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CONTINUING EDUCATION

2.4 ANCC Contact Hours

Features of Computerized Clinical Decision Support Systems Supportive of Nursing Practice

A Literature Review

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This study aimed to organize the system features of decision support technologies targeted at nursing practice into assessment, problem identification, care plans, implementation, and outcome evaluation. It also aimed to identify the range of the five stage-related sequential decision supports that computerized clinical decision support systems provided. MEDLINE, CINAHL, and EMBASE were searched. A total of 27 studies were reviewed. The system features collected represented the characteristics of each category from patient assessment to outcome evaluation. Several features were common across the reviewed systems. For the sequential decision support, all of the reviewed systems provided decision support in sequence for patient assessment and care plans. Fewer than half of the systems included problem identification. There were only three systems operating in an implementation stage and four systems in outcome evaluation. Consequently, the key steps for sequential decision support functions were initial patient assessment, problem identification, care plan, and outcome evaluation. Providing decision support in such a full scope will effectively help nurses' clinical decision making. By organizing the system features, a comprehensive picture of nursing practice–oriented computerized decision support systems was obtained; however, the development of a guideline for better systems should go beyond the scope of a literature review.

KEY WORDS

Computerized clinical decision support systems • Features • Nursing care • Sequential decision support

According to the Institute of Medicine,[1] the development and implementation of more sophisticated information systems are essential not only to enhance quality and efficiency of patient care but also to support clinical decision making. Clinical decision support becomes more and more a core function of health information systems to eliminate preventable medical errors,[2] and the investments in decision support technologies targeted at nursing practice have increased.[3] A computerized clinical decision support system (CDSS) refers to any electronic system designed to aid directly in clinical decision making. To generate patient-specific recommendations, CDSSs use the characteristics of individual patients; these recommendations are then presented to nurses for consideration.[4,5] The knowledge base embedded in CDSSs contains the rules and logic statements that encapsulate knowledge required for clinical decisions so that it generates tailored recommendations for individual patients.[6] With this, CDSSs assist nurses in completing the knowledge base rule–driven decision making or standardized rule-driven decision making,[7] instead of using their own biases and intuition.[8–10] On the one hand, CDSSs applied to nursing care are an expansion of the CDSS prototype defined above. For example, CDSSs for nursing care provide prebuilt forms for data entry of patient assessment, care plans, or outcome evaluation on given nursing interventions.[8] Although it is not the case of recommendations automatically generated by the algorithm, the predesigned forms help decision making for nurses because these present the full scope of components that should be included for related nursing care activities. Thus, CDSSs for nursing care in this study include all the CDSS prototypes and the expanded versions.

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The author has disclosed that she has no significant relationships with, or financial interest in, any commercial companies pertaining to this article.

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DOI: 10.1097/01.NCN.0000432127.99644.25

Because using CDSSs to support nurses' decision making is widespread, it is worth capturing which features of CDSSs were empirically effective for optimum decision support for frontline nurses. Currently, there are studies on CDSSs used to improve the clinical practice of nurses; however, system features addressing particular nursing care activities have been dispersed in individual reports. Nursing does not have the well-organized knowledge base on the features of nursing practice–oriented CDSSs in real practice settings. The purpose of this study was to organize the features of CDSSs useful for nursing practice through a literature review, especially using the categories of assessment, problem identification (ie, diagnosis), care plans, implementation, and outcome evaluation. The current decision support technologies typically operate in these five stages. A certain CDSS helps decision making in a single stage, while other CDSSs help decision making in two or more stages. However, because of a lack of empirical investigations, it has not been clear whether a CDSS providing decision support in all the stages from assessment to outcome evaluation was more clinically useful than a CDSS operating, for example, in only a single stage of assessment. If there are evidential data to answer this question, the evidence should be included as an important feature for better decision support. As a preliminary to conducting an empirical study to address the question above, the first priority was in conducting a literature review to identify to the extent of sequential decision support provided by CDSSs in the stages from assessment to outcome evaluation. In this study, the sequential decision support, which is another important concept, is one of the CDSS features.

METHODS

Studies Eligible for Review

To obtain the most relevant studies, studies eligible for inclusion were primary studies on CDSSs used for nursing practice and designed to contain at least two aspects of assessment, problem identification, care plans, implementation, and outcome evaluation. Studies published in peer-reviewed journals and in English were included. On the other hand, studies were excluded if they were studies on a nonelectronic decision support system such as a paper-based system, studies not providing a description on a CDSS, and studies providing only a technical description of a CDSS application (ie, testing algorithms of an application). Review studies on CDSSs were also excluded.

Data Sources

Databases of MEDLINE, CINAHL, and EMBASE were searched up to 2012 by using the search terms *computer-assisted decision support system*, *automated decision support*, *computerized evidence-based decision making*, *computerized evidence-based practice*, and *evidence, decision support system*, having *nursing* in common. Conference proceedings and the reference lists of all included articles were reviewed to identify additional primary studies.

Study Selection

The author reviewed titles and abstracts of identified references and rated each article as "potentially relevant" or "not relevant" by using the inclusion and exclusion criteria. The author reviewed the full texts of potentially relevant primary studies and again rated each article as "potentially relevant" or "not relevant" using a screening checklist. Thus, the final selection of studies for review was made. A screening checklist was to check the presence or absence of and appropriateness of data that should be extracted from studies. Its content is identical to a data extraction form for double-checking (see "Data Extraction" section). Use of the checklist prevented important data from inadvertently being omitted. Before actual use of the checklist, the author piloted it on a sample of three articles to address the issues of arranging the checklist items in user-friendly sequence and completing the checklist.[11]

Data Extraction

The author extracted necessary information from each of the finally selected articles by using a data extraction form. The form was to record study purpose, study design, data collection methods, study settings and participants, nursing care areas addressed by the use of a CDSS, functions of a CDSS, study results, and features of a CDSS. The functions of a CDSS were categorized into assessment, problem identification, care plans, implementation, and outcome evaluation. A CDSS was considered having the functions of the stages from assessment to outcome evaluation: when a CDSS had preformulated forms for data entry that are embedding evidence to support clinical decision making relating from assessment to outcome evaluation, when the rule engine of a CDSS automatically generated recommendations or instructions for a next action based on data entered in a prior step, or when the sections from assessment to outcome evaluation were automatically linked to each other for a logical continuity of clinical decision making and then relevant data have to be entered in a prebuilt form or selected from a prebuilt list. For example, if an assessment entry form existed, the CDSS had the function for patient assessment. If care plans were automatically generated based on assessment data entered, the CDSS had the functions of assessment and care plans. When a set of care plans was linked to patient outcome evaluation and then an outcome measurement

form should be filled out, the CDSS had the functions of care plans and outcome evaluation. Study results are any changes by the use of a CDSS. These would include improvement or nonimprovement in terms of, but not limited to, nurses' decision making, nurse performance, and patient outcomes.

As the features of CDSSs, components of CDSSs that improved nurses' decision making, nurse performance, or patient outcomes were extracted. If some components deteriorated them (eg, "the need to devise care plans made nurses spend much time"), the author treated the logically opposite component as a potential improvement component (eg, "removing the need to devise care plans made nurses save time").[12,13] In addition, if authors of studies mentioned important features of their CDSS, the features were also included here. The functions of CDSSs mentioned above were integrated as part of the features of CDSSs. The author recorded extracted information on the data extraction form and also double-checked extracted information with original articles for accuracy.

Data Analysis

The extracted data, including study purpose, design, data collection methods, settings and participants, nursing care areas addressed by the use of a CDSS, functions of a CDSS, and study results, were organized in tables. To synthesize CDSS features across the reviewed studies, the author carefully read and compared the features extracted from each study and divided them into meaning units. The meaning units were assessment, problem identification, care plans, implementation, and outcome evaluation. The author integrated or separately organized the features into key words and phrases capturing core content of each unit. The synthesized results were organized in a separate table.

RESULTS

Of 681 potentially relevant studies published from 1990 to 2012, 27 studies met the eligibility criteria and the items on the screening checklist. The study description in Table 1 combines study purpose, design, data collection methods, settings, and participants. Table 2 presents a summary of Table 1, which includes study purpose, design, data collection methods, CDSS-applied nursing care areas, and sequential decision support functions of CDSSs. Of the 27 studies reviewed, 17 were system development, and eight of the 17 studies piloted their system immediately after system development (Table 2). In the study purpose of Table 2, others included two studies examining barriers to use of computerized advice[6,26] and a study evaluating completeness of nursing documentation.[19]

The designs of 20 studies that conducted system evaluation or pilot test, except for seven studies of system development only, varied (Table 2). When considering the presence of a CDSS as the given intervention, 15 studies, which were mostly pilot tests, were posttest studies without a control group. Two pretest-posttest studies used different groups for comparison before and after system use. Four studies used a one-group pretest-posttest format. Also included were a quasi-experimental study with two nonrandomized control groups and a randomized controlled trial. Three studies used two different designs for their system evaluation or pilot test[7,25,34]; thus, they were counted twice in the design. Data collection methods used in the 20 studies for system evaluation or pilot test were individual interviews, focus group interviews, observations, chart review, analysis of screen usage, questionnaires for nurses and other healthcare providers, and questionnaires for patients. Eight studies collected data by mixed methods; three studies, by quantitative methods; and nine studies, by qualitative methods.

Nursing care areas addressed by the use of a CDSS varied; however, fall, pressure ulcer, pain, blood glucose control, and patient referral overlapped, as shown in Tables 1 and 2. Eighteen studies targeted a single area of nursing care, while nine studies covered multiple areas of nursing care. Two mobile-based decision support systems targeted multiple areas of nursing care (Table 2).

Table 1 presents the functions of CDSSs that provided decision support in the stages available from assessment to outcome evaluation. The reviewed CDSSs showed the diverse ranges of sequential decision support functions. Sequential decision support for patient assessment and care plans existed in all of the reviewed CDSSs (Table 2). With reference to the sequence, movement to a next stage such as from assessment to problem identification or to care plans occurred as a next screen automatically showed up or was clicked after completion of a prior stage; a nurse was forced to implement the movement. Two studies' assessment entry forms were to assess patients' responses to treatments (ie, patient outcomes),[34,35] instead of initial assessment for patients (Table 1). Most CDSSs started their function for patient assessment with a nurse's entry in an electronic assessment form (Table 2). Five CDSSs started their function as they automatically retrieved necessary data from hospital databases or other connected information systems and a nurse inputs additional information. Three CDSSs were a real-time system for patient assessment,[23,29,37] and two of them were tele-advice systems.[29,37] Two CDSSs automatically assessed patients without input of a nurse (Table 2).[23,29] For the details of CDSS functions from problem identification to outcome evaluation, see Table 1.

Table 1 presents the study results on patient outcomes, nurse performance, and nurses' decision making by the use of CDSSs. The CDSSs were of benefit to patients and nurses as they improved patient status in the

Table 1

Characteristics of the 27 Studies Reviewed—Part 1

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Single nursing care area				
Delirium care				
Fick et al (2011)[14]	Pilot study for feasibility (1) using questionnaires for 15 patients and their caregivers in a medical-surgical unit and (2) by analysis of screen uses and 34 nurses' feedback at an acute care hospital in the central Pennsylvania region	A decision support system for delirium superimposed on dementia within the electronic medical record (EMR)	A: Delirium is assessed by the system with a nurse's input and delirium-associated data automatically pulled from other electronic records. P: Presence of delirium is triggered by the system.[a] C: Individualized nonpharmacological care plans for the management and prevention of delirium are generated by the system.	93% of patients improved or stayed the same on their mental health scores from admission to discharge. Overall, nurses did not have problems in using the system.
Fall-injury management				
Browne et al (2004)[15]	System development System evaluation by chart review after system use in all units at the Methodist Healthcare System of San Antonio in Texas	A computerized documentation system for fall risk stand-alone)	A: Fall risk is assessed by the system with a nurse's input. The system rates a risk score. P: Fall risk category–specific problems are generated by the system. C: Problem-specific care plans are generated by the system. Fall risk information is integrated into an interdisciplinary communication network including report sheets, care conferences, and audits until solved.	Fall and injury rates decreased but were not statistically significant at 6 mo after system use.
Bakken et al (2007)[16]	System development at the Columbia University Medical Center campus of Presbyterian Hospital in New York	A fall-injury risk management system within the hospital-wide information system	A: Fall-injury risk is assessed by the system with a nurse's input. The system rates a risk score. C: Institution-specific standard care plans are preselected and a nurse selects care plans from a drop-down box, based on a risk score.	

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Pressure ulcer management				
Quaglini et al (2000)[17]	System development Pilot study of feasibility by chart review for 40 patients in a general medicine ward	A system for pressure ulcer prevention and treatment within the electronic patient record (EPR)	A: Pressure ulcer risk is assessed by the system with a nurse's input and data automatically retrieved from the EPR. New inputs are required by pre-set time intervals. C: Care plans are generated by the system. Care plans can be overruled by entering a justification. I: Completion and noncompletion of care activities are entered at the end of a shift. Tasks not completed automatically go over to the next shift. E: Ulcer development is evaluated during every shift. New care plans are generated by the system. Every shift starts with new care plans.	Improved care plans, detailed documentation, and facilitating handing on noncompletion to a next shift were useful. More flexibility on risk assessment and setting action timings and minimizing data entrys time were required.
Clarke et al (2005)[18]	System development Pilot study for feasibility using questionnaires and qualitative data for nurses, mentors, experts in seven healthcare organizations (acute, home, intermediate, and extended care) in a Canadian urban health region	A decision support system for pressure ulcer prevention and treatment (stand-alone)	A: Pressure ulcer is assessed by the system with a nurse's input. C: Care plans are generated by the system. Nurses can revise the care plans.	The system increased knowledge about pressure ulcer prevention, treatment strategies, and resources required. Barriers were lack of administrative leadership, competencies on learning computer skills, implementing new guidelines, and technological deficiencies.
Gunningberg et al (2009)[19]	A study examining the quality and comprehensiveness of nursing documentation by chart review before and after system use in a surgical, medical, and geriatric unit at the Swedish University Hospital	A nursing documentation system for pressure ulcer within the electronic health record	A: Pressure ulcer is assessed by the system with a nurse's input. The system rates a risk score. C: Standard care plans are generated by the system. In addition, nurses were required to record nursing diagnosis, implementation of care plans, and evaluation of care. It was not part of the system.	There were significant improvements in quality and comprehensiveness of recording pressure ulcer after system use, although more improvement about recording was required.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Fossum et al (2011)[20]	System evaluation by a pretest-posttest study with nonequivalent control groups using questionnaires for 491 patients in 46 units at 15 nursing homes in four counties from rural areas in Norway	A decision support system for pressure ulcer and malnutrition prevention within the electronic health record	A: Pressure ulcer and nutrition are assessed by the system with a nurse's input. C: Patient-specific care plans are generated by the system.	The proportion of malnourished patients decreased in the intervention group using the system. Risk and prevalence of both pressure ulcer and malnutrition showed no difference between groups.
Pain management				
Im and Chee (2003)[21]	System development (19 nursing faculty members in oncology from 10 countries participated in e-mail discussions and an online survey to identify culturally sensitive pain descriptions)	A decision support system for cancer pain management (stand-alone)	A: Pain is assessed by the system with a nurse's input. The system computes the assessment result. C: Specific pain treatment strategies following the WHO recommendation are generated by the system.	
Huang et al (2003)[22]	System development Pilot study for feasibility by two test-retest studies using questionnaires for 24 patients with bone metastasis-related pain and using a focus group of four physicians	A decision support system for pain management (stand-alone)	A: Pain is assessed by the system with a patient's input. The system generates a single-page summary on pain assessment. C: Pain management notes are generated by the system.	The system was feasible and acceptable for patients and healthcare providers.
Body temperature monitoring				
Kroth et al (2006)[23]	System evaluation by a randomized controlled trial examining the effect of system use of bedside nursing staff in a medical-surgical unit at the Wishard Memorial Hospital in Indiana	A bedside system for temperature monitoring	A: Vital data are continuously measured and displayed by the bedside system. P: When a low temperature is identified, a warning pop-up window is generated by the system. C: Instruction to remeasure body temperature is generated by the system. The instruction can be overruled by selecting an ignoring reason from a menu or by typing a free text answer.	The system was effective for nurses in improving the accuracy of temperature collection at the bedside.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Blood glucose control				
Henry et al (1998)[24]	System development	A nursing documentation system for an initial visit of diabetes mellitus within the electronic health record.	A: The assessment screens for initial visit of diabetes mellitus are completed by a nurse's input. A nurse can make some changes in the assessment template. C: Care plans containing check boxes, blanks, and free-text entries within a structured text template are generated by the system. The system provides hyperlinks to resources for care plans.	
Vogelzang et al (2005)[25]	System development System evaluation (1) by chart review after system use and (2) a pretest-posttest study using questionnaires for nurses in a 12-bed surgical intensive care unit at a tertiary teaching hospital	A decision support system for insulin therapy linked to the central databases	A: Blood glucose is assessed by the system, with relevant data automatically retrieved from the central laboratory database and a nurse's input. C: A new insulin infusion rate and a next blood sampling time are generated by the system and stored in the hospital database. The recommendations can be overruled at any time. The main screen of the system shows the overview of glucose controls by applying different colors to the beds in the intensive care unit. Each bed on the screen is clickable to yield a more detailed information panel.	The system provided safe and efficient blood glucose control. Nurses' acceptance was high.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Sward et al (2008)[6]	A study examining reasons of declining computerized advice (1) by analysis of nursing records and (2) using questionnaires for 14 nurses in an adult intensive care unit at a tertiary care hospital	A decision support system for insulin therapy (stand-alone)	A: Blood glucose is assessed by the system with a nurse's input. C: A new insulin infusion rate is generated by the system. A nurse can refuse the recommendation by typing his/her reason for declining the recommendation or choosing reasons for decline from a drop-down list.	The recommendations were refused by related patient data, physician orders, nurses' disagreement, nurse workload, medication errors, patient or family requests, and software problems.
Campion et al (2011)[26]	A study examining barriers and facilitators to using computerized advice by observations and unstructured interviews for nurses in a 21-bed surgical and a 31-bed trauma intensive care unit at Vanderbilt University	A decision support system for insulin therapy linked to other hospital information systems	A: Blood glucose is assessed by the system with a nurse's input. P: Hypoglycemia or hyperglycemia is triggered by the system. C: An insulin order including dose, rate, and duration, and next glucose test time is generated by the system. Rationale for insulin recommendations is viewed on the same screen. The recommendation can be overruled.	Facilitators were trust in the system, nurse resilience, and paper serving as an intermediary between patient bedside and the system. Barriers were workload tradeoff between system use and direct patient care, inadequate user interfaces, and potential errors in operating medical devices.
Blood potassium control				
Hoekstra et al (2010)[7]	System evaluation (1) by chart review before and after system use in a 12-bed surgical and a 14-bed cardiothoracic intensive care unit and (2) using questionnaires for 76 nurses in intensive care units after system use at a tertiary academic center	A decision support system for potassium regulation linked to the central databases	A: Blood potassium is assessed by the system with a nurse's input and relevant data automatically retrieved from the central laboratory database. P: The value is categorized to hypokalemia, normokalemia, or hyperkalemia, and if abnormal, it is triggered by the system.	The system reduced the prevalence of hypokalemia and hyperkalemia. Nurses indicated improvement in potassium control by use of the system and a full compliance rate beyond 5 wk.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
			C: A potassium administration rate and a next blood sampling time are generated by the system. In case of extremely abnormal potassium values, the system prompts notification of the attending clinician. This can be overruled by nurses and physicians, and such instances are automatically recorded.	
Referral automation				
Heermann and Thompson (1997)[27]	System development Pilot study for feasibility by chart review for 19 transported neonates	A decision support system for stabilization of neonates before transport (stand-alone)	A: Neonate stability is assessed by the system with a nurse's input. C: Instructions to stabilize and prepare a neonate's condition before transport are generated by the system.	The system was safe and effective for neonate transport.
Guite et al (2006)[28]	System development Pilot study for feasibility by compliance audit, training scenario, and staff meetings and using a questionnaire for nurses in a surgical and a medical-surgical unit at the Christiana Care System in Delaware	A decision support system for automation of admission referral process within the electronic health record	A: Admission information is assessed by the system with a nurse's input using a wireless device at the patient's bedside and previous data automatically pulled from the hospital database. C: A list of all referrals with detailed information for each referral is generated by the system. The system sends electronic referrals to appropriate departments. I: Completion of the task is recorded by the referral departments. The original nurse identifies the completed task on screen.	The system simplified nursing work and led to more appropriate referrals to ancillary departments. Automatic retrieval of patient information by the system eliminated duplicate documentation.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Tele-advise system Adams et al (2003)[29]	System development	A tele-decision support system for children with persistent asthma linked to the EMR	A: A child is assessed by the system with automated telephone conversation responding to a child's/parent's call and asking a child/parent additional questions. P: When problems are identified during conversations, the system generates alerts and sends to tele-asthma nurses. C: Customized education and behavioral intervention are provided by the system and a tele-asthma nurse. Tele-conversation logs and tele-asthma nurses' case management are transferred to the EMR as a summary report and then physicians provide new orders based on it.	
Multiple nursing care areas Jirapaet (2001)[30]	System development Pilot study for feasibility by a one-group pretest-posttest study using questionnaires on case simulations given to 16 nurses in a neonatal intensive care unit at a tertiary care hospital	An expert system for mechanically ventilated neonate (stand-alone)	A: A neonate is assessed by the system with a nurse's input. The data entry form for assessment provides links to videos, pictures, tables, and graphs illustrating normal and abnormal neonatal data were for nurses' accurate data entry. P: Diagnoses are generated by the system by a click of a diagnosis button. C: Prebuilt care plans specific to the suggested diagnosis are generated by the system.	The system increased nurses' performance of diagnosis and managed care and nurses' information access and clinical judgment ability.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
			A nurse queries nursing activities under the care plans on the system. The system provides references on 21 topics of newborn critical care to guide neonatal intensive care unit nurses.	
Lee et al (2002)[13]	System evaluation by interviews with 12 nurses after system use in three respiratory intensive care units in Taiwan	A computerized nursing care plan system (stand-alone)	A: A nurse selects ones applicable from prebuilt patient assessment data. P: A nurse selects nursing diagnoses from NANDA on the system. C: The system lists standardized guidelines of care plans. Based on these, patient-specific care plans are selected or devised by a nurse's input. Each nursing diagnosis is evaluated every shift and care evaluation is documented on paper. It was not part of the system.	The system eliminated a need to write care plans by hand and provided standardized care guidelines. There was no consensus among nurses about diagnoses selected by them.
Keenan et al (2002)[31]	System development Pilot study for feasibility by chart review, and dialogue, focus group, and observations of nurses before and after NOC use in an ambulatory and two home care units in Michigan.	An automated nursing data system (stand-alone)	A, P, C, and E: The system is a Web-based application used to create care plans using the standardized terminologies, NANDA, NOC, and NIC. These terminologies are linked to each other and sequentially embedded in the system. A nurse selects appropriate things for care plans through sequential access to NANDA, NOC, and NIC. All the entries are stored and updated from admission to discharge. The system scores patient outcomes on both current and expected status.	Charting time on the system decreased. The process of documenting and information accessible were useful in planning and evaluating care.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
Kim et al (2007)[32]	System development at the Severance Hospital in Korea	A nursing diagnosis automation system within the EMR	A: A nurse selects ones applicable from prebuilt patient assessment data. The prebuilt assessment data were developed from nursing plans and activities that are done in real hospital settings. P: The system automatically presents nursing diagnoses from NANDA based on the selected assessment data. C: NANDA is linked to the NIC items. The nursing plans and activities done in real settings were located as a substructure of the NIC items. E: NANDA is linked to NOC. NOC is tied to nursing plans and activities that are done in real hospital settings.	
Kim et al (2007)[33]	System development Pilot study for feasibility by chart review of 1141 patients about activity tolerance from a medical, surgical, and intensive care unit at the Aurora Health Care in Wisconsin	A clinical documentation system for 22 nursing phenomena within the electronic health record	A: The structured assessment form is completed by a nurse's input. P: The problem is triggered and placed on the problem list by the system. C: Preformulated care plans for the triggered problem are generated by the system. Nursing activities are included in care plans. The system provides hyperlinks to references of care plans. I: Care activities are implemented and documented by a nurse. The triggered problem is automatically removed from the problem list.	The results indicated a need on the system redesign to adapt nurses' decisional workflow and increasing staff education.

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
			E: An outcome measurement form included in preformulated care plans is completed by a nurse. The system covers 22 nursing phenomena associated with activity tolerance, medication adherence, delirium, fall, sedation, fluid overload, venous thromboembolism, depression, discharge readiness, knowledge deficit on heart failure, intravenous infection, urinary tract infection, dyspnea, and health promotion with hypertension.	
Doran et al (2010)[34]	Pilot study for feasibility (1) using questionnaires, interviews, and observations for 30 nurses and seven other healthcare providers after system use and (2) by chart review for 38 patients before and after system use in two inpatient units at a large mental health facility in Canada	A computerized care planning system for mental health disorders and substance addictions (stand-alone)	A or E: Patient outcomes on treatments are assessed by the system with a nurse's input. Real-time feedback on the assessment is generated by the system. C: Best practice guidelines in a drop-down box are triggered by the system. A nurse selects or customizes care plans from guidelines. The system provides a hyperlink to sources of the practice guidelines.	Overall, users were satisfied with the system. There was a significant improvement in some patient outcomes, specifically, aggressive behavior, depression, withdrawal, and psychosis.
Doran et al (2007)[35]	System development (35 nurses from medical and surgical units of two hospitals and 16 nurses from two home care settings in Canada participated in focus group interviews and work sampling observations to identify nurses' information needs before development)	A PDA-based decision support system linked to the electronic health record	A or E: Patient outcomes on treatments are assessed by the system with a nurse's input. Real-time feedback on the assessment is generated through the PDA. C: Care plans from best practice guidelines are generated by the PDA. Benchmarking outcome	

(continues)

Table 1

Characteristics of the 27 Studies Reviewed—Part 1, Continued

Study	Study Description	CDSS	CDSS Functions of Assessment (A), Problem Identification (P), Care Plans (C), Implementation (I), and Outcome Evaluation (E)	Study Results on Patient Outcomes and Nurses' Performance and Decision Making
			achievement of similar patients is possible through the PDA. The best practice guidelines for assessment, prevention, and treatment on pressure ulcers, pain, dyspnea, and falls were developed as formats suitable for PDA use.	
Lee and Bakken (2007)[36]	System development at the Columbia University in New York	A PDA-based decision support system for depression, obesity, and smoking cessation (stand-alone)	A: The PDA's encounter screen and screening screen are completed by a nurse's input. One screening screen from the options of obesity, smoking, and depression is selected by a nurse. C: Five parts on the care plan screen are completed by a nurse's input. The five parts are diagnostics, procedures, medications, teaching and counseling, and referrals. They are displayed in drop-down boxes, and if not necessary based on entered patient data, they are automatically dim.	
Ernesäter et al (2009)[37]	System evaluation by semistructured interviews for eight tele-nurses after system use at three telephone call centers in Sweden	A tele-decision support system for triage and advice	A: A patient is assessed by the system with automated telephone conversation with a caller and additional input by a nurse asking relevant questions while hearing the conversation. C: Either visit to a health center or self-care advice is generated by the system. Tele-nurses can override the system by entering a justification.	The system was both supporting and inhibiting for tele-nurses. The system simplifies nurse work, complemented nurse knowledge, and enhanced nurse credibility. However, there were disagreements between nurses and advice by the system.

[a]A CDSS of each study.

Table 2

Characteristics of the 27 Studies Reviewed—Part 2

Characteristics: Number of Studies (Reference/s)
Study purpose
System development: seven (16, 21, 24, 29, 32, 35, 36)
System development and pilot: eight (17, 18, 22, 27, 28, 30, 31, 33)
System development and evaluation: two (15, 25)
System evaluation: five (7, 13, 20, 23, 37)
Pilot: two (14, 34)
Others: three (6, 19, 26)
Stand-alone CDSSs: 11 (6, 13, 15, 18, 21, 22, 27, 30, 31, 34, 36)
Design of pilot and evaluation studies (except seven studies of system development only)
Posttest without a control group: 15 (6, 7, 13–15, 17, 18, 22, 25–28, 33, 34, 37)
Pretest-posttest using different groups: two (19, 31)
One-group pretest-posttest: four (7, 25, 34, 30)
Pretest-posttest with nonequivalent control groups: one (20)
Randomized controlled trial: one (23)
Data collection methods of pilot and evaluation studies
Mixed methods: eight (6, 7, 14, 18, 22, 25, 28, 34)
Quantitative methods: three (20, 23, 30)
Qualitative methods: nine (13, 15, 17, 19, 26, 27, 31, 33, 37)
Nursing care areas addressed by CDSSs
A single area of nursing care: 18
Delirium care: one (14)
Fall-injury management: two (15, 16)
Pressure ulcer management: four (17–20)
Pain management: two (22, 21)
Body temperature monitoring: one (23)
Blood glucose control: four (6, 24–26)
Blood potassium control: one (7)
Referral automation: two (27, 28)
Tele-advice for asthma: one (29)
Multiple areas of nursing care: nine
Depression, obesity, and smoking (mobile based): one (36)
Pressure ulcer, pain, dyspnea, and fall (mobile based): one (35)
For mechanically ventilated neonates: one (30)
Mental health disorders and substance addition: one (34)
22 nursing phenomena (see Table 1): one (33)
All nursing care areas: three (13, 31, 32)
All nursing care areas (tele-advice): one (37)
Sequential decision support functions of CDSSs
Assessment, problem identification, and care plans: eight (7, 13, 14, 15, 23, 26, 29, 30)
Assessment, problem identification, care plans, and outcome evaluation: two (31, 32)
Assessment and care plans: 27 (all studies)
Assessment, care plans, and implementation: one (28)
Assessment, care plans, implementation, and outcome evaluation: one (17)
Assessment, problem identification, and care plans, implementation, and outcome evaluation: one (33)
Starting patient assessment
By a nurse's input: 18 (6, 13, 15, 16, 18–21, 24, 26, 27, 30–36)
By a nurse's input and automatic retrieval of data saved in other electronic systems or databases: five (7, 14, 17, 25, 28)
By real-time automatic collection of data: two (23, 29)
By real-time automatic collection of data and a nurse's input: one (37)
By a patient's input: one (22)

CDSS-applied nursing care areas,[7,14,15,20,34] improved nurses' work,[7,13,17,19,22,23,25,27,28,30,31] simplified nurses' work,[13,28,37] and complemented nurses' knowledge.[18,30,31,37] However, there were still problems in integration with nurses' workflow,[6,17,33] system flexibility,[17] user interface,[26] learning computer skills, and implementing

new guidelines.[18] Other problems were malfunctioning computer system issues, lack of administrative leadership,[18] and disagreement on system advice.[6,13,37]

In the studies of system development, because it was common that an interdisciplinary team participated in their system development, it was not described as study subjects in Table 1. As sources of knowledge embedded in decision support systems, all of the studies reviewed basically used scientific evidence such as nationally recognized clinical practice guidelines, randomized controlled trials, systematic review studies, literature review of other study designs, and topic-specific, valid assessment tools. The patterns and types of evidence used were similar among the studies.

The features of CDSSs across the studies are synthesized and organized in Table 3. The system features collected

Table 3

Features of Computerized Decision Support Systems Used for Nursing Practice

- Assessment (reference/s)
  - Providing a prepackaged entry form for accurate and comprehensive patient assessment (all studies)
  - Allowing selection of assessment data applicable to a patient from a prebuilt set (13, 32)
  - Automatically assessing a patient after input of a nurse and/or automatic retrieval of necessary data from other electronic systems/records or databases (all studies, except 13, 24, 31, 36)
  - Automatically transferring assessed data to the electronic medical record for an update (29)
  - Not having an assessment form that is too long to fill it out or to update it (34)
  - Generating some default values of assessment to eliminate the need of entry (17, 31)
- Problem identification/diagnosis (reference/s)
  - Automatically identifying and triggering a problem of a patient based on assessment data entered (7, 14, 15, 23, 26, 29, 30, 33)
  - Providing NANDA nursing diagnoses translated for cultural differences (13)
- Care plans (reference/s)
  - Providing evidence-based, standardized, and preprocessed recommendations/guidelines/protocols (all studies)
  - Generating problem-specific care plans based on assessment data (all studies, except 13, 16, 24, 31, 34, 36)
  - Allowing selection of tailored care plans from a drop-down box, a list or check boxes without the need to come up with them (13, 16, 24, 34, 36)
  - Providing recommendations with simple text explanation of the logic, instead of providing only instructions (6, 24, 26)
  - Providing entry space to customize care plans for a specific patient (13, 18, 24, 34, 37)
  - Not providing care plans that are too wordy and have too much text (22)
  - Allowing declination of suggested care plans by selecting reasons from a drop-down list or by typing free text answers (6, 7, 17, 23, 25, 26, 37)
  - Providing hyperlinks to sources of evidence-based guidelines/recommendations (24, 30, 33, 34)
  - Providing nursing activities under care plans (30, 32, 33)
- Implementation (reference/s)
  - Automatically putting tasks not completed into a next shift (17)
  - Showing completion of the planned referral for a patient (28)
  - Removing a solved problem from a problem list (33)
- Outcome evaluation (reference/s)
  - Providing a prebuilt form for outcome measurement on implemented care (17, 31, 33)
  - Generating new care plans based on evaluation (17, 34, 35)
- Others (reference/s)
  - Providing automatic links between CDSS functions (all studies)
  - Using structured (prebuilt) and standardized electronic formats (all studies)
  - Available at the point of care from any location (all studies)
  - Being used in a clinical routine (all studies)
  - Being integrated into nurses' workflow by allowing of access to CDSS functions at the point of care (all studies)
  - Being integrated into the nursing charting system as the necessary part of documentation, such as generating automatic documentation on care plans, instead of the extra part (15, 17, 24, 26, 28, 33)
  - Having simplicity of the entire routine to use CDSS, such as having fewer screens to access (7, 14, 28)
  - Using standardized terminologies in the forms for sharing data and care continuity among departments (16, 24, 28, 31, 33, 36)
  - Providing adequate user interfaces of the CDSS itself and between other systems and the CDSS to avoid medical errors and for easy use (25, 26, 36)
  - Being easy to personalize templates without requiring specialized skills (19, 24)
  - Limiting the number of reminders to avoid alert fatigue (17, 26)
  - Providing a link to an interdisciplinary communication network such as care conferences and audits for care continuity across settings (15, 24, 34)

represented the characteristics of each category of the five stages from patient assessment to outcome evaluation. However, there were differences in the numbers of the system features extracted for each category. The features separately grouped as "others" in Table 3 were associated with the five stages. Certain features, such as being available at the point of care and being used in a clinical routine, were common among all of the CDSSs reviewed. The first feature in the others of Table 3, "providing automatic links between CDSS functions," means the sequential decision support of CDSSs provided in the stages available from assessment to outcome evaluation.

DISCUSSION

This study aimed to organize the features of CDSSs useful for nursing practice into assessment, problem identification, care plans, implementation, and outcome evaluation. As a part of the CDSS features, the study identified the diverse ranges of sequential decision support of CDSSs that operated in the stages from assessment to outcome evaluation.

The CDSS features related to patient assessment and care plans comparatively varied, whereas the features related to implementation and outcome evaluation did not (Table 3). This indicates that a small number of related studies limited the number of features to be extracted. In fact, there were only three CDSSs providing decision support in an implementation stage and four CDSSs operating in an outcome evaluation stage (Table 2). Eleven of the reviewed CDSSs operated in the stage of problem identification and two features for it were identified. In a single area of nursing care addressed by CDSSs, the step of problem identification by CDSSs would be skipped because the CDSSs were developed and implemented to address the targeted nursing care area. For example, in the study by Gunningberg et al,[19] problem identification by a CDSS was not needed because the target area of nursing care was pressure ulcer and the CDSS was used to address the identified problem. However, CDSSs, which operated in multiple areas of nursing care, needed to have useful features for problem identification. In the study by Lee et al,[13] nurses had to select nursing diagnoses from a list from the North American Nursing Diagnosis Association (NANDA) that are consistent with patient assessment data. However, there was no consensus among nurses about the diagnoses selected by them. In the implementation step of care plans (Table 3), the CDSSs provided three features about checking the completion of care activities. Unlike other categories with prebuilt formats embedding evidence from literature, decision support in the implementation step was grounded on the performance of nurses. The CDSSs in four studies provided decision support in an outcome evaluation stage (Table 2). Outcome evaluation is a very important stage that should not be omitted for quality patient care. Outcome evaluation allows nurses to determine relationships between patients' outcome achievement and nursing interventions. After the effectiveness of care plans and intervention is evaluated, the results are fed back into nursing practice.[35] Outcome evaluation is an ongoing activity to conduct reassessment of patient status, reordering of priorities, new goal-setting, and revision of care plans. However, most CDSSs reviewed in the study, except the four studies, did not include the function of outcome evaluation on the given nursing care. In two studies, outcome evaluations were implemented outside their CDSS function.[13,19] In the case that patient outcome evaluation is not a routine, nurses need to search for appropriate measurements or evidence for patient outcome evaluation; however, such a search may not be carried out for many reasons including a lack of time based on workload, difficulty accessing computers, and/or difficulty finding proper materials. A CDSS needs to provide a prepackaged measurement form or evidence-based recommendations for outcome evaluation. On the other hand, Table 3 shows the common features provided by all of the CDSSs reviewed. Through the organized system features, a comprehensive picture of nursing practice–oriented CDSSs that were attempted up to now was identified.

All of the CDSSs reviewed provided sequential decision support in at least two steps; nine CDSSs, in three stages; three CDSSs, in four stages; and a CDSS, in five steps (Table 2). The important thing to which we have to pay attention is the decision support provided in the full scope from initial assessment to outcome evaluation. As grounded in this review, the key steps of a CDSS for sequential decision support were initial patient assessment, problem identification, care plan, and outcome evaluation. It is to provide decision support at the most effective level of nursing care. If such a CDSS is used in a clinical routine, it allows for safe and continuous decision support from the initial stage of patient assessment to the outcome evaluation. Such decision support must be an indispensable part of the CDSS features for quality patient care.

There were limitations, although various studies were included in this review to extract the features of CDSSs useful for nursing practice. As most of the studies reviewed were in the stage of system development immediately followed by pilot test or evaluation, one limitation would be that the CDSS features were extracted from such studies, instead of rigorous study designs such as randomized controlled trials. Regardless, the types of the reviewed studies became an advantage in discerning the features of each CDSS because they focused on CDSS functionality. Of the 27 studies reviewed, three studies developed a CDSS as a tool to implement evidence-based practice in nursing, as carefully reviewed and selected evidence was embedded

in a CDSS.[16,18,36] One study developed a CDSS as a tool to increase the completeness and quality of nursing documentation.[19] Therefore, there was a limitation to extracting the features of CDSSs because these studies focused on compliance with evidence-based recommendations and nursing documentation. Lastly, as one study lacked information on system function[31] and one study lacked information on outcome evaluation,[32] there was difficulty describing the system functions from those studies.

For nursing practice and research, the development of a guideline toward an optimum CDSS that best supports nursing practice will have to go beyond the scope of system features identified from a literature review. The steps of sequential decision support by a CDSS were identified, and its importance was emphasized. On the other hand, for empirical support, there is the need to conduct a study to examine clinical effectiveness of CDSSs providing decision support in sequence from initial assessment to outcome feedback. Two suggestions for further research to mitigate the weakness of the reviewed studies are the following: that more nursing care areas become targets of CDSSs and that the effectiveness of CDSSs on decision support for nurses, nurse performance, and patient outcomes be evaluated by rigorous study designs, to have stronger nursing practice-oriented CDSSs.

CONCLUSION

This study organized the features of CDSSs useful for nursing practice into the categories of assessment, problem identification, care plans, implementation, and outcome evaluation, and identified the diverse ranges of the five category-related sequential decision supports that CDSSs provided. This review added the evidence-based knowledge regarding the features of nursing practice-oriented CDSSs. To design the optimum CDSS for nursing practice, a wider range of evidence-based knowledge is needed. Furthermore, providing continuous decision support from the initial stage of patient assessment to outcome evaluation cannot be overemphasized.

Acknowledgment

I specially thank Dr Jane White at the College of Nursing and Public Health for her assistance with editing.

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