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Research paper

# From nurse concerns to standardised nursing statements: Mapping intensive care unit intervention notes with clinical care classification

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ABSTRACT

*Background:* Patients in intensive care units (ICUs) are at high risk of clinical deterioration, and ICU nurses document their clinical judgements in the electronic medical record system, where documentation patterns can be operationalised as indirect indicators of nurses' concerns. Despite their clinical importance, unstructured documentation hinders the representation of nurses' concerns, underscoring the need for systematic approaches.

*Aim:* The aim of this study was to map unstructured intervention notes reflecting ICU nurses' concerns into standardised nursing terminology such as the Clinical Care Classification (CCC) system.

*Methods:* This study utilised the Medical Information Mart for Intensive Care IV database. Intervention notes were defined as sentence-level documentation related to nursing interventions recorded during ICU stays. Nurses' concern categories were defined based on the comprehensive literature review. The mapping process comprised (i) extraction of intervention notes; (ii) review of these notes based on nurses' concerns; (iii) validation of the matched intervention notes and nurses' concerns; and (iv) mapping of the validated notes to the CCC.

*Results:* Among 17 587 757 note entries from 39 904 ICU admissions, a total of 9 614 214 intervention-note entries from 39 711 ICU admissions were obtained. Given the data characteristic that notes were often repeated, 269 unique intervention notes, obtained after removing duplicates, were selected. Of the 269, 107 notes were matched with 15 concern categories and were then mapped into the CCC terms. A total of 63 CCC intervention codes were finalised, reflecting ICU nurses' primary concerns with respiratory- and fluid-related clinical deterioration and predominantly addressed through direct nursing care.

*Conclusions:* Nurses' concerns were successfully mapped to standardised terms. Based on theoretical knowledge and practical clinical insights, this study can contribute to transforming nurses' concerns into quantifiable nursing data for decision support and strengthening the infrastructure for interoperable nursing data across healthcare settings.

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## 1. Introduction

Nurses express their concerns regarding patient deterioration and exchange relevant information with other healthcare professionals through electronic medical records (EMRs).[1,2] These documents contain nurses' situational awareness and clinical judgements regarding subtle changes in a patient's condition and provide valuable information for predicting adverse outcomes.[3–6] Specifically, documentation patterns in the EMR system can serve as indirect indicators of nurses' concerns, within which their clinical judgement is embedded through documentation activities that translate nursing practice into recorded data.[3] In the intensive care unit (ICU), nurses need to be highly sensitive and responsive to symptoms, signs observed in patients, or alarm alerts from monitoring equipment since patients' condition can fluctuate rapidly.[7] The records documenting their concerns consist of structured formats providing specific information, such as frequency of monitoring vital signs or medication withholding,[2] or unstructured formats comprising additional comments or

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narratives.[8,9] Information regarding nurses' concerns should be captured from these records to effectively recognise and respond to ICU patients' deterioration risks.

The extraction of important features is more difficult from unstructured nursing records than from structured formats.[10] Several studies refer to natural-language processing (NLP) techniques to handle the complexities of unstructured data[11,12] and extract nursing concepts from them.[8] NLP can process and analyse large volumes of text data, facilitating data-driven patient care decision-making.[13,14] However, because of the variability in the use of clinical language across different institutions, NLP outputs often require extensive processing to ensure consistency and accuracy when applied across diverse settings.[15–17] To address these difficulties and increase interoperability, studies have mapped unstructured nursing records to standard terminologies to capture meaningful nursing concepts.[9,18] A standardised approach is required for the consistent identification of meaningful nursing concepts, such as nurses' concerns, from the unstructured nursing records documented in EMRs across diverse settings. Furthermore, structured concern documentation, serving as a surrogate for capturing nurses' clinical judgement in the EMR,[3,19] has the potential to inform downstream clinical interventions and support optimal decision-making for patients at a risk of deterioration.

The standardisation of free-text documentation to incorporate nursing terminologies has long been a topic of discussion in the nursing informatics field.[20,21] The Clinical Care Classification (CCC) system is one of the standardised nursing terminologies that have been validated in clinical practice across diverse healthcare settings worldwide.[22,23] The CCC system better captures the overall nursing process through the coding of free-text documentation in EMRs[23–25] and can be effectively leveraged to improve the visibility of nurses' concerns.[9,19,25] Although nursing documentation has gained increasing attention, prior studies have not clarified how nurses' concerns, as early indicators of patient deterioration, can be standardised or preserved the semantic hierarchy of the CCC.

The aims of this study are to standardise the unstructured intervention notes reflecting nurses' concerns by mapping them to CCC intervention codes and to provide a detailed mapping process while preserving the accuracy and consistency of the CCC framework. By leveraging the internationally validated CCC standards, this approach will enhance the visibility of nurses' concerns and provide a foundation for nursing researchers, practitioners, policymakers, and stakeholders to advance clinical decision-making support in ICU environments and to promote the exchange of nursing data across hospital EMR systems.

## 2. Methods

This study included a retrospective evaluation of EMRs recorded from previously treated ICU patients. The study was reported using the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cross-sectional studies. Fig. 1 depicts an overview of the mapping process.

### 2.1. Extraction of nursing intervention notes from Medical Information Mart for Intensive Care IV

This study utilised Medical Information Mart for Intensive Care (MIMIC) IV version 2.2, a publicly available database containing deidentified patient data from the Beth Israel Deaconess Medical Center from 2008 to 2019.[23] In MIMIC-IV, most nursing documentation consists of structured data (e.g., physiological indicators and Glasgow Coma Scale scores) and unstructured nursing care plans recorded as note entries, which record narrative descriptions of interventions, goals, expected outcomes, and outcome met. Among these, intervention notes describe nurses' activities, actions, or treatments.

To extract intervention notes (Fig. 2), we identified 17 587 757 nursing note entries from 39 904 ICU admissions, documented from admission to discharge in the relational table "chartevents". Researchers with ICU expertise reviewed these notes based on a conceptual framework of nurses' concerns regarding clinical deterioration[3]; 7 973 543 nonintervention notes were excluded, leaving 9 614 214 intervention-note entries from 39 711 admissions. Because many notes repeated identical content within the same ICU stay, 9 613 945 duplicate notes were removed. Ultimately, 269 unique nursing intervention notes were retained as the units of analysis.

### 2.2. Subject matter experts' review of nursing intervention notes based on nurses' concern

Through the extraction process shown in Fig. 2, 269 unique intervention notes were selected. These notes were reviewed by subject-matter experts (SMEs) to align them with predefined categories of nurses' concerns. The initial categories were derived from a comprehensive review of the literature, including signs and symptoms underlying nurses' worry or concern[1,4] and clusters of natural-language entities linked with concerns.[2,3,9,26] Items with overlapping or synonymous meanings were consolidated into broader categories. For example, descriptions such as back pain, chest pain, and headache were merged into "pain", and variations in respiratory changes such as abnormal breathing rate and effort of respirations were merged into "abnormal respiratory state". This process yielded 15 final concern categories: abnormal respiratory state, fluid volume alteration, monitoring, pain, infection, fall risk, circulatory deficit, abdominal discomfort, improper renal function, abnormal mental state, general concerns, abnormal heart rhythm, violent behaviour, abnormal temperature, and mood disorder. The definitions of these concern categories were primarily based on the CCC diagnoses reported in previous literature to identify the concept of nurses' concerns,[2,9,26] with additional categories (i.e., general concerns and monitoring) defined from signs and symptoms described in prior studies. Full definitions are presented in Table S1.

The SMEs comprised three research team members with extensive ICU experience and nursing informatics expertise. Two SMEs independently matched the unique intervention notes to the predefined concern categories. Notes judged as inappropriate by both SMEs were excluded, while disagreements were reviewed by the third SME. Consensus was reached based on their clinical expertise in critical care and the definitions of concern categories derived from the literature. Only notes deemed appropriate or ambiguous by consensus among the three SMEs were retained for the next step.

### 2.3. Validation of matching between nursing intervention notes and nurses' concerns

To assess whether the matches between intervention notes and nurses' concern categories were clinically relevant, we conducted an expert evaluation with a content validity assessment. Eligible participants were nurses with at least 3 years of experience in adult ICUs at tertiary hospitals. To select a representative group of experts who were able to fully understand the purpose of this study and appropriately conduct the validity evaluation, we purposively recruited ICU nurses who had participated in a prior qualitative study[32] and voluntarily agreed to participate. Considering that clinical expertise and patient care settings (medical vs. surgical ICU) may influence nurses' perspectives on nursing

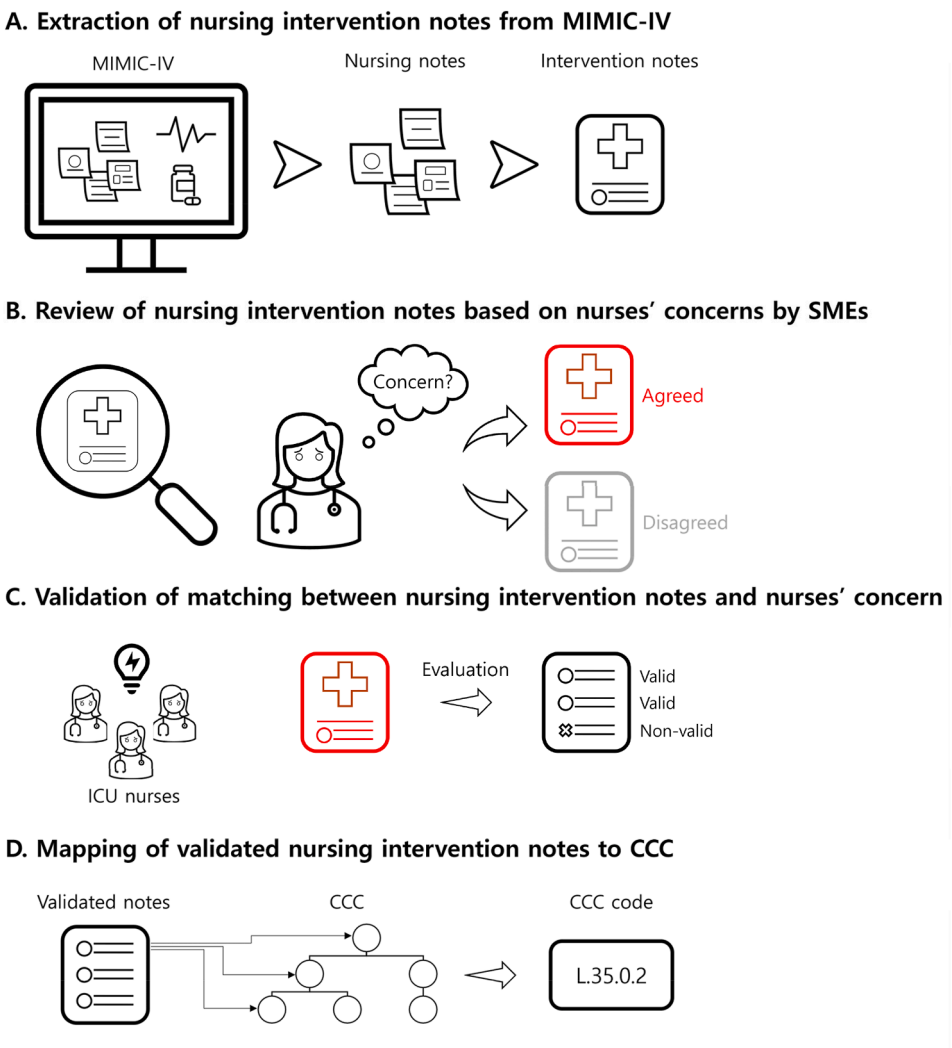


**Fig. 1. Overview of the overall mapping process.** The overall mapping process involves (A) extracting nursing intervention notes from MIMIC-IV, (B) reviewing them by SMEs based on nurses' concerns, (C) validating the matches between the intervention notes and nurses' concern categories through the evaluation of ICU nurses, and (D) mapping the validated intervention notes to the CCC terminologies. CCC: Clinical Care Classification, MIMIC-IV: Medical Information Mart for Intensive Care IV, SMEs: subject-matter experts.

concerns,[1–3,7] we further recruited participants through snowball sampling. Participants rated the clinical relevance of the matches on a four-point scale (1 = not valid, 2 =somewhat valid, 3 = quite valid, and 4 = highly valid) and were invited to provide free-text comments. They remained blinded to the SME judgements from the preceding stage.

The item content validity index (I-CVI) was calculated, and values of 0.78 or higher were considered indicative of acceptable validity.[27] In cases where a note was mapped to multiple concern categories, the highest-priority category related to ICU patient deterioration was determined through consensus among the SMEs, based on prior literature, participants' qualitative comments, and the intended use of categories in a subsequent prediction model.

### *2.4. Mapping of validated nursing intervention notes to the Clinical Care Classification*

We used the CCC system version 2.5 (https://clinicalcareclassification.org/) to map the unique intervention notes that matched the highest-priority-concern category to CCC terms. The CCC provides a standardised framework to document nursing practices in EMRs.[23] This framework has a hierarchical structure that consists of, from top to bottom, healthcare patterns, care components, nursing terminologies (nursing diagnoses, interventions, and outcomes), and qualifiers. Each nursing intervention is coded using a five-character alphanumeric system, in which the first character represents the care component (e.g., A for Activity); the next two or three digits denote the specific nursing intervention concept (e.g., A.02); and the final digit indicates one of the four action types, such as monitoring, performing, teaching, or managing (e.g., A.02.1).

Figure S2 illustrates the process of selecting unique intervention notes, matching them to nurses' concern categories, and mapping them to CCC terms. Unique intervention notes assigned to the highest-priority-concern category were mapped using the coding structure of the CCC system.[23] Two SMEs independently mapped each note to CCC terms based on the CCC term definitions. Inter-rater agreement was assessed using Cohen's kappa coefficient, where 0.61 and 0.80 indicated substantial agreement and >0.80 indicated almost perfect agreement.[28] Disagreements were reviewed with the third SME, and consensus was reached by selecting the CCC-term definition that best fit each unique intervention note.

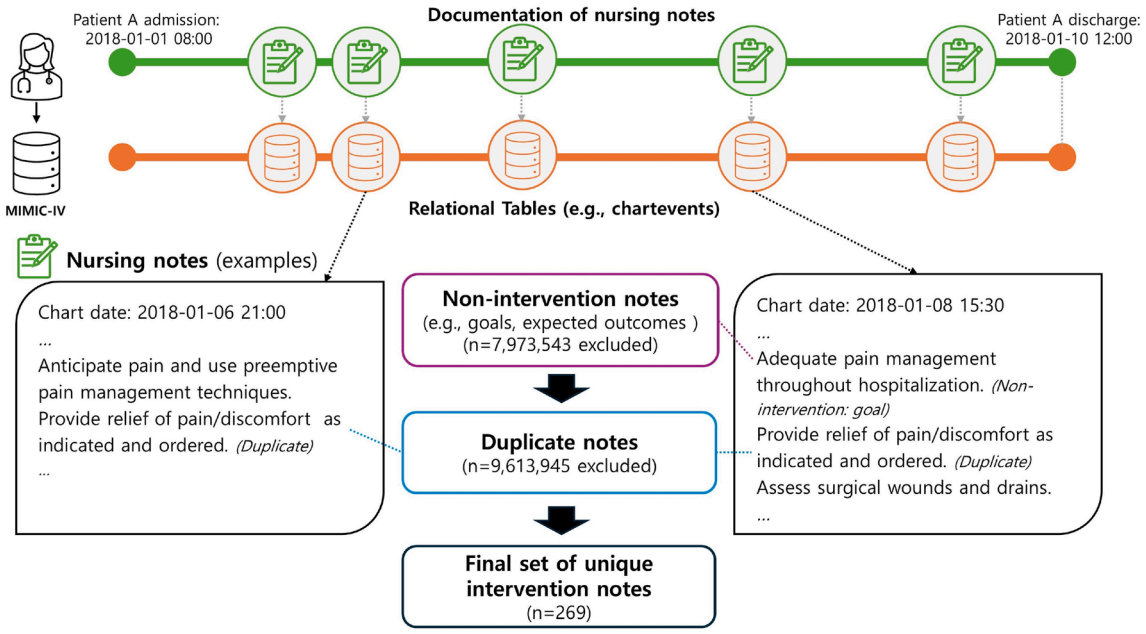


**Fig. 2. Extraction process of intervention notes in MIMIC-IV.** Nursing notes documented during ICU stays were reviewed, and non-intervention and duplicate notes were excluded. This process yielded 269 unique intervention notes as units of analysis, with examples illustrated for clarity. ICU: intensive care unit, MIMIC-IV: Medical Information Mart for Intensive Care IV.

### *2.5. Ethical consideration*

This study utilised two data sources with different ethical considerations. First, all MIMIC-IV database data were deidentified and informed consent was waived by the Institutional Review Boards (IRBs) of the Massachusetts Institute of Technology and Beth Israel Deaconess Medical Center. A researcher (Yeo.K) completed the required ethics training and obtained authorised access (certificate number: 56165614). Second, for the validity evaluation survey conducted among nurses in South Korea, informed consent was obtained from all survey participants after receiving ethical approval from the IRB of Yonsei University Health System (IRB Approval No. 4-2023-1542). All procedures were conducted in accordance with IRB guidelines.

## 3. Results

### *3.1. Extraction of nursing intervention notes from Medical Information Mart Intensive Care-IV*

Of 17 587 757 nursing note entries, a total of 9 614 214 intervention-note entries from 39 711 ICU admissions were identified, as shown in Fig. 2. Table 1 presents the characteristics of intervention-note entries and ICU admissions. The mean age of patients was 62 years (standard deviation: 16.74), and approximately two-thirds of ICU admissions were women. Surgical ICU settings generated intervention-note entries (n = 4 100 256, 42.7%), which corresponds to ICU admissions (n = 17 882, 45.0%). Among the comorbidities, cardiovascular diseases such as myocardial infarction, congestive heart failure, and peripheral vascular disease included intervention-note entries (n = 1 027 323, 10.7%) and ICU admissions (n = 4103, 10.3%). Approximately two-thirds of intervention-note entries were documented from nonsurgical patients.

After duplicate inputs were removed from each intervention-note entry, 269 unique intervention notes were identified for subsequent analysis.

### *3.2. Subject matter experts' review of nursing intervention notes based on nurses' concern*

Of the 269 unique intervention notes, those inappropriately matched based on the definitions of concern categories were excluded, resulting in 117 unique intervention notes. These 117 notes were matched to the 15 concern categories, yielding a total of 208 matches.

### *3.3. Validation of matching between nursing intervention notes and nurses' concerns*

To evaluate the clinical validity of the 208 matches between 117 unique intervention notes and 15 concern categories, a total of 34 ICU nurses participated in the evaluation. They had a mean ICU experience of 7 years (standard deviation: 4.10) across six tertiary hospital settings. Most of them worked in medical (n = 22), surgical (n = 8), and mixed (n = 4) ICUs.

The median I-CVI of the 208 matches was 0.97, with an interquartile range of 0.91–1.00 (S3 Table). Among the 117 unique intervention notes included in the 208 matches, five notes showed an I-CVI of less than 0.78 and were excluded from the final set. The two notes exhibited heterogeneity in I-CVIs, being considered valid in some nurses' concern categories and invalid in others. One example was *Use short sentences and ask only one question at a time*, which was invalid in the abnormal mental state category but valid in the general concern category. Another example was *Implement interventions for angioedema*, which was invalid in the abnormal respiratory state category but valid in the abnormal heart rhythm category. These notes were excluded from the final set based on the comments obtained from ICU nurses. Three notes—*Speak slowly and distinctly, repeat key words to avoid confusion*; *Supplement verbal communication with meaningful gestures*; and *Obtain swallow consults*—were also excluded. Consequently, a total of 107 unique intervention notes were considered clinically relevant. By comprehensively considering the definitions of concern categories and participants' comments, these notes were matched to the highest-

**Table 1**
Characteristics of intervention-note entries and ICU admissions.

| Category | Intervention-note entries (n = 9 614 214) | ICU admissions (n = 39 711) |
|---|---|---|
| ICU type, n (%) | | |
| Medical | 3 059 056 (31.8) | 12 970 (32.7) |
| Surgical | 4 100 256 (42.7) | 17 882 (45.0) |
| Mixed | 2 454 902 (25.5) | 8859 (22.3) |
| Comorbidity, n (%) | | |
| Cardiovascular | 1 027 323 (10.7) | 4103 (10.3) |
| Metabolic | 579 702 (6.0) | 1933 (4.9) |
| Renal | 550 151 (5.7) | 2117 (5.3) |
| Gastrointestinal/hepatic | 447 168 (4.7) | 1242 (3.1) |
| Neurological/cognitive | 364 902 (3.8) | 1058 (2.7) |
| Malignant | 132 902 (1.4) | 425 (1.1) |
| Musculoskeletal | 46 357 (0.5) | 225 (0.6) |
| Respiratory | 41 080 (0.4) | 88 (0.2) |
| Surgery, n (%) | | |
| Yes | 3 981 192 (41.4) | 16 967 (42.7) |
| No | 5 633 022 (58.6) | 22 744 (57.3) |

The ICU type category is classified as medical (including medical and cardiac ICUs), surgical (including surgical, cardiovascular, trauma, and neurosurgical ICUs), and mixed (a combination of medical and surgical ICUs). The comorbidity category was counted multiple times using International Classification of Diseases (ICD)-9 and ICD-10 diagnosis codes. The surgery category was counted using the medical services provided on admission to the ICU; ICU: intensive care unit.

priority concern category for clinical deterioration among ICU patients. The resulting matches accounted for duplicate inputs repeatedly documented in MIMIC-IV, and Fig. 3 presents the distribution of intervention note entries across the 15 concern categories. The largest proportion corresponded to abnormal respiratory state (1 201 218/4 819 327; 25.0%), followed by fluid volume alteration (15.7%), monitoring (12.7%), pain (11.2%), and infection (8.5%).

### *3.4. Mapping of validated nursing intervention notes to the Clinical Care Classification*

A total of 107 unique intervention notes, matched to the highest-priority-concern category, were mapped to CCC terms according to the coding structure. Table S4 presents examples of CCC mapping based on nurses' concern categories. For example, the intervention note *Encourage cough and deep breathing* was mapped to the care component "L, Respiratory", assigned the intervention code "36.0, Pulmonary Care", and then refined to the subintervention code "36.1, Breathing Exercise", producing L.36.1. Finally, the action-type qualifier code "3, Teach/Educate/Instruct/Supervise" was linked, resulting in the CCC intervention code "L.36.1.3".

The inter-rater agreement between the two SMEs demonstrated substantial agreement (Cohen's kappa = 0.82, 95% confidence interval: 0.73–0.91). After resolving discrepancies through consensus with the third SME, 63 CCC intervention codes were finally identified.

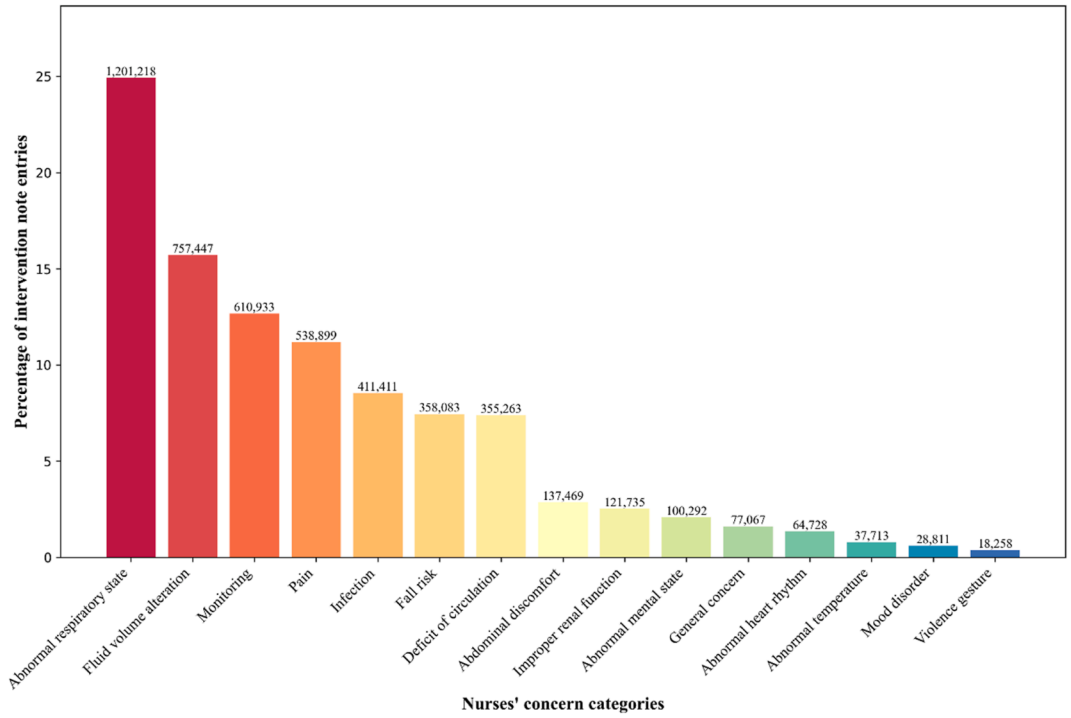


**Fig. 3. Distribution of intervention-note entries by nurses' concern categories.** Numbers above the bars indicate the total counts of intervention-note entries for each category of nurses' concern. Percentages were calculated using the total number of intervention-note entries (n = 4 819 327). Counts were derived from the matches between 107 unique intervention notes and their highest-priority-concern category, with duplicate-note inputs removed.

Table 2 presents examples of the CCC hierarchical structure of finalised intervention codes for each nurses' concern category, while Table S5 provides extended details, including the hierarchical matches of the 63 finalised CCC codes across the 15 concern categories and the distribution of 107 unique intervention notes and 4 819 327 intervention-note entries. The finalised CCC intervention codes comprised 17 care components, 49 interventions/subinterventions, and four action-type qualifiers. The finalised set of 63 CCC intervention codes included four codes that appeared more than once (e.g., G.21.0.4, T.73.0.1, K.31.0.2, and N.42.1.2). To avoid double-counting, these duplicates were aggregated and counted only once. Table S5 shows respiratory-related matches accounted for the largest proportion of intervention-note entries, followed by fluid-volume alteration and monitoring-related matches.

Based on the CCC hierarchy, action-type qualifiers indicated that direct care–based action (i.e., monitor/assess/evaluate/observe, perform/direct care/provide/assist, and teach/educate/instruct/supervise) were broadly represented across the 63 CCC intervention codes, whereas indirect care–based actions (i.e., manage/refer/contact/notify) were rarely observed. Intervention-note entries were most frequently mapped to the physical regulation component (1 510 974/4 819 327; 31.4%), followed by the respiratory (12.6%), fluid volume (12.0%), sensory (10.7%), and safety (7.8%) components (Table S5, Figure S6).

Figure S7 illustrates the proportions of care components according to nurses' concern categories. Most abnormal respiratory state cases were mapped to both respiratory and physical regulation components, whereas fluid volume alterations were predominantly mapped to the fluid-volume component. Pain was almost exclusively linked with the sensory component, while fall risk and violent gesture were mapped only to the safety component.

## 4. Discussion

This study demonstrated how ICU nurses' concerns can be transformed into standardised nursing terms through the mapping of unstructured intervention notes to the CCC hierarchical structure. A total of 63 standardised intervention codes were identified, reflecting that ICU nurses' primary concerns centred on respiratory- and fluid-related clinical deterioration, which were predominantly addressed through direct nursing care. Moreover, several CCC components were shared across multiple categories of nurses' concerns, highlighting the interconnected nature of nursing practice.

In our study, ICU nurses' primary concerns were mapped to respiratory- and fluid-related deterioration, conditions that often deteriorate rapidly and necessitate prompt recognition and timely intervention to prevent further complications.[29,30] This finding is consistent with previous studies showing that nursing documentation in the EMR was frequently mapped to breathing pattern impairment, gas exchange impairment, respiration alterations, and fluid loss or overload.[9,18] Such concerns may be attributed to the tendency of ICU nurses to perform optimal clinical judgement in delivering the most essential interventions to prevent clinical deterioration.[31]

Beyond simple frequency counts, the mapped concern categories may provide actionable clinical insights that inform decision-making. For example, when a patient reports dyspnoea accompanied by decreased oxygen saturation, the nurse needs to determine the underlying cause of hypoxia. If the EMR system highlights an increasing pattern of mapped respiratory- and fluid-related concerns, the nurse may be prompted to consider fluid overload as a potential contributor. Such insights can extend nursing actions beyond immediate respiratory assessment to include evaluating fluid balance, reviewing intake and output, checking body weight, and confirming pulmonary congestion through chest radiography. These clinically relevant insights could serve as a critical foundation for future work aimed at predicting clinical deterioration in critically ill patients and developing clinical decision support tools, such as early warning systems.

This study presents the CCC system in detail, from care components to action-type qualifiers, according to the hierarchical structure constituting the finalised intervention codes. In particular, the action-type qualifiers serve as verb phrases that represent different aspects of nursing services, enabling the conversion of intervention notes into standardised terminology.[23] In our findings, the action-type qualifiers of the finalised CCC intervention codes were primarily connected with ICU nurses' concerns related to direct nursing care, such as observing and evaluating patient conditions and providing therapeutic actions, whereas indirect nursing care was infrequently identified. This may suggest that indirect nursing care was under-represented in EMR documentation because it may have been omitted, was difficult to capture, or was documented in alternative documentation formats.[32]

The resulting mapping hierarchy, which delineates the multifaceted components of the care process within the CCC system,

**Table 2**
Examples of the hierarchical structure of finalised CCC intervention codes across nurses' concern categories.

| Nurses' concern | CCC | | | |
|---|---|---|---|---|
| Category | Care component, letter | Intervention/subintervention | Action-type qualifiers | Finalised intervention codes |
| 1. Abnormal respiratory state | Physical regulation, K | Respiration | 1 | K.33.4.1 |
| 2. Fluid volume alteration | Fluid volume, F | Fluid therapy | 2 | F.15.0.2 |
| 3. Monitoring | Physical regulation, K | Clinical measurements | 1 | K.31.4.1 |
| 4. Pain | Sensory, Q | Pain control | 2 | Q.47.0.2 |
| 5. Infection | Physical regulation, K | Infection control | 3 | K.30.0.3 |
| 6. Fall risk | Safety, N | Safety precautions | 2 | N.42.0.2 |
| 7. Deficit of circulation | Tissue perfusion, S | Circulatory care | 1 | S.70.0.1 |
| 8. Abdominal discomfort | Bowel/gastric, B | Bowel care | 1 | B.06.0.1 |
| 9. Improper renal function | Urinary elimination, T | Haemodialysis care | 2 | T.59.1.2 |
| 10. Abnormal mental state | Cognitive/neuro, D | Neurological system care | 2 | D.78.0.2 |
| 11. General concern | Health behavioural, G | Speech therapist service | 4 | G.21.6.4 |
| 12. Abnormal heart rhythm | Cardiac, C | Cardiac care | 2 | C.08.0.2 |
| 13. Abnormal temperature | Physical regulation, K | Temperature | 2 | K.33.2.2 |
| 14. Mood disorder | Self-care, P | Mental health promotion | 2 | P.45.2.2 |
| 15. Violence gesture | Safety, N | Environmental safety | 2 | N.42.1.2 |

Table 2 is extended with detailed information in S5 Table. Action-type qualifiers are classified by four categories (1 = monitor/assess/evaluate/observe; 2 = perform/direct care/provide/assist; 3 = teach/educate/instruct/supervise; 4 = manage/refer/contact/notify); CCC: Clinical Care Classification.

offers a valuable methodological resource for future integration of the CCC structure into EMRs.[23,33] Moreover, it holds the potential to support nursing policy through CCC-based mapping by enabling the exchange of standardised nursing data across institutions nationally and globally via the adoption of validated CCC standards.[25,34,35]

Our study revealed the commonly mapped CCC intervention codes and their corresponding care components across nurses' concern categories, consistent with previous studies.[9,36] The overlapping CCC mappings across concern categories can be utilised in future research to explore distinct concern clusters, reflecting the interconnected nature of nursing interventions.

This study has several limitations. First, the intervention notes were documented at the sentence level, which limited the availability of contextual details during CCC mapping. To mitigate this, we supplemented the mapping with concern categories defined based on prior literature. Furthermore, ICU nurses from multiple institutions reviewed the mapped intervention notes for clinical relevance based on their professional expertise and practical experience. This process helped integrate literature-based nursing knowledge with practice-based expertise; nevertheless, some contextual loss remains unavoidable. Second, while matching intervention notes to nurses' concern categories and mapping them to CCC intervention codes, we focused on prioritised nurses' concerns. This approach may introduce bias, such as variability arising from subjectivity in standardised terminology mapping influenced by SMEs' clinical judgement. To enhance reproducibility, future studies should incorporate iterative reliability evaluations among SMEs and establish consensus building across hospitals and disciplines. This would ensure that diverse ICU workflows and practices are better represented.

Third, the intervention notes containing context-specific details were often mapped to broader, higher-level CCC concepts. More precise mapping between real-world ICU documentation and CCC terminology may require expanding CCC terminology with context-specific extension terms. Fourth, because the intervention notes of MIMIC-IV were drawn from a single U.S. academic hospital, the findings may have limited generalisability and transferability. Documentation practices in such ICUs are shaped by high workload and structured EMR designs to support efficiency[37,38] which may differ substantially from practices in community hospitals or other healthcare systems. Transferability across diverse EMR systems and data-exchange contexts may also be constrained by variations in system design and documentation practices. Fifth, duplicate intervention notes with identical text content were removed to retain only unique descriptions, which may have limited the representativeness of the final dataset.

## 5. Conclusion

This study identified structured, standardised intervention codes using the CCC hierarchical framework. By integrating theoretical concepts with practical insights, the mapping process aimed to ensure the accurate capture of nurses' concerns aligned with clinical scenarios. These findings contribute to transforming nurses' concerns into quantifiable nursing data, facilitating data exchange across healthcare settings and generating real-world evidence to enable the prediction clinical deterioration in nursing practice.

## CRediT authorship contribution statement

**Yeonju Kim**: Conceptualisation, Methodology, Formal analysis, Investigation, Data curation, Resources, Visualisation, Writing – Original Draft, Writing – Review & Editing.

**Yesol Kim**: Conceptualisation, Methodology, Formal analysis, Validation, Data curation, Writing – Review & Editing.

**Mona Choi**: Conceptualisation, Methodology, Validation, Supervision, Resources, Writing – Review & Editing, Project administration, Funding acquisition.

All authors have approved the final version of this manuscript.

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## Data availability statement

The dataset used in this study is from a publicly available Medical Information Mart for Intensive Care IV database provided by the Massachusetts Institute of Technology. Access to Medical Information Mart for Intensive Care IV requires completion of the Collaborative Institutional Training Initiative program and adherence to the data use agreement. The dataset related to the survey of intensive care unit nurses analysed in this study is available upon reasonable request to the authors.

## Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Declaration of generative AI and AI-assisted technologies in the writing process

We declare that artificial intelligence and artificial intelligence–assisted technologies were utilised as tools to improve readability and clarity of the manuscript.

## Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aucc.2025.101518.

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