily shared and compared across disparate EHRs. If nursing data are organized in a standard way, they can also be shared and compared across regional or national databases to identify trends, report outcomes, and research new opportunities to improve nursing practice.8 Nursing data include nursing assessments, interventions, and patient outcomes.

We describe here the development of a prototype for a common nursing information model and standard terms to capture, re-use, and share patient data across care settings and systems to support evidence-based nursing practice and promote interoperability.

COLLABORATIVE GOALS

Nursing leaders at Kaiser Permanente and the U.S. Department of Veterans Affairs (VA) chartered a collaborative effort to: 1) develop a common nursing information model for a nursing-sensitive quality indicator; 2) document the process as a repeatable methodology; and 3) demonstrate an interoperability plan for data sharing between large integrated health delivery networks. A nursing information model describes theory-guided and evidence-based nursing knowledge and practice related to patients’ responses to a health condition or treatment. A successful prototype of a common nursing information model would provide evidence-based data elements related to nursing care that could be standardized, facilitating the inclusion of appropriately structured patient information related to nursing care for meaningful health information exchange, clinical decision support, quality reporting, and research.

Each organization had multiyear experience with a robust, integrated EHR system that included inpatient nursing documentation. Collaborative objectives included:

• Identifying and validating appropriate data models and value sets to represent a nursing-sensitive quality indicator;
Creating a reproducible, practice-based common nursing information model for validation across disparate organizations and EHR systems;

Documenting the methodology to facilitate replication; and

Engaging with standards organizations to validate and facilitate adoption of the common nursing information model.

**MEASURE SELECTION**

Collaborative leaders selected hospital-acquired pressure ulcer (HAPU) risk assessment and prevention as a prototype nursing-sensitive quality indicator. A costly and largely preventable condition, HAPUs are highly sensitive to nursing care; evidence-based best nursing practices are well documented.\(^{19}\) HAPUs are associated with increased mortality and utilization.\(^ {10–13}\) All-stage HAPU prevalence among US inpatients is \(\sim 5\%\) and costs an estimated aggregate US$ 11 billion annually.\(^ {10–13}\) HAPUs are serious reportable events; US hospitals are subject to financial penalties for high rates of hospital-acquired conditions, including HAPUs.\(^ {14}\)

HAPUs exemplify patient-level nursing data routinely collected and shared across settings for patient care purposes and with external reporting agencies. Currently, health care organizations manually extract data at significant cost despite efforts to standardize non-nursing quality measures for automated reporting.\(^ {5,15,16}\)

**DEVELOPING THE MODEL**

Model development began in February 2010; over the next several months, bi-weekly 2-h web conferences included 2 to 10 participants, depending on the objectives. In addition, two 1-to-3 day in-person work sessions accelerated the pace of model development. Developing the common nursing information model entailed nine steps.

**Form a project team and define scope**

Executive engagement and sponsorship across nursing and technical domains provided vision and momentum. Team composition ensured that the nursing information model reflected current best practices and available evidence. The core workgroup comprised 11 Kaiser Permanente and VA clinical and technical experts; additional external experts contributed assistance and insights. Participants had expertise in all relevant domains:

- Wound and skin care
- Terminology
- Quality management
- Nursing informatics
- Information architecture and data modeling
- System analysis

Wound and skin care experts included Kaiser Permanente and VA advanced practice nurses and representatives of national organizations focusing on HAPU prevention and perioperative nursing care. They helped design clinical scenarios reflecting best practices across organizations. Identifying project scope, team member responsibilities, and timelines provided a framework and focus.

**Identify the evidence base**

A literature review was essential to comprehensively identifying evidence-based data elements and value sets. It focused on evidence related to two domains: HAPU risk assessment and prevention and the use of standardized nursing terminology and nursing information models. Quality reporting requirements, such as those from the National Quality Forum and the Centers for Medicare and Medicaid Services, provided useful context.\(^ {15,17}\) Nursing wound care experts contributed evidence-based best practice expertise, such as the National Pressure Ulcer Advisory Panel clinical guidelines, to help select data elements related to risk assessment, observations, interventions, and outcomes.\(^ {18}\)

**Identify and harmonize data elements**

The workgroup gathered data elements used to describe HAPU risk and prevention in existing nursing documentation within each organization’s EHR environment. These were captured as discrete data elements within nursing flowsheets and templated textual notes. No free text is used in quality reporting in either EHR environment. To harmonize terms, data elements were compared, identifying direct matches, ambiguities, and gaps (table 1). There were no significant semantic differences in data elements between the two systems, rendering harmonization straightforward.

These data elements formed the basis for the common information model. An optimal dataset was defined by comparing the emerging dataset to the evidence collected through the literature review and subject matter expert opinion. Wound and skin care experts identified key data elements that neither organization routinely collected. For example, perfusion status and relevant comorbidities influence HAPU risk but were not routinely collected in a standardized way.

**Modeling with mind-mapping software**

To begin to translate the clinical knowledge of wound and skin care experts into clear structural relationships between data elements, the workgroup used mind-mapping software.\(^ {19}\) This was an essential step in moving from the way that nurses organized their thinking about HAPU assessment and interventions to a machine-interpretable organization. Figure 1 provides an example of mind mapping applied to skin assessment. Validated by wound and skin care experts, the mind maps identified all data elements to capture at the point of care, regardless of the specific EHR environment.

**Develop use cases**

The mind mapping schematic represented relationships between data elements but did not depict care processes. To explicate care processes, the workgroup developed use cases representing common clinical scenarios. Use cases ranged from risk assessment of an uncomplicated, low-risk patient to assessment of a complex surgical patient at high HAPU risk.
### Table 1: Example of harmonization of data elements

<table>
<thead>
<tr>
<th>VA data elements</th>
<th>Kaiser Permanente data elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursing intervention: manage moisture</td>
<td>Nursing intervention: incontinence / moisture management</td>
</tr>
<tr>
<td>Maintain clean and dry skin</td>
<td>Not present</td>
</tr>
<tr>
<td>Apply condom catheter</td>
<td>Urinary containment device in place</td>
</tr>
<tr>
<td>Apply fecal collector (especially if skin breakdown)</td>
<td>Fecal containment device in place</td>
</tr>
<tr>
<td>Apply protective barrier ointment</td>
<td>Applied moisture barrier ointment/cream</td>
</tr>
<tr>
<td>Offer bedpan at scheduled intervals to bed-bound patient</td>
<td>Not present</td>
</tr>
<tr>
<td>Offer urinal at scheduled intervals to bed-bound patient</td>
<td>Prompted voiding</td>
</tr>
<tr>
<td>Schedule toileting</td>
<td>Prompted voiding</td>
</tr>
<tr>
<td>Instruct patient/caregiver to request assistance as needed</td>
<td>Not present</td>
</tr>
<tr>
<td>Not present</td>
<td>Absorbent underpad in place</td>
</tr>
</tbody>
</table>

### Figure 1: Mapping of data elements related to HAPU risk assessment.
Wound and skin care experts and bedside nurses used them to describe nursing care workflows and key data elements, which helped identify a sample data set for the common nursing information model.

Identify optimum data sets

Contemporaneously with model development, the U.S. Department of Health and Human Services adopted the Continuity of Care Document within the HL7 Clinical Document Architecture standard as an option for meeting “meaningful use” goals related to clinical data exchange. The Continuity of Care Document is intended to provide a core set of clinical and demographic patient information for exchange between providers. Because some VA patients also receive care at Kaiser Permanente, the workgroup identified situations in which exchanging clinical information was necessary. Use cases helped identify required data, the process for sharing them across settings, the actors involved, and their roles and possible uses of data.

Although the workgroup recognized that HAPU assessment and prevention must be addressed at many different points throughout the continuum of care, the focus of the nursing information model was on inpatient hospital care with the primary actor identified as the hospital bedside nurse caring for adults at risk for HAPUs.

This step identified the contexts in which the common nursing information model would be used. For example, the workgroup developed an example use case and data elements in conjunction with the American Organization of Peri-Operative Registered Nurses (AORN) (Supplementary Data 1). In this example, nursing data are collected and exchanged between peri-operative and inpatient settings. Colleagues from AORN mapped the data elements to standardized peri-operative nursing terms from the Peri-Operative Nursing Data Set.

Map data elements to reference terminologies

The workgroup mapped local terms to concepts represented by standardized terminologies, mapping questions, or observation categories to Clinical Logical Observation Identifiers Names and Codes (LOINC) and the response values to Systematized Nomenclature of Medicine - Clinical Terminology (SNOMED CT) (table 2). This step required collaboration with clinical developers at SNOMED CT through the International Health Terminology Standards Development Organization and Clinical LOINC. The collaborative engaged the Clinical LOINC Nursing Subcommittee. The harmonization completed in partnership with the Clinical LOINC Nursing Subcommittee established guidelines for following mapping heuristics and developed criteria for inclusion/exclusion of terminology content in the nursing information model.

Formalize the model

The project team diagrammed interrelationships between data elements using unified modeling language (UML), linking terminology binding at the level of value sets and attributes. UML modeling was completed for skin assessment, skin alteration assessment observations and findings, skin alteration risk assessment observations and findings, pressure ulcer interventions, and the Braden skin assessment scale for adults, children, and neonates.

Figure 2 contains a UML detailed clinical model for skin assessment. It includes question or observation categories and response values for skin assessment indication, body structure (anatomic location), skin color, moistness, temperature, turgor, presence of a skin patch, hair growth/condition, nail shape, color, and texture. It is among the simplest UML models; the UML model for skin alteration assessment includes 59 question or observation categories and response values.

### Table 2: Example reference terminology mapping table

<table>
<thead>
<tr>
<th>Observation</th>
<th>LOINC</th>
<th>Value set</th>
<th>SNOMED</th>
<th>SNOMED FSN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser Permanente</td>
<td>VA</td>
<td>Kaiser Permanente</td>
<td>VA</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>Skin Color</td>
<td>39107-8</td>
<td>Normal</td>
<td>297952003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Normal for race</td>
<td>119419001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cyanotic</td>
<td>487860000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dusky</td>
<td>Ashen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flushed</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jaundiced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mottled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pale</td>
</tr>
</tbody>
</table>

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Validate the common nursing information model

The common nursing information model was first validated by expert consensus. The data elements were submitted to the LOINC Nursing Subcommittee, which recruited nursing informatics leaders and harmonized skin/wound assessment from six institutions. The LOINC committee focused on the skin assessment subset of content because this was a voluntary effort and a pilot project. Part of the common nursing information model was taken up by the HL7 Patient Care Work Group, which created a HAPU prevention domain analysis model that includes preliminary work on interventions. The current version of the model is available at http://www.hl7.org/documentcenter/private/standards_temp_37189BC8-1C23-BA17-0C458F8C5E7BE328/v3/V3_DAM_PRULCERPREV_R1_INFORM_2013AUG.pdf.

In addition, an independent demonstration validated the model. From the beginning, nurse leaders at Kaiser Permanente and VA wanted to explore operationalizing interoperability. They believed that interoperability was unattainable without common standards and an implementable information model, and that standard and model development needed a concomitant operational component. They found a kindred spirit in Deputy Director Judy Murphy at the Office of the National Coordinator for Health IT and the Health 2.0 Developer Challenge program, administered by Department of Health and Human Services. Kaiser Permanente, VA, and Health 2.0 announced the “Mobilizing Data for Pressure Ulcer Prevention Challenge” (Challenge) in December 2012. The purpose was to promote the use of the HL7 balloted standard information model and its requisite LOINC and SNOMED CT standards to build a mobile application. Winners among 15 competitors were announced at the Summer Institute for Nursing Informatics in July 2013. The winning mobile health application has the capacity to transmit data demonstrating meaningful use and contributing to quality measures and research.

DISCUSSION

Kaiser Permanente and the VA collaboratively developed a process for comparing nursing data across health care organizations and disparate EHRs. Using HAPU prevention as a prototype, this project demonstrates the rigor required to harmonize and standardize nursing concepts for coding to Clinical LOINC and SNOMED CT. It provides a framework for other teams to generate rigorous evidence-based nursing information models. In addition, the process and approach are applicable to domains outside nursing. Open source application and EHR development follow development of standards and contextual models. Without similar rigor, applications may exacerbate, not reduce, the problem of information exchange.

A strength of this project is the development of use cases that were tied to important clinical and business processes, such as patient transfers and quality reporting. An additional strength is the collaboration with partners such as the AORN to develop use cases and validate the data elements. A limitation of the project is that it occurred in organizations with advanced

![Figure 2: UML mapping related to skin assessment.](https://academic.oup.com/jamia/article-abstract/22/3/608/775729)
EHR systems. Replication would be more difficult in organizations without this enabling health information technology.

The Kaiser Permanente/VA collaborative encountered several challenges in developing the common nursing information model. One related to an ongoing debate within nursing about which data standards to adopt. It was only after this project was well under way that the Office of the National Coordinator for Health IT proposed using LOINC terms for questions or stems and SNOMED CT for responses. In addition, vended EHR systems store data within proprietary structures, which can limit data availability.

An additional and very substantial challenge pertains to the general ability of existing EHR systems, including those at Kaiser Permanente and the VA, to support common information models. Heterogeneous EHR systems are the norm in health care, severely constraining the potential to achieve interoperability, including the health information exchange this project is intended to support. Data harmonization between the organizations is not operational due to architectural limitations. Without solutions such as service-oriented architecture or middleware, no common information model will enable interoperability.

Solving challenges related to interoperability and robust health information exchange across settings is beyond the scope of this project. The collaborative successfully demonstrated a process for establishing a common nursing information model for HAPU prevention and assessment. It has the demonstrated potential to support improved nursing care through mobile health applications. This represents the tip of the iceberg in terms of the potential for common nursing information models to contribute to improved quality and care experiences as systemic interoperability issues are resolved. In addition, the processes and concepts described here are applicable to domains outside of nursing.

CONCLUSIONS
The project described here provides a roadmap for developing common nursing information models to improve patient care coordination, efficiency, and quality. By developing information models that reflect best evidence and clinical expertise and are linked to national terminology standards, nursing can support clinical users and improve patient care.

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CONTRIBUTORS
M.C. and M.B. designed the study, interpreted the data, and revised the article. A.O. designed the study, interpreted the data, and drafted and revised the article. She is guarantor. P.G. analyzed and interpreted the data and revised the article. T.C. analyzed the data and revised the paper. D.D. and D.B. collected, analyzed, and interpreted data and revised the article. All authors approved the final version.

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COMPETING INTERESTS
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SUPPLEMENTARY MATERIAL
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