Development and evaluation of a terminology-based electronic nursing record system

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Abstract

The present study was conducted to develop and evaluate a terminology-based electronic nursing record system. The narrative nursing notes of 63 obstetric patients collected over 395 hospital days were decomposed and cross-mapped with the Korean version of the beta version of the International Classification for Nursing Practice (ICNP). The terminology-based nursing record system was developed with a terminology server to manage nursing concepts and nursing phrases, and a user application system to document nursing notes. The system was evaluated in two Korean hospitals by 20 nurses documenting nursing notes of 57 patients. Patterns were found in nursing notes reflecting the nursing process. A total of 14,727 phrases were used for documenting nursing notes, with these phrases consisting of 237 unique phrases. Among the 259 unique nursing concepts extracted from the 237 unique phrases, 103 concepts (39.8%) did not map onto the ICNP. The users were able to find nursing phrases with a success rate of 89.4%. The mean time required for documentation at each input session decreased significantly from 276 to 158 s as the users became more experienced.

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1. Introduction

In the past, patient records were merely a data repository that helped healthcare personnel to recall what they had done, whereas currently patient records play a role as a communication tool among healthcare personnel [1]. Computer-based patient records, which offer more accurate, accessible, and timely information compared to paper-based records, have been introduced as a strategy to maximize the usefulness of medical records [2–5]. Traditional paper-based nursing records limit the utilization of patient data due to dispersion, inaccuracy, redundancy, disparity in the quality and frequency of records [6], and missing data [7]. Furthermore, the lack of linkage with the records of other healthcare professionals means that nursing records are not being shared effectively. Many other healthcare professionals have little confidence in nursing records because they are not written in a systematic way and are often filled with redundant clinical laboratory test results or repetitive clinical information [8]. Thus, computerization of nursing records involves more than a simple automation of existing paper-based records. The records themselves must be changed so that data selection, mapping, coding schemas, identification of relations between data items, data searching, analysis processes, and the technology fit the information system paradigm [9].

There are many potential problems—both qualitative and quantitative—when documenting services provided by nurses. Among these problems, nursing concepts and data standards that could support nursing practice are essential not only for the development of a nursing information system but also for developing other components of hospital information systems [10]. The past 10 years have seen progress in the development of nursing vocabularies taking place in parallel with the development of nursing information systems [11–15]. However, existing nursing vocabularies are inadequate due to lack of content coverage at the desired level of granularity, lack of consistent meanings for concepts.

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and their relationships, and lack of explicit, formal concept-representation principles [16].

The International Classification for Nursing Practice (ICNP) was launched in 1989 by the International Council of Nurses to meet the demand for a common language for nursing. The beta version of the ICNP uses combinatorial terminology for nursing practice that allows terms used in nursing practice to be cross-mapped with existing nursing vocabularies and classifications. The ICNP is a multi-axial and polyhierarchical classification of nursing phenomena, nursing actions, and nursing outcomes that facilitates expression of nursing diagnoses, interventions, and outcomes [17].

The purpose of this article is to describe three phases in the design and evaluation of a terminology-based electronic nursing record system: (1) analysis of nursing notes including decomposition into phrases and cross-mapping with the ICNP; (2) development of terminology server and electronic nursing record system; and (3) evaluation of terminology server and electronic nursing record system.

This article presents methods and results of each phase following by discussion.

2. Phase 1: analysis of nursing notes and cross-mapping with ICNP

2.1. Methods

The development of an electronic nursing records system requires an understanding of the content of narrative nursing notes in current nursing practice. Here the nursing notes of patients who were discharged from the obstetric units of a Korean tertiary teaching hospital prior to March 2000 were analyzed. The narrative nursing notes were decomposed into phrases and coded by meaning. Each phrase in turn was decomposed into concepts and cross-mapped with the ICNP. Patients were divided into five categories: (i) normal delivery, (ii) scheduled caesarian section, (iii) normal delivery with complications, (iv) antepartum problems, and (v) postpartum problems. Analysis of nursing notes was stopped when no more new phrases were found—for each subject category this occurred when the nursing notes of around 15 patients had been analyzed. In total, the nursing notes of 63 patients were analyzed.

2.2. Results

The most important finding during the process of decomposing nursing notes was of patterns in the narrative nursing notes. They appeared in the following order: patient’s complaints or nursing assessment followed by nursing problem, actions taken by nurses to solve the nursing problem, and patient’s response to the nursing actions. Even though there were fewer phrases on nursing problems or patient’s responses compared to other phrases, this pattern appeared repetitively throughout the nursing notes analyzed.

Decomposed phrases were divided into three groups according to their content: (i) 5907 patient-problems-related phrases (40.1%), (ii) 8459 nursing-actions-related phrases (57.4%), and (iii) 361 other phrases (2.5%) (see Table 1). When the redundant phrases (in terms of meaning) were removed, there were 98 unique patient-problems-related phrases, 114 unique nursing-actions-related phrases, and 25 other phrases, giving a mean of 62.1 repetitions per phrase. Twenty-five other unique phrases that could not be classified into either nursing problems or nursing actions were used to describe contextual information where nursing services were provided, an example of which is a phrase quoting a patient’s statements or a doctor’s care plan. When the frequencies of these unique phrases were examined, 24 patient-problems phrases appeared more than 100 times, representing 78.3% of all nursing-problems-related phrases, and 19 nursing-actions phrases appeared more than 100 times, representing 71.0% of nursing-actions-related phrases. There were 105 unique phrases with frequencies of less than 20 times each, representing only 6.5% of all phrases.

Decomposing the 237 unique phrases resulted in the extraction of 259 unique concepts. Among these 259 concepts, 101 concepts (39%) were related to nursing phenomena and the other 158 concepts (61%) to nursing actions. Of these concepts, 43 nursing-phenomena concepts (16.6%) and 60 nursing-actions concepts (23.2%) did not cross-map onto the ICNP (Table 2).

A nursing phrase can provide information that is not yet included in the ICNP. For example, the phrase ‘‘300 cm³ of amber-colored urine is well dripping through an indwelling catheter’’ is a nursing-action phrase stating that urine dripping through an indwelling catheter was observed, and this phrase was combined
with axes (see Table 3) 2A (“observing”), 2B (“urine”), and 2C (“urine catheterization”). There is no concept to describe urine color and amount in the beta version of the ICNP, and hence we treated the information on urine color and amount as an attribute of the phrase “urine was observed through a urinary catheter,” where the specific values of this attribute were “amber” and “300 cm³.”

3. Phase 2: development of terminology server and electronic nursing record system

3.1. Methods

A Web-based ICNP terminology server was developed, the functions of which were ICNP navigation, concept management, and precoordinated-phrase management. The ICNP navigation function allows the users to explore the structure and content of the ICNP. The concept-management function is used to extend the original ICNP by adding a new concept, or updating or deleting a concept added to the original ICNP. Precoordinated-phrase management allows the users to create, update, or delete a library of precoordinated phrases for nursing problems, signs and symptoms, diagnoses, goals, interventions, and evaluations. Each precoordinated phrase can have attributes for detailed expression. For the development of the user application system, phrases of narrative nursing notes were structured according to the nursing process. The design of this system took into consideration the cyclical process of ongoing nursing assessment, intervention, and evaluation.

The relationship between the terminology server and the user application system was identified and designed as a logical system model. From the system analysis and design, a Web-based ICNP terminology server and client/server based user application system were developed and implemented on the Microsoft Windows platform. The Korean version of the beta version of the ICNP, which was translated by the Nursing Informatics Research team [18], was used for the ICNP terminology server. The terminology server and user application system shared the same database, and thus the precoordinated phrases created by the ICNP terminology server were used in the user application system.

3.2. Results

Fig. 1 shows the core elements of the electronic nursing record system. The user application system, which forms part of the clinical information system, communicates with the clinical data server to obtain patient demographic data and to upload nursing records. Staff nurses access the clinical information system via workstations (usually IBM-compatible PCs using client module software). The ICNP terminology-server administrator accesses the terminology server through an Internet browser.

A total of 2737 concepts including existing ICNP concepts and 103 new concepts found during the analysis of nursing notes, and 237 precoordinated phrases are managed with the ICNP terminology server (see Fig. 2). Users document with precoordinated phrases in the electronic nursing record system. Fig. 2 shows the logical cycle of the presenting process of the precoordinated phrases and representing process of finding new phrases. The users documented nursing notes using the precoordinated phrases, and the terminology administrator in turn managed precoordinated phrases through the representing process of new phrases.

A version of the ICNP terminology server that runs on the Windows 2000 Server operating system is available on the Web. Users can locate an ICNP concept by hierarchical navigation or keyword searching. The ICNP hierarchy is displayed graphically to make it easy for users to understand its structure.
hierarchy can be used to refine searches and to check the context of terms. The keyword searching can be performed in either Korean or English. A function for searching different areas (i.e., code, synonyms, or definitions) is also available. Fig. 3 shows a navigation result when using the ICNP view function. Once the browser locates a nursing concept, it displays the English concept label, ICNP code, and definition of the concept.

The terminology browser is designed to allow users to create a library of precoordinated phrases using the ICNP axes, and to define links among the concepts. For example, let us assume that we want to create the following precoordinated phrase: “there is edema in the left lower extremity.” The user could search for “edema” from the focus axis of the phenomena classification, and add this to a nursing phrase (see Fig. 4). The user could then search for the concept “yes” from the judgment axis, and add this to the nursing phrase. Finally, the user could search for the concept “left lower extremity” from the body-site axis, and add this to the nursing phrase. The user can reorder the concepts added to the nursing.

### Table 3
Characteristics of subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Frequency (%)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>20–29</td>
<td>5 (25.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30–39</td>
<td>13 (65.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40–49</td>
<td>2 (10.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20 (100.0)</td>
<td>32.5 (4.3)</td>
</tr>
<tr>
<td>Education</td>
<td>Diploma</td>
<td>4 (20.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baccalaureate</td>
<td>11 (55.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Master</td>
<td>5 (25.0)</td>
<td></td>
</tr>
<tr>
<td>Working experience in nursing (month)</td>
<td></td>
<td></td>
<td>113.3 (45.2)</td>
</tr>
<tr>
<td>Working experience in maternity nursing (month)</td>
<td></td>
<td>61.6 (40.7)</td>
<td></td>
</tr>
</tbody>
</table>
phrase to improve the way that it is expressed. If the precoordinated phrase matches any phrase from an existing nursing terminology or classification system, the browser displays its corresponding code.

The user application system was developed to support documenting narrative nursing notes using a controlled library of precoordinated phrases. The user interface consists of two main modes of data display and input. The display shows the selected patient's nursing notes from the admission date through to three views of a summary table of the patient's problems (nursing assessment and evaluation), a summary table of nursing actions, and narrative nursing notes composed of the selected precoordinated phrases (see Fig. 5). In the input mode, the users can select a precoordinated phrase or combinations of phrases by navigation and search functions (see Fig. 6). Users can add detailed information to a phrase by inputting attributes or free text. For easier data input, precoordinated phrases are displayed in a hierarchy of categories. A re-entry function for already selected precoordinated phrases is also available (see Fig. 6).
4. Phase 3: evaluation of terminology server and electronic nursing record system

4.1. Methods

When evaluating the terminology-based electronic nursing record system, we tested the performance of the terminology server and the user application system at the same time. Two tertiary teaching hospitals that have hospital information systems were selected as test beds. Twenty volunteer nurses with a minimum experience of 1 year in obstetric nursing care were recruited. All participants agreed to think aloud and be videotaped while they used the user application system to document the nursing notes of three patients per day during their six duty days. The videotape was transcribed and annotated to reflect how nurses behaved whilst documenting nursing notes.

We categorized the process of data entry into three groups based on the success in finding a desired pre-coordinated phrase: (i) if the user was able to select a pre-coordinated phrase that matched exactly what the user wanted to document, this was categorized as a “success”; (ii) if the user could not find a desired pre-coordinated phrase and consequently did not enter the data, this was categorized as a “failure”; and (iii) if the user selected a pre-coordinated phrase which did not match what the user wanted to document, this was categorized as “suboptimal.” The failure and suboptimal categories were further categorized into “insufficient coverage” (where there was no appropriate pre-coordinated phrase in the library), “inadequate representation” (where the user could not locate the desired pre-coordinated phrase—even though it was in the library—due to a missing synonym or unrecognized abbreviation), and “usability problems” (user-interface problem). We measured the time required to document the nursing notes.

4.2. Results

The characteristics of the participants are listed in Table 3. Most (65%) of the subjects were 30–39 years old, and 80% of the subjects were qualified to at least baccalaureate level. The mean working experience in nursing was 113.3 months (SD 45.2 months), with the mean working experience in maternity nursing being 61.6 months (SD 40.7 months) (Table 3).

Analysis of the videotape of nurses’ interactions with the electronic nursing record system, 20 nurses documented the nursing notes of 57 patients 158 sessions with 1126 phrases (see Table 4). On average, each nursing-note-documenting session consisted of 5.6 phrases (SD 2.6 phrases). Out of 1126 phrases, 394 (35.0%) pre-coordinated phrases were used to describe patient problems, 31 (2.8%) pre-coordinated phrases described nursing diagnoses, and 455 (40.4%) pre-coordinated phrases described nursing actions. Three hundred and ninety-seven phrases were described in more detail, with 481 attribute values. Nurses added 246 free-text phrases, in situation where they could not find an appropriate phrase from the library of pre-coordinated phrases. Most of these free-text phrases described contextual information, such as quoting a patient’s words or a doctor’s care plan. Nurses used keyword searching more than other input methods when they needed to locate an appropriate pre-coordinated phrase; an average 1.35 keywords were used in this searching process. The time required to find and input a pre-coordinated phrase ranged from 2 to 159 s, with a mean of “23.93” s.

Table 5 shows the data relating to whether or not a desired pre-coordinated phrase was found successfully. Users were able to find 787 out of 880 (89.4%) pre-coordinated phrases successfully. Out of 93 suboptimal or failed phrase selections, 84 phrases (47 phrases for patient problems and 37 phrases for nursing actions) were
not matched with what they intended to describe. Nurses failed to find nine desired precoordinated phrases (five phrases for patient problems and four phrases for nursing actions). Out of 93 suboptimal or failed phrase selections, 35 phrases were not available in the library of the precoordinated phrases. Users failed to find 40 of the desired phrases even though they were in the library: this was due to nurses choosing an incorrect phrase or entering free-text phrases. The most frequent reason for failure was that the precoordinated phrases did not have synonym or abbreviation that users were looking for (such as “shaving” for “skin preparation”). There were 18 failed phrases due to interface problems.

The time required to document nursing notes was analyzed. Fig. 7 compares the input time with the selection of precoordinated phrases, free text and total input. The figure shows that the total mean input time required for each nursing-notes-documenting session decreased significantly from 276 to 158 s as the users became more experienced.

4.3. Discussion

This study was conducted to see how a concept-based terminology can be used for the computerization of narrative nursing notes and how nurses interact with the controlled terminology when performing data entry. This study began by investigating what nurses wrote in nursing notes through the content analysis of narrative nursing notes, which revealed that the decomposition of phrases well reflected the nursing process. This finding verified that mirroring the nursing process is a feasible way of structuring narrative nursing notes. Furthermore, the fact that 14,727 phrases could be expressed with only 237 unique phrases strongly demonstrates the feasibility of computerizing narrative nursing notes.

Most (156 of 257, 60.2%) nursing concepts from 237 unique nursing phrases cross-mapped with the ICNP. The mapping rate of this study was lower than that in Ryu and Park’s analysis of electronic nursing records for

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Table 4
Input events and required time, categorized by search task

<table>
<thead>
<tr>
<th>Task</th>
<th>Search method (%)</th>
<th>Input time per event mean (SD)</th>
<th>Average no. of keyword input (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Keyword</td>
<td>Navigation</td>
<td>Etc.</td>
</tr>
<tr>
<td>Nursing phenomena</td>
<td>Patient problem</td>
<td>312 (79.2)</td>
<td>58 (14.7)</td>
</tr>
<tr>
<td></td>
<td>Nursing diagnosis</td>
<td>6 (19.4)</td>
<td>10 (32.3)</td>
</tr>
<tr>
<td>Nursing actions</td>
<td>302 (66.4)</td>
<td>119 (26.2)</td>
<td>34 (7.5)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>620 (70.5)</td>
<td>187 (21.3)</td>
<td>73 (8.3)</td>
</tr>
<tr>
<td>Free text</td>
<td>246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1126</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. C, insufficient coverage; R, inadequate representation; and U, user interface problem. Numbers in parentheses are percentage of total.

Table 5
Analysis of data entry events by phrase input task

<table>
<thead>
<tr>
<th>Statement input task</th>
<th>Total phrases</th>
<th>Successful</th>
<th>Suboptimal or failed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Nursing phenomena</td>
<td>394</td>
<td>342 (43.5)</td>
<td>27 (77.1)</td>
</tr>
<tr>
<td>Patient problems</td>
<td>31</td>
<td>31 (9.9)</td>
<td>0</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>455</td>
<td>414 (52.6)</td>
<td>8 (22.9)</td>
</tr>
<tr>
<td>Nursing Actions</td>
<td>853</td>
<td>787 (100.0)</td>
<td>35 (100.0)</td>
</tr>
<tr>
<td>Free text</td>
<td>246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1126</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Fig. 7. Comparison of input time (s) by session.
internal medicine and cardiology patients at Samsung Medical Center [19]. The main reason for this difference is probably that Ryu and Park cross-mapped already-standardized phrases with the ICNP, whereas in the present study paper-based nursing notes without any standardization were cross-mapped with the ICNP. Most of the terms not mapped with the ICNP belonged to the focus axis of the nursing phenomenas classification or the target axis of the nursing-actions classification, whereas very few unmapped terms belonged to the judgment axis of nursing-phenomenas classification or action-type axis of the nursing-actions classification. This implies either that the judgment axis or action-type axis of the ICNP is well developed so that ICNP covers most of the terms used in nursing notes, or that nurses did not use diverse concepts in their nursing notes. The latter reason is more likely.

The results of this study imply that computerization of narrative nursing notes is feasible when using a concept-based nursing terminology such as the ICNP [20]. However, when computerizing nursing records, it is essential to identify specific local terminology not mapping with the ICNP to improve the expressiveness of the nursing notes.

A terminology server called the “ICNP browser” was developed and used to illustrate the basic principles of its combinatorial design. It was also used to add 103 new concepts, synonyms, and to create 237 precoordinated phrases for use in the user application system. The multi-axial structure of the ICNP was found to be very useful for creating precoordinated phrases.

The ICNP browser is also designed so that users can access it and it can be managed via the Internet. The server could therefore be used for the widespread dissemination of the ICNP and education of nurses about the ICNP. It could be also used in retrieving and analyzing data accumulated in clinical data servers using the concept-mapping relationship. These mechanisms facilitate the reusability of clinical nursing data and enhance their clinical study.

The evaluation method used in this study was also used in the studies of Elkin et al. [21] and Cimino et al. [22]. Their studies were carried out in the medical domain, and reported the clinicians’ behaviors whilst entering the patient-problem, adverse-reaction, and medication data. Their reports did not include narrative records nor perform usability tests in real clinical settings.

In system usability testing in the present study, users succeeded in entering the desired phrases in 89.4% of data-input events. The observation of nurses during documenting nursing notes using electronic nursing record system revealed that in 6% of cases the users chose an inadequate phrase because the library of precoordinated phrases lacked an appropriate phrase. This implies that the application of a terminology-based electronic nursing records system in a clinical setting requires supplementation of the precoordinated phrases.

Entering data into the system includes tree navigation, keyword searching, and re-entry function for already selected precoordinated phrases. The keyword-search function with a standard approach to coded data entry allows the user to type in a phrase and attempt to match it to a known phrase was used the most frequently. However, the tool for navigating the hierarchy of the precoordinated phrases was used only 21.3% of the total time, and re-entry function was used only 8.3% of the time. This is attributable to the users not being familiar with the tree-walking method. Many users stated they had forgotten that such functions were available, and so presumably these functions would be useful in the future.

In terms of time taken to enter data, users exhibited rapid adaptation in that the mean time required dropped from 276 to 158 s as they became more experienced. Considering that the users did not receive any formal training, other than guidance about how to use the program, such a result highlights that the use of such a program is feasible in real clinical settings.

In conclusion, this study used a systematic approach to analyze, design, implement, and evaluate a terminology-based electronic nursing records system. By evaluating the entry of coded data—from beginning to end—in actual clinical situations, we have been able to evaluate the effectiveness of the user interface and the vocabularies developed, thereby providing a basis for the iterative refinement and improvement of both. Although this study was limited to obstetric nursing, our approach could also be applied to the computerization of records in other areas of nursing. Future studies need to focus on determining how to reuse and process standardized nursing data accumulated in the clinical data server for purposes such as quality and cost management, clinical research, decision support, and healthcare policy development.

References


