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Implementation of a Next-Generation Electronic Nursing Records System Based on Detailed Clinical Models and Integration of Clinical Practice Guidelines

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Objectives: The purpose of this paper is to describe the components of a next-generation electronic nursing records system ensuring full semantic interoperability and integrating evidence into the nursing records system. **Methods:** A next-generation electronic nursing records system based on detailed clinical models and clinical practice guidelines was developed at Seoul National University Bundang Hospital in 2013. This system has two components, a terminology server and a nursing documentation system. **Results:** The terminology server manages nursing narratives generated from entity-attribute-value triplets of detailed clinical models using a natural language generation system. The nursing documentation system provides nurses with a set of nursing narratives arranged around the recommendations extracted from clinical practice guidelines. **Conclusions:** An electronic nursing records system based on detailed clinical models and clinical practice guidelines was successfully implemented in a hospital in Korea. The next-generation electronic nursing records system can support nursing practice and nursing documentation, which in turn will improve data quality.

Keywords: Computerized Medical Records Systems, Nursing Records, Semantics, Evidence-Based Practice

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I. Introduction

Since the digitization of nursing records began in the late 1980s, a vast amount of data has been accumulated in electronic nursing records (ENR) systems, and there has been a heightened interest in collecting, sharing, and reusing patient information generated during nursing care [1-3]. To effectively share and reuse data of ENR systems, ensuring semantic interoperability [4] is a key factor. To ensure full semantic interoperability, one approach is to document nursing records using a data model, such as a detailed clinical model (DCM) [5,6]. A DCM consists of an entity-attribute-value (EAV) triplet where an entity is a core or focus concept of a datum, an attribute is a qualifier that represents the en-

tity in more detail, and a value set is a uniquely identifiable set of valid values describing instances of an attribute.

A data model such as DCM is more suitable for structured data entry than for unstructured data entry. Nursing documentation using nursing narratives can reduce the burden of data entry and improve readability [7,8]. Structured narratives allowing the benefits of both narratives and structured data entry have been proposed and used in nursing in the United States [9]. We propose DCM-based nursing narratives which allow structured data entry even though they look like natural language text. To automatically generate nursing narratives using DCM, a natural language generation (NLG) system is suggested.

Improving patient safety and outcomes is always an important issue of healthcare; therefore, evidence-based practice to reduce variability in practice and resulting patient outcomes is recommended. To encourage evidence-based practice, clinical decision support systems that provide digitized clinical practice guidelines (CPGs) and critical pathways are being actively introduced into the medical field for the health professional's use in clinical settings.

There have been several studies integrating clinical guidelines or pathways into the clinical decision support system to promote the selection and implementation of the most appropriate interventions in nursing practice [10,11]. However, the current ENR system has not yet incorporated the available evidence in the CPGs [12]. To enhance the nursing

record beyond its obvious use as a note-keeping system, a link between evidence-based practice and the nursing record is needed.

Therefore, a next-generation ENR system based on DCM, NLG, and CPG is proposed to ensure full semantic interoperability and integrate evidence into nursing records systems. This paper describes the components and features of a next-generation ENR system developed at Seoul National University Bundang Hospital (SNUBH).

II. Case Description

The proposed next-generation ENR system was implemented at SNUBH in 2013. SNUBH is a public tertiary general hospital located in the Seoul metropolitan area; it opened in May 2003 as the first fully digitized general hospital with the first standard nursing terminology-based ENR system in the world. SNUBH is equipped with 8 specialized centers and 23 clinical departments; it has 1,360 beds and approximately 5,000 outpatient visits per day. The hospital employs approximately 732 doctors, 996 nurses, and 870 other staff members.

The proposed ENR system comprises a terminology server and a nursing documentation system (Figure 1). The terminology server manages the International Classification for Nursing Practice (ICNP) concepts, DCMs, and nursing narratives. The nursing documentation system provides nurses
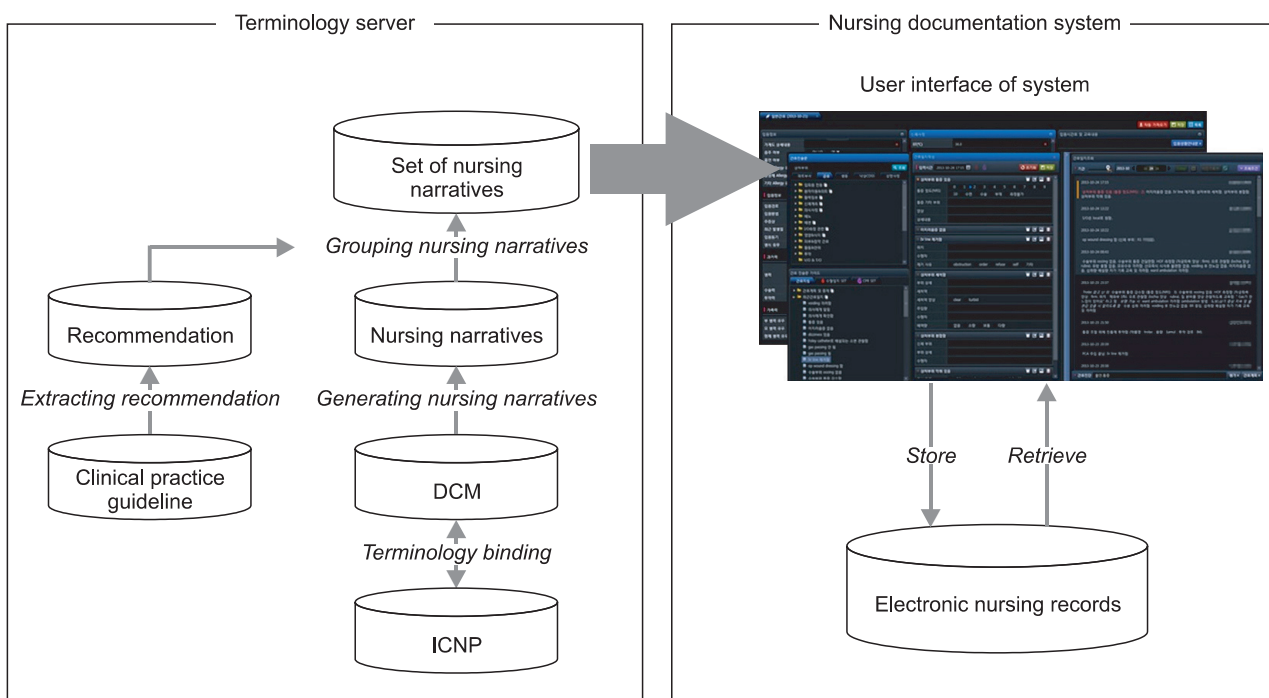

Figure 1. Elements of a detailed clinical model (DCM), natural language generation, and clinical practice guideline–based electronic nursing records system. ICNP: International Classification for Nursing Practice.

with a set of nursing narratives arranged around the recommendations extracted from CPGs. Nurses can document nursing records by selecting appropriate nursing narratives. Nurses can add values of attributes to the narratives.

To successfully implement the next-generation ENR system, we developed a prototype system with these components and conducted a feasibility study in terms of content and system user interface. Development of the system was conducted in the following four phases:

1. Developing and Managing DCM

DCMs were developed in four phases. 1) The entities of data elements were identified by analyzing nursing narratives documented in the ENR system in this hospital and by reviewing nursing literature, CPGs, and ICNP concepts. 2) The attributes of an entity were identified, including qualifiers or modifiers representing the entities in more detail as well as the values of each attribute. This was done by analyzing nursing narratives documented in the ENR system; reviewing ICNP concepts; characterizing categories of the ISO/DTS 22789, which is a conceptual framework for patient findings and problems [13]; characterizing semantic domains of the ISO 18104, which is a reference terminology model for nursing [14]; characterizing qualifier values of the Systematized Nomenclature of Medicine Clinical Terms, nursing literature, and CPGs; and interviewing the domain experts. 3) DCMs were modeled by linking an entity and its corresponding attributes with values and specifying the data type and optionality of its attributes. 4) Finally, DCMs were evaluated by domain experts and were applied to case reports. Detailed information on development of the DCMs can be found in the work of Park et al. [15].

In total, DCMs with 902 entities, 1,356 attributes, and 1,943 values were developed to fully represent the nursing concepts describing signs and symptoms, nursing problems, patients' responses, and nursing activities of nursing care.

The DCM management system controls the creation and modification of entities, attributes, values, entity-attribute relationships, attribute-value relationships, data types, and optionality of attributes. Supplementary Figure 1 shows the registration of 'pain' as an entity and the attributes of pain describing the entity with their optionalities.

2. Generating Nursing Narratives

The NLG system accepts an entity and attributes of the DCM as input and produces nursing narratives as output through the generator which processes semantic, contextual, and syntactic knowledge according to the input.

The NLG system has semantic, contextual, and syntactic

knowledge as its components. Semantic knowledge includes DCMs, type of statement, and a plausible set of attributes. The entity and attributes of a DCM determine the structure of nursing narratives to be generated, while terms describing an entity and possible values of attributes determine the surface representation of the nursing narratives. The type of statement determines a plausible set of attributes and a verb to be used in the nursing narratives, where a plausible set of attributes is a valid combination of attributes in a nursing narrative. Syntactic knowledge includes the sequence of the entity, attributes, and a verb in a nursing narrative and case markers. Contextual knowledge includes the tense of the verb and the source of information.

The NLG goes through three phases to generate nursing narratives. 1) The system provides valid types of statement and plausible sets of attributes for the entity entered. 2) The sequence of the entity and attributes is determined by the type of statement. The type of verb and its tense are provided in accordance with the type of statement and the source of information. 3) Finally, the attributes are replaced by value sets, and nursing narratives with entities and values are generated. The generated nursing narratives are then refined with case markers for the entities and for the values. The combination and sequences of attributes of a DCM play an important role in determining the structure of nursing narratives to be generated from the DCM.

Supplementary Figure 2 shows a screenshot of the generated nursing narratives using the 'pain' entity, 'anatomical site', 'severity', and 'presence' attributes. The system generated 22 nursing narratives, which included 10 for measurement-type statements, nine for patient's verbal statements, and three for judgment-type statements.

One example of the generated nursing narratives included an entity 'pain (통증)' coded E000057, three values for three attributes, such as 'abdomen (복부)' coded V900911, 'severe (심한)' coded V000190, and 'present (있음)' coded V000167, and the adverbial case marker, 'e (에)', coded M000007 and the nominative case marker, 'i (이)', coded M000013. The generated nursing narrative, along with the associated metadata such as nursing narrative ID, type of statement, EAV triplet and case markers, was stored in a relational database. The generated nursing narratives were expressed with codes 'S00001012; SC00004: {A000005=V900911, M000007, A000083=V000190, E000057, M000013, A000074=V000167}' (Figure 2).

3. Presenting Nursing Narratives Based on CPGs
The presentation of nursing narratives based on CPGs comprises three phases: 1) identification of the relevant CPGs,
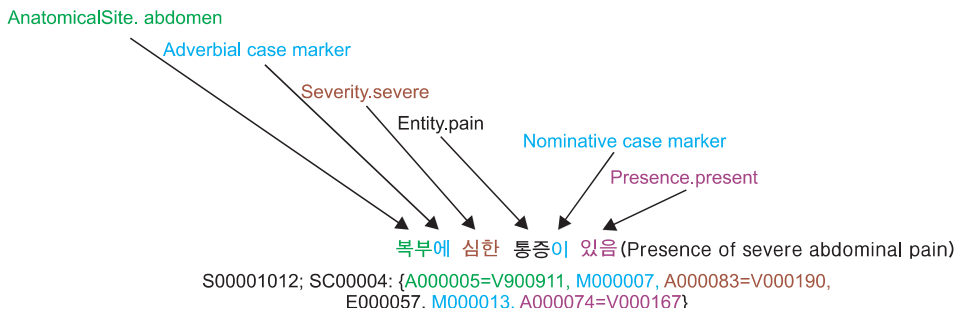
Figure 2. An example of a generated nursing narrative.

2) extraction of recommendations relevant to nursing care from these CPGs and rearrangement of recommendations by each phase of the nursing process and patient problem, and 3) linking of nursing narratives with evidence by arranging the set of nursing narratives around the recommendation. Detailed information on the integration of CPGs into nursing records systems can be found in the work of Park et al. [16].

The CPG-based nursing narrative management system controls the creation and modification of guidelines, recommendations, guideline-recommendations relationships, and recommendations-nursing narratives relationships. Supplementary Figure 3 shows a sample screenshot of CPG-based nursing narratives management, creating the 'monitor blood pressure' recommendation of 'antenatal care for normal pregnancy' guideline. The guidelines were categorized by stages of labor, different types of delivery, and pregnancy risk levels, and recommendations were arranged and grouped according to the stages of labor and patient problems.

4. Nursing Documentation System for Data Entry and Data Retrieval

The nursing documentation system displays the nursing narratives with different levels of granularity and with different value sets, which are arranged by recommendation for nurses to select for nursing documentation. Supplementary Figure 4 shows how nurses document nursing progress notes using the nursing narratives which look like natural language text.

The DCMs developed for nursing records provide not only data set for structured nursing documentation, such as initial nursing assessment (Supplementary Figure 5), but also nursing narratives for unstructured nursing documentation, such as nursing progress note (Supplementary Figure 4).

The DCM-based nursing records system enables the content of nursing records to be searched using not only core concepts, but also attributes and their value sets from any nursing forms while documenting nursing records. Thus, nurses can selectively view previous nursing records and review the trend of nursing documentation. Supplementary Figure 6 shows a screenshot of a nurse viewing previous re-

cords filtered for the 'severity' attribute of the 'pain' entity to review the trend of pain intensity while documenting nursing progress notes for patients with pain.

III. Discussion

Nursing documentation using DCM enables integrated management of narratives documented in unstructured nursing forms, such as nursing progress notes, and data items documented in the structured nursing forms, such as initial assessment document form, vital sign sheet, and nursing activity document form. This solves the problems [17] of linking and integration of various types of data input in ENR systems.

If a system manager adds or modifies a DCM, the addition or modification of DCM can be applied to all documentation in various forms. Furthermore, if a nurse wants to enter the same data into different forms repeatedly or view the same data across several forms, this is possible due to the interoperability of data. In addition a nurse can view or search contents of nursing documentation extensively using entity concepts, attributes or values sets of the attributes.

We tried to automatically generate nursing narratives from DCM using NLG technology. The combination and sequences of attributes of a DCM play an important role in determining the structure of nursing narratives generated from the DCM. Narratives generated from the DCM allow structured data entry seemingly as natural as human language and provide nursing narratives with different levels of granularity.

However, more studies are needed to verify that data entry using nursing narratives is more natural and easier for nurses to view and facilitates easier and faster documentation than structured data entry.

We tried to implement an ENR system integrating evidence which not only guides nurses for best practice, but also helps them document nursing practice around the best practice. For nurses documenting the nursing progress notes of a patient, ENR offers detailed recommendations from CPGs to

guide nursing practice according to the patients' diagnosis, and presents what is to be documented as a set of nursing narratives should the nurse perform the nursing practice according to the recommended guidelines.

In our prototype ENR system, guidelines were categorized by stages of labor, different types of delivery, and pregnancy risk levels, and recommendations were arranged and grouped according to the stages of labor and patient problems. Thus, recommendations provided in the ENR system were more customized for different stages of labor and patient problems [16].

In future studies, it should be confirmed whether 1) the next-generation ENR system proposed in this study offers easier input and view for the user, 2) the narratives used have consistent structure and offer diverse level of granularity, and 3) the data collected can be reused more effectively for research and educational purposes because the quality of data is improved with this proposed system.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

Supplementary Materials

Supplementary materials can be found via http://e-hir.org/src/sm/hir-19-301-S001. Figure 1. Screenshot of detailed clinical model development and management. Figure 2. Screenshot of the nursing narratives generator. Figure 3. Screenshot of the clinical practice guideline-based nursing narratives management system. Figure 4. User interface system of nursing documentation using entity-attribute-value based nursing narratives (nursing progress note). Figure 5. User interface system of structured nursing documentation using entity-attribute-value triplets (initial nursing assessment). Figure 6. Screenshot of nursing narrative searched with severity attribute of pain.

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