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The electronic health record's impact on nurses' cognitive work: An integrative review

Kirsten Wisner*, Audrey Lyndon[1], Catherine A. Chesla

Department of Family Health Care Nursing, University of California, San Francisco, United States

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ABSTRACT

Background: Technology use can impact human performance and cognitive function, but few studies have sought to understand the electronic health record's impact on these dimensions of nurses' work.
Objective: The purpose of this review was to synthesize the literature on the electronic health record's impact on nurses' cognitive work.
Design: Integrative review.
Data sources: MEDLINE/PubMed, CINAHL, Embase, Web of Science, and PsycINFO.
Review methods: The literature search focused on 3 concepts: the electronic health record, cognition, and nursing practice, and yielded 4910 articles. Following a stepwise process of duplicate removal, title and abstract review, full text review, and reference list searches, a total of 18 studies were included: 12 qualitative, 4 mixed-methods, and 2 quantitative studies from the United States (13), Scandinavia (2), Australia (1), Austria (1), and Canada (1). The Mixed Methods Appraisal Tool was used to assess the quality of eligible studies.
Results: Five themes identified how nurses and other clinicians used the electronic health record and perceived its impact: 1) forming and maintaining an overview of the patient, 2) cognitive work of navigating the electronic health record, 3) use of cognitive tools, 4) forming and maintaining a shared understanding of the patient, and 5) loss of information and professional domain knowledge. Most studies indicated that forming and maintaining an overview of the patient at both the individual and team level were difficult when using the electronic health record. Navigating the volumes of information was challenging and increased clinicians' cognitive work. Information was perceived to be scattered and fragmented, making it difficult to see the chronology of events and to situate and understand the clinical implications of various data. The template-driven nature of documentation and limitations on narrative notes restricted clinicians' ability to express their clinical reasoning and decipher the reasoning of colleagues. Summary reports and handoff tools in the electronic health record proved insufficient as stand-alone tools to support nurses' work throughout the shift and during handoff, causing them to rely on self-made paper forms. Nurses needed tools that facilitated their ability to individualize and contextualize information in order to make it clinically meaningful.
Conclusion: The electronic health record was perceived by nurses as an impediment to contextualizing and synthesizing information, communicating with other professionals, and structuring patient care. Synthesizing and communicating information at the individual and team levels are known drivers of patient safety. The findings from this review have implications for electronic health record design.

What is already known about the topic?

- There has been widespread implementation of electronic health records in developed countries in the past decade.
- Electronic health records were expected to enhance patient safety by increasing access to information and preventing clinical errors.
- A growing body of literature suggests that electronic health records have introduced some unintended, negative consequences to cognitive processing and communication.

* Corresponding author.
E-mail address: Kirsten.wisner@ucsf.edu (K. Wisner).
[1] Audrey Lyndon is now at New York University, Rory Myers College of Nursing, New York, NY, United States.

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What this paper adds

- The electronic health records' focus on data aggregation and completeness has introduced cognitive challenges for users as they compile and synthesize information from throughout the medical record.
- Navigating the structure of the electronic health record may not always match how nurses think and work, generating additional work to integrate it into their complex, dynamic workflow.
- Clinicians reported difficulty formulating and maintaining an overview of the patient when using the electronic health record.
- Limited narrative notes in the electronic health record hindered clinicians' ability to communicate and understand others' clinical reasoning regarding care decisions.

1. Background and significance

The implementation of electronic health records (EHRs) was conceived as a system-level safety intervention aimed at improving communication and access to information, reducing medication-related errors, supporting decision-making, improving clinical guideline adherence, and assisting with data analysis (Aspden et al., 2004; Page, 2004). Since the widespread implementation of EHRs in the last decade, a growing body of research suggests that their use has introduced unintended consequences related to usability, alterations in communication or information exchange, and system complexity (Bristol et al., 2018; Campbell et al., 2006; Cresswell et al., 2012; Harrington et al., 2011; Koppel et al., 2005).

Achieving many of the quality, safety, and efficiency outcomes related to meaningful use of EHRs (HealthIT.gov, 2014) has necessitated EHR infrastructures to support the aggregation, storage, and visibility of data, as well as the creation of automated or built-in functions designed to remind and aid clinicians to compile and record information. Human factors and sociotechnical systems frameworks suggest that this focus on data completeness, aggregation and storage, and the associated work processes create challenges for end-users. Users encounter difficulties when they try to compile and synthesize information from the EHR, and integrate cumbersome EHR-related workflows with the dynamic and demanding nature of clinical work (Holden, 2011).

Despite recognition that new technologies can impact human performance and cognitive function (Dekker, 2015; Perrow, 1999), few studies have sought to understand the EHR's impact on clinicians' cognitive work. The frameworks of clinical grasp (Benner et al., 1999,2009) and situation awareness (Endsley, 1995) conceptualize cognitive work as a higher order, dynamic, and evolving understanding of the patient's status, situated in a particular clinical context, and dependent on the clinician's ability to continually contextualize and synthesize data over time across information sources. Information retrieved from the EHR represents one of many important data sources used by clinicians to continually update their individual and shared perceptual understanding of clinical situations. This ability to perceive, understand, and anticipate information about a patient in evolving clinical situations is seen as a vital contributor to patient safety (McComb and Simpson, 2014). The purpose of this review was to summarize the literature about the EHR's impact on nurses' cognitive work.

2. Methods

An integrative review methodology was used since it allows for the synthesis of experimental, non-experimental, and theoretical data, and is particularly useful for exploring complex phenomena (Whittemore and Knafl, 2005). The steps in this method include problem identification, literature search, data evaluation, data

Table 1
Search Terms Used.

Search Terms Used for Each Concept		
Electronic Health Record	Nursing	Mental Processes/Cognition
Electronic health record/s	Primary nursing	Mental Processes
Electronic medical record/s	Nursing	Cognition
Electronic documentation	Nursing care	Workload
Computerized documentation	Nurse's role	Mental workload
Electronic charting	Nursing staff	Workflow
Computerized medical records systems	Nursing process	Work routines
	Nurse(s)	Clinical reasoning
Computerized patient documentation	Nurs*	Clinical decision making
EMR		Decision making
EHR		Situation awareness
		Clinical overview
		Patient story/ies
		Clinical summary/ies
		Distraction/s
		Perception/s
		Perspective/s
		Thinking
		Cognitive function
		Human performance
		Information seeking behavior
		Critical thinking
		Mental performance
		Narratives
		Problem solving
		Psychology
		Unintended consequence/s
		Attitude to computers

analysis, and presentation. Problem identification is addressed in the background section.

2.1. Literature search

The search focused on three main concepts: the EHR, cognition, and nursing practice. See Table 1 for a list of all search terms used. Search terms related to cognition were challenging to define since there is no single definition of cognitive work in the healthcare literature, and there are numerous clinically relevant mental processes that may be impacted by EHR use. These include concepts and terms such as situation awareness, clinical grasp, decision-making, critical thinking, and clinical overview but also encompass mental processes such as perception, thinking, or problem solving. Some of these concepts have been identified as secondary or incidental findings in studies focused on the EHR's impact on workflow, communication, or collaboration. Hence, search terms such as workload, workflow, work routines, and attitudes were added to capture the breadth of literature on the EHR's impact on nurses' work. This ensured that studies with incidental cognitive findings were identified. Research came from literature in three main fields: healthcare, psychology, and information science.

With assistance from a medical librarian with extensive experience searching healthcare literature, five databases were chosen based on their likelihood of containing literature related to clinical care (MEDLINE/PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Embase), psychology (Web of Science and PsycINFO), and information science (PubMed, CINAHL, Embase, Web of Science, PsycINFO). No limiters were applied in order to capture literature not yet indexed.

2.2. Data evaluation

A total of 4910 articles were retrieved. Duplicates were removed by a reference manager software and by hand. The titles and/or abstracts of the remaining 3821 records were screened according to inclusion and exclusion criteria, and 3801 were excluded, leaving 20 articles to assess for eligibility. During full text review, 6 articles were excluded based on inclusion criteria. The reference lists of eligible records were reviewed and work by prominent EHR researchers was searched to ensure data completeness (Whittemore and Knafl, 2005), adding 4 additional records. A total of 18 records met eligibility criteria for this review. See Fig. 1 for the stepwise process used for study selection.

2.2.1. Inclusion criteria

Studies had to meet the following inclusion criteria: a) written in English; b) be original qualitative, quantitative, or mixed methods research published in a peer-reviewed journal; c) sample included direct-care nurses in hospital settings; and either d) the study reported findings related to the EHR's (or synonym) effect on nurses' cognitive work as defined in the mental processes/cognition search terms; or, e) the study outcomes included concepts related to collaborative decision-making or team situation awareness.

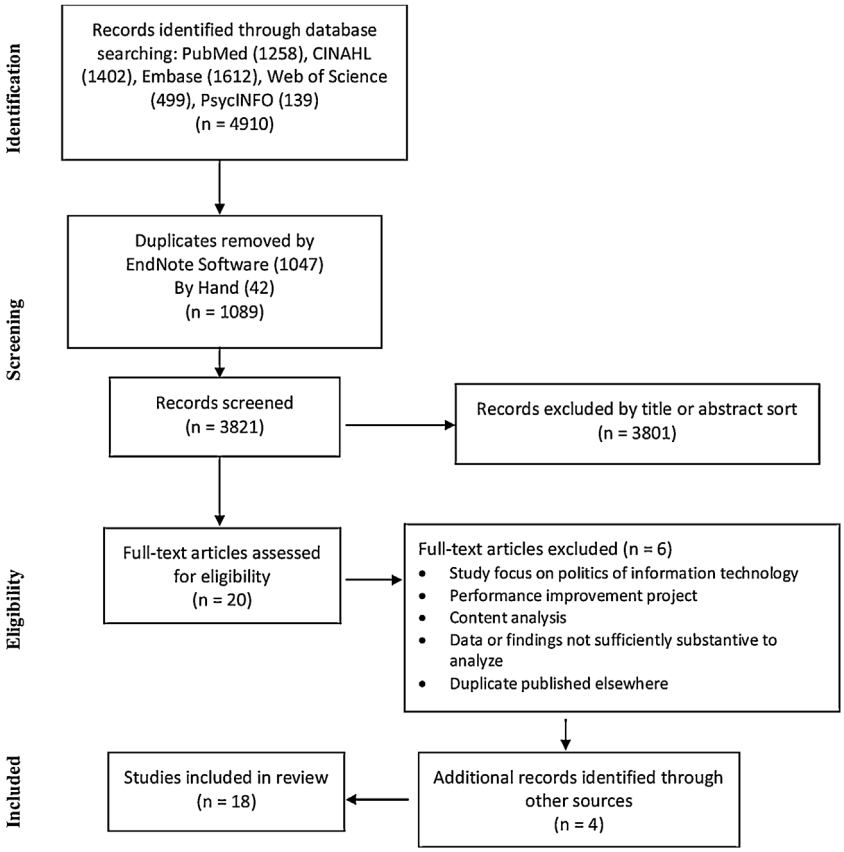

Fig. 1. Study Selection Process.

2.2.2. Exclusion criteria

Studies were excluded if they met any of the following criteria: a) focused on technology or computers generally instead of the EHR (or synonym); b) EHR use was secondary to EHR-related features or processes such as displays, software, checklists, care plans, or decision support; d) focused on EHR implementation strategies, or user adoption, satisfaction, acceptance or perceptions, where cognition was not part of the findings; e) focused on workflow, productivity, or documentation time with findings unrelated to cognition; or f) the study focused on computerized physician order entry without evaluating other elements of the EHR.

2.2.3. Quality appraisal

The Mixed Methods Appraisal Tool ([MMAT], Pluye et al., 2011) was used to appraise the quality of eligible studies. The MMAT is designed to evaluate the methodology of quantitative, qualitative, and mixed-methods research studies. Each study was assessed according to MMAT criteria based on the study methodology, which included qualitative, quantitative (further delineated by type: randomized controlled trial, non-randomized, and descriptive), and mixed methods. The appraisal process involved scoring 4 quality questions for each study type, and another 3 questions for mixed-methods studies. Examples of criteria addressed in the scored questions for qualitative studies included data quality and sources, analytic processes, and researcher positionality. The quantitative questions varied according to study type, but in general addressed sampling strategy and/or representativeness, measurement processes, and response rates. Mixed methods questions addressed research design and appropriate integration of methods (Pluye et al., 2011). One point was assigned for each of the 4 questions meeting defined criteria, yielding an overall score of 0–4. When scoring mixed-methods studies, the lowest of the quantitative and qualitative scores was assigned according to the scoring guidelines, since the overall quality of a study is reflected by its weakest element (Pluye et al., 2011).

All studies were first screened using two questions about the clarity of the research questions or objectives and if appropriate data were collected to address these. Pluye et al. (2011) caution that if the answer to either screening question is no or unknown, further appraisal may not be appropriate. Because the body of literature for this integrative review was limited, certain studies were included when the response to one of the screening questions was unknown. If the answer to both screening questions was no or unknown, the study was excluded. See Table 3 for a summary of MMAT scores assigned to each study.

3. Results

3.1. Data analysis

Eighteen studies met eligibility criteria. See Table 3 for a summary of included studies. Twelve studies were qualitative (grounded theory, interpretive phenomenology, ethnography, content analysis, thematic analysis, network analysis, interpretive descriptive). Four were mixed-methods, and two were quantitative descriptive. Publication dates ranged from 2004 to 2016. Studies were from the United States (13), Scandinavia (2), Australia (1), Austria (1), and Canada (1).

Instruments used in the quantitative and mixed-methods studies included the NASA-TLX: Task Load Index (1), an amended Health Information Systems (HIS)-monitor instrument (1), the Information Systems Expectations and Experiences (ISEE) survey (1), an adapted Masrom's Technology Acceptance Model and E-learning survey (1), and researcher-developed surveys (2). Interviews (8), focus groups (5), observations (8), think-aloud and think-after sessions (1) and artifacts analysis (7) were used alone or in combination in the mixed-methods and qualitative studies. One study used network analysis.

The quality of the studies evaluated using the MMAT ranged from 1 to 3 (0–4 scale), with 9 studies considered moderate quality (MMAT score $\geq$3), and 9 as low quality. One point was deducted for half of the qualitative studies because researcher positionality was not addressed (Pluye et al., 2011). These six studies would have been judged high quality (4 on a scale of 0–4) had that been included (Collins et al., 2011; Embi et al., 2013; Keenan et al., 2013; Staggers et al., 2011, 2012; Varpio et al., 2015). See Table 2 for an overview of methods, instruments, and MMAT scores for all studies.

Twelve of the studies focused on RNs only. The other six studies focused on physicians and RNs (3); midwives and RNs (1), and multiple stakeholders including RNs (2). Most studies were conducted in inpatient acute care units within community or tertiary hospitals. Inpatient units included pediatrics, neonatal intensive care, perinatal, medical surgical, oncology, orthopedic, and critical care settings. One study was conducted in 25 different practice settings across Australia. Another study took place in 4 U.S.

Table 2
Summary of Themes.

Forming and Maintaining an Overview of the Patient	Studies suggested that clinicians found the process of forming and maintaining an overview of the patient challenging when using the EHR. Overview has been defined as a dynamic clinical skill that resulted in a cumulative and comprehensive understanding of the patient's history, current status, data patterns and future plan (Varpio et al., 2015).
The Cognitive Work of Navigating the EHR	In most studies, clinicians found that entering, retrieving, understanding, and synthesizing information was difficult in the EHR and either increased clinicians' cognitive workload or failed to provide necessary cognitive support.
The Use of Cognitive Tools	The available EHR-generated summary reports and screens were insufficient as stand-alone tools to support nurses' information management during their shift and/or at handoff. These tools often did not match how nurses thought or worked, resulting in reliance on paper notes and verbal exchanges.
Forming and Maintaining Common Ground and a Shared Understanding of the Patient	Findings indicated that the increased volume and electronic exchange of information did not enhance communication in a way that facilitated arriving at common ground and shared situation awareness. Common ground refers to having a mutual understanding of a situation, and shared situation awareness (or understanding) refers to having a mutual understanding of its meaning.
The Loss of Information and Professional Domain Knowledge	Nurses relied heavily on paper notes and other disposable forms of documentation, which may have implications for loss of information when this is not recorded in the EHR. Representations of nurses' work and knowledge were not captured in the EHR, or nurses' notes and documentation were not read by others, suggesting that in certain settings, nurses' work and professional knowledge are not integrated into team processes.

Table 3
Overview of Studies.

	Citation	MMAT Score	Methods	Study Focus	Contribution to Themes[a]
Mixed Methods	Ammenwerth et al. (2011)	MM-1	Health Information Systems (HIS)-monitor instrument; content analysis of open-ended questions.	Information processing	A, B
	Chao (2016)	MM-3	Case study, thematic analysis, network analysis, researcher-developed survey, interviews, observations, artifact analysis.	Collaborative work routines, interdisciplinary communication	A, B, C, D, E
	Kossman et al. (2013)	MM-2	Mixed methods convergent, descriptive. Researcher-developed survey, content analysis of open-ended questions, focus groups.	Cognitive artifacts support of clinical judgment and team communication	C
	Schenk et al. (2016)	MM-1	Mixed methods; pre- post-survey and interviews. Adapted survey. Qualitative method not stated but consistent with content or thematic analysis.	RN perceptions, ease of use, usefulness, attitudes	A, B, C, E
Quant	Colligan et al. (2015)	Quan-3	Quantitative descriptive, NASA-TLX.	Cognitive workload, computer attitudes, EHR implementation	B
	Ward et al. (2011)	Quan-2	Quantitative; descriptive. Information Systems Expectations and Experiences (ISEE) Survey.	Implementation, RN perceptions	B
Qual	Collins et al. (2011)	Qual-3	Clinical communication space and distributed cognition frameworks used to analyze and map data. Ethnographic observations, interviews, focus groups.	Types of communication and information activities during interdisciplinary rounds	B, C, D, E
	Darbyshire (2004)	Qual-2	Qualitative, Interpretive Phenomenology. Focus groups.	Perspectives and understandings of EHR	B
	Embi et al. (2013)	Qual-3	Qualitative, cross-sectional. Thematic analysis. Focus groups.	Computerized documentation effect on clinician's work	A, B, C, D, E
	Keenan et al. (2013)	Qual-3	Qualitative, content analysis. Ethnographic observations, artifact analysis.	Information management and flow, communication patterns, use of artifacts	A, C, D, E
	Kossman and Scheidenhelm (2008)	Qual-2	Researcher-developed survey w/open ended questions to explore boundaries of phenomena, interviews, observations. Analysis not clear, consistent with thematic analysis.	EHR use during care, RN practice patterns, problems with EHR use, patient outcomes	B, C, E
	Staggers et al. (2012)	Qual-3	Qualitative; interpretive, descriptive. Audiotaped handoffs, interviews, observations, field notes, artifact review.	Handoff, use of cognitive artifacts	A, B, C
	Staggers et al. (2011)	Qual-3	Qualitative; interpretive, descriptive. Audiotaped handoffs, interviews, observations, field notes, artifact review.	Handoff, electronic summary reports	A, C
	Stevenson and Nilsson (2012)	Qual-2	Qualitative; content analysis. Focus groups.	Use of EHR, overview, medication module	A, B, D, E
	Varpio et al. (2015)	Qual-3	Qualitative; constructivist grounded theory. Observations, interviews, artifact analysis, think-aloud and think-after sessions.	Building the patient's story when using the EHR	A, B, D
	Vikkelsø (2005)	Qual-2	Qualitative, grounded theory, actor-network theory. Observation, field notes, artifacts analysis, photos, interviews.	Practice, workflows, interaction	A, D, E
	Weir et al. (2011)	Qual-3	Qualitative; used Clark's theory of communication to focus on one theme (communication and coordination) from prior study. Focus groups.	User experiences, collaboration, coordination	A, B, D, E
	Zadvinskis et al. (2014)	Qual-2	Qualitative, phenomenology. Interviews.	Nurses' perceptions of EHR and barcode medication administration	B, C

Note. EHR = electronic health record; MM = mixed-methods; MMAT = Mixed-Methods Appraisal Tool; NASA-TLX = NASA Task Load Index; Qual = qualitative; Quan = quantitative; RN = registered nurse; VS = vital signs.
[a] A = forming and maintaining an overview of the patient; B = the cognitive work of navigating the EHR; C = the use of cognitive tools; D = forming and maintaining common ground and a shared understanding of the patient; E = the loss of information and professional domain knowledge.

Veterans Administration sites. The focus of the studies included clinician perceptions of the EHR; its impact on collaboration, communication, practice and workflows, care coordination or information processing; overall effect on work, use of the EHR during handoff, evaluation of cognitive artifacts in the EHR, and measurement of cognitive workload.

Five themes were identified: 1) forming and maintaining an overview of the patient, 2) the cognitive work of navigating the EHR, 3) the use of cognitive tools, 4) forming and maintaining common ground and a shared understanding of the patient, and 5) the loss of information and professional domain knowledge. In the following sections, we use the term nurses for results from studies with nurses only and when distinct findings for nurses were reported. In studies with nurses and other clinicians, and when findings were not delineated by provider group, we use the term clinicians.

3.2. Data presentation

3.2.1. Forming and maintaining overview of the patient

Eleven of the studies reported on clinicians' ability to obtain or maintain an overview of the patient. Most findings indicated that forming and maintaining an overview of the patient's status is complex and difficult when using the EHR. While the EHR has facilitated the ability to collect and store vast amounts of information, findings suggested that this information often lacked clinical utility.

Overview was described as a vital and dynamic clinical skill that resulted in a cumulative and comprehensive understanding of the patient's history, current status, data patterns and future plan of care (Varpio et al., 2015). Clinicians assembled an overview by consolidating, analyzing, interpreting and contextualizing various data derived from their own and others' assessments and communications, the medical record, patient history, and interactions with patients and colleagues. Overview represented a synthesis of information and a cognitive framework that clinicians used to guide their thinking, interpret and respond to clinical findings and data, and to anticipate the patient's clinical trajectory (Varpio et al., 2015). While the process of assembling and synthesizing information across data sources, and contextualizing and synthesizing information was described differently in various studies, it was seen as fundamental to the process of forming the big picture or overview of the patient and supporting clinical work (Embi et al., 2013; Keenan et al., 2013; Staggers et al., 2011, 2012; Stevenson and Nilsson, 2012; Varpio et al., 2015; Weir et al., 2011).

While template-driven documentation facilitated data entry, the information generated was less informative than free text documentation (Embi et al., 2013). The emphasis on documentation completeness and increased volume of information in the record made it difficult to readily locate and process desired content, thus diminishing its clinical usefulness and failing to offer a concise summary of the patient's status (Embi et al., 2013). The EHR facilitated the collection and storage of more information; however, it scattered and fragmented parts of the patient's story, distributing pieces throughout the record (Chao, 2016; Schenk et al., 2016; Varpio et al., 2015; Vikkelsø, 2005). This made the process of consolidation, interpretation, and synthesis more difficult to achieve, complicating clinicians' ability to acquire a summative understanding of the patient's status (Varpio et al., 2015), and did little to facilitate the understanding and synthesis needed by clinicians to support their cognitive work (Weir et al., 2011). Vikkelsø (2005) reported that an overview was particularly difficult to obtain surrounding the patient's medications, and that the work of assembling an overview for the care team was taken up informally by nurses.

Findings from studies examining nurses' handoff processes and information management and flow reported lack of a standardized overview in the EHR, causing nurses to rely on paper forms containing their personal notes (Keenan et al., 2013; Staggers et al., 2011, 2012). Chao (2016) also reported this in a study examining collaborative work routines. These paper forms contained synthesized, dynamic information derived from various sources, tailored by nurses to both align with and support their work throughout the shift and during handoff (Chao, 2016; Staggers et al., 2012, 2011). These synthesized data provided the cognitive support needed for nurses to prioritize and organize their work and were not available in the EHR despite it containing an electronic summary intended for this purpose (Chao, 2016; Staggers et al., 2012, 2011). In particular, the electronic summary lacked contextual information necessary to formulate an overview such as vital sign trends, or the integration of information such as seeing medications in the context of vital signs or with pertinent laboratory data (Staggers et al., 2011).

Clinicians found the narrative note features and processes in the EHR problematic. Across several studies, the visibility of colleagues' thought processes (including their intentions, clinical interpretations, and reasoning) was fundamental to achieving an overview the of patient's clinical status (Embi et al., 2013; Varpio et al., 2015; Weir et al., 2011). The EHR restricted the amount and quality of narrative notes which hindered clinicians' ability to both share and decipher the intentions and clinical reasoning behind care decisions and activities (Embi et al., 2013; Varpio et al., 2015; Weir et al., 2011). Like other information in the EHR, narrative notes were fragmented and scattered across the medical record, making it difficult to formulate a chronological narrative (Varpio et al., 2015). Clinicians described the process of sorting and interpreting information in narrative notes to reconstruct the chronology of events as cumbersome and difficult (Weir et al., 2011). They had difficulty reconstructing details about the patient's course of care across various problems and encounters, which hindered their ability to decipher symptom patterns and the course of disease (Embi et al., 2013), and created undue cognitive work as they compiled data from across the record to build the patient's story (Varpio et al., 2015).

One mixed-methods study reported improved overview when using the EHR; however, this was based on favorable responses to several survey questions that evaluated perceptions about access to information and visibility of open tasks, supported by content analysis of open-ended responses (Ammenwerth et al., 2011). Other studies using immersive data collection methods such as interviews, observations and artifact analysis suggested that access to and visibility of information in the medical record did not enhance an overview, and in many cases rendered information opaque and more difficult to interpret. Stevenson and Nilsson (2012) and Schenk et al. (2016) reported mixed findings about overview. In both studies, nurses felt that access by multiple users to the medical record was advantageous, and that information in the EHR was more comprehensive; however, this information was fragmented (Schenk et al., 2016), difficult to retrieve and synthesize, and challenged users' ability to track the patient's progress (Stevenson and Nilsson, 2012), making the increased volume of information less useful.

3.2.2. The cognitive work of navigating the EHR

Fourteen studies reported findings related to navigation in the EHR and its effect on cognitive workload or cognitive support. Most findings indicated that entering, retrieving, understanding, and synthesizing information was difficult in the EHR and increased clinicians' cognitive work or failed to provide necessary cognitive support. These issues were related to the scattering or fragmenting of information, information overload or complexity, poor quality of

information, inability to decipher intent and clinical reasoning, and lack of chronology.

Findings related to access to and usefulness of information needed for certain aspects of cognitive work were mixed. Kossman and Scheidenhelm (2008) reported improved access to information needed for decision-making, and better organization of information and tasks within the EHR, thus enhancing nursing work. A study using the Health Information Systems (HIS)-monitor instrument reported improved information processing, including support for compiling the patient's medical history and other information for the admission process and for creating and updating the care plan (Ammenwerth et al., 2011). On the other hand, a study using the Information Systems Expectations and Experiences Survey (ISEE) reported that nurses felt less confident that they had access to the right information for patient care and reported poorer access to information that improved their ability to make good patient care decisions (Ward et al., 2011).

Other investigators suggested that clinically relevant information retrieval from the EHR was difficult and cumbersome (Collins et al., 2011; Darbyshire, 2004; Weir et al., 2011; Zadvinskis et al., 2014). Processes such as inputting and locating vital signs during care were perceived as problematic (Stevenson and Nilsson, 2012). Clinicians found it hard to search across documents located throughout the medical record to find relevant information. The EHR scattered and fragmented information, making its retrieval and synthesis challenging. This created more cognitive work for clinicians and did not provide the cognitive support needed to synthesize and understand the information (Chao, 2016; Embi et al., 2013; Schenk et al., 2016; Varpio et al., 2015; Zadvinskis et al., 2014).

Finding relevant, clinically meaningful information from lengthy printouts or screens containing irrelevant, truncated, or outdated information increased clinicians' cognitive work (Chao, 2016; Embi et al., 2013; Staggers et al., 2012; Varpio et al., 2015; Weir et al., 2011), and impeded the interpretive process central to synthesizing and comprehending information (Varpio et al., 2015). When clinicians detected that the copy and paste function was used for narrative notes, they mistrusted the currency and accuracy of information, and engaged in more cognitive work to validate and cross-check such data (Weir et al., 2011).

One study used the NASA-TLX to assess cognitive workload during data entry and retrieval tasks in a matched sample of 74 nurses. The survey was administered prior to EHR implementation, at the end of each nurse's 1st, 5th, and 10th work shifts post-implementation, and again at 4 months post-implementation (Colligan et al., 2015). Cognitive workload was statistically significantly higher for nurses after their 1st and 5th work shifts, returning to baseline for most participants by their 10th shift, suggesting that cognitive challenges were limited to the early implementation period.

3.2.3. The use of cognitive tools

Ten of the studies focused on or reported incidental findings about the cognitive tools available in the EHR. In all these studies, available EHR-generated summary reports and screens were seen as insufficient as stand-alone tools to support nurses' information management throughout the shift or surrounding handoff. Nurses reported that these EHR summary report tools and templates did not match how they thought and worked, resulting in the persistence of paper forms or reliance on verbal exchanges.

Across several studies, nurses did not use available EHR-generated summary reports during the shift or for handoff. When used, nurses augmented and tailored them to provide missing information (Chao, 2016; Staggers et al., 2011, 2012). Some nurses found printouts such as medication administration records, flowsheets, orders and care plans helpful, but still relied heavily on personal notes and scraps of paper that they continually updated and revised throughout the shift to support handoff (Keenan et al., 2013). Most EHR-generated summary tools were too long and contained truncated or extraneous information and did not meet nurses' needs for a concise (Chao, 2016), contextualized, synthesized summary (Staggers et al., 2011, 2012). Nurses tailored their paper forms to contain the significant information they needed to know, using these forms to plan and organize activities individually and collectively for assigned patients, as well as to collect and synthesize information throughout the shift (Keenan et al., 2013; Staggers et al., 2011, 2012). This recorded content helped nurses to structure clinical judgments and prioritize and plan actions for the day. Writing on the forms was not just about collecting information; nurses reported that it supported how they remembered and processed their thoughts, and helped them verify that they had pertinent information to structure their work for the shift (Staggers et al., 2011, 2012). Nurses wanted to tailor self-made or EHR-generated tools to each patient; for example, they may forgo certain demographic data on patients who were familiar to them, or add highlighted information that required special attention or vigilance such as a high-risk medication that required specific timing (Staggers et al., 2011).

Nurses used their paper forms more often after EHR implementation for handoff and throughout the shift to mitigate new documentation issues encountered with the EHR. They found they were using these self-made forms to track information and document later, resulting in duplicate documentation (Chao, 2016). The EHR's focus on the aggregation and storage of information was at odds with clinical work (Chao, 2016) and yielded electronic tools that were too generic and cluttered with immaterial information to be useful to nurses as they planned and performed their work (Staggers et al., 2011, 2012).

Clinicians found information retrieval from their personal notes or verbal communication easier than from the EHR, causing an increased reliance on verbal exchanges (Collins et al., 2011). They wanted succinct and up-to-date summaries of the patient's status and overall goals of care, and found the templated and exhaustive information in the EHR confusing, limiting their ability to understand the course of care (Embi et al., 2013). Nurses reported that documentation in the EHR did not match the fast-paced, mobile and team-based nature of their work. Tools and structures in the EHR were difficult to access and use, forcing duplicative documentation, first on paper notes and later in the EHR (Embi et al., 2013). Nurses reported frustration that support for patient care was not built into the EHR (Schenk et al., 2016). The physical assessment templates did not correspond to how nurses performed and thought about their assessment, resulting in inefficiency and frustration (Zadvinskis et al., 2014), and the mandate to document a care summary in shift notes was at odds with their continuous data collection and entry (Embi et al., 2013).

Kossman et al. (2013) evaluated seven cognitive artifacts for their support of nurses' clinical judgment and communication. These included six EHR-generated tools and the nurses' self-made worklists. Nurses rated their self-made worklists as more useful overall for clinical judgment and communication than any of the EHR-generated tools except for the medication administration record. The EHR-generated templates, problem lists and summary reports failed to organize and display information in ways that aligned with and supported important aspects of nursing work (Kossman et al., 2013; Staggers et al., 2011), such as how they were accustomed to finding information and thinking about their patients (Staggers et al., 2011). The self-made tools organized and displayed information in a way that supported their workflow and style by making information portable, easily accessible and prompting memory (Kossman et al., 2013; Staggers et al., 2011). While work lists and automated alerts in the EHR enhanced

efficiency and aided memory, and information for clinical decision-making was more accessible, nurses expressed concern that heavy reliance on drop-down menus, cut and paste features, and checkboxes could impair their critical thinking and documentation accuracy (Kossman and Scheidenhelm, 2008).

Simply having information in a printout or screen was insufficient, since individualizing and contextualizing information was integral to synthesizing the information in a clinical context. For example, nurses wanted to see vital sign trends, view the patient's apical pulse when giving a cardiac medication, or evaluate clotting factors when giving a blood thinner (Staggers et al., 2011). Findings suggested that nurses engaged more readily in this process of contextualizing and individualizing information when using their self-made tools, as opposed to the EHR-generated tools that did not provide sufficient support (Staggers et al., 2011, 2012).

3.2.4. Forming and maintaining common ground and a shared understanding of the patient

Eight studies reported findings related to some aspect of clinician/team communication or the EHR's effect on care coordination, collaborative decision-making, and achieving common ground and a shared understanding of the patient's status. Common ground refers to individuals having a mutual understanding of a situation, and shared situation awareness (or understanding) refers to having a mutual understanding of its meaning (Weir et al., 2011). The findings indicated that communication—the fundamental element required for clinicians to organize and advance a shared understanding of the patient's status—was not enhanced by the increased volume and exchange of information and data. Instead, clinicians needed access to contextualized information that helped them form and maintain common ground and to expedite a shared situation awareness (Weir et al., 2011), especially in uncertain and dynamic clinical situations.

The EHR provided limited support for interprofessional communication and care coordination (Chao, 2016; Keenan et al., 2013), and nurses' use of verbal communication with physicians increased after EHR implementation, presumably because computer-mediated communication was insufficient for understanding physicians' intentions (Chao, 2016). The EHR contained a structure for orders and shared goals (such as documenting the plan of care in a physician's note), and alerting functions regarding abnormal findings, such as laboratory values. However, the EHR provided insufficient support for activities like collaborative decision-making, conveying updates aimed at establishing a shared understanding of the clinical situation, or contextualizing certain clinical findings relative to a patient's case (Collins et al., 2011). The EHR did not facilitate deciphering and prioritizing goals and understanding the clinical reasoning behind orders, and did not facilitate communication of information needed to establish common ground during uncertain or evolving clinical situations, as with unstable patients (Collins et al., 2011).

Clinicians felt the EHR was inadequate as a single information source, and multiple modes of communication were required to support effective clinical communication and care coordination (Embi et al., 2013). This was especially problematic since clinicians reported that the EHR changed work routines in a way that reduced their direct communication with each other (Embi et al., 2013). Nurses reported continued reliance on verbal report to ensure an understanding of the patient and care priorities (Stevenson and Nilsson, 2012).

As noted in other themes in this review, narrative notes were appreciably limited in EHR documentation, which emphasized capturing objective information via drop-down features, check boxes, and other preconfigured templates. Features and structures in the EHR impeded clinicians' ability to decipher colleagues' interpretations and subjective impressions of the patient's status (Varpio et al., 2015; Weir et al., 2011), resulting in loss of shared situation awareness. Clinicians identified the process of reading colleagues' notes and their interpretations, intentions, and clinical reasoning as central to how they formed and maintained an individual and shared understanding of the patient's status and clinical trajectory. Loss of access to others' reasoning impeded the team's collective work of developing this shared understanding (Varpio et al., 2015). Deciphering the meaning of the situation relied on being able to see the chronology of events and linkages between certain data and points in time, as well as being able to extract and synthesize relevant and temporal information from the vast stores of information in the medical record (Weir et al., 2011). The copy and paste functions in the EHR were frequently used and produced narrative notes that were cluttered and missing a sense of dialogue and interpretation (Weir et al., 2011).

Some findings were mixed. While there was better coordination of certain aspects of the patient's case—in particular the medical aspects of care (medications, diagnosis), the EHR led to a diminished focus on nurses' perspectives and care activities. Ways to represent psychosocial aspects of care and the patient's perspective were reduced and thus there were fewer opportunities for this information to be shared among the team (Vikkelsø, 2005).

3.2.5. The loss of information and professional domain knowledge

Nine studies reported findings related to lost or missing information. A subtheme was the continued reliance on personal notes, scraps of paper, or other disposable forms of documentation, which may have implications related to information loss if such information is not recorded in the EHR. In numerous studies, representations of nurses' work and knowledge were not captured in the EHR, or nurses' notes were not read, which suggests that in certain settings the work and knowledge of nursing are not integrated into team processes.

Several studies reported increased variability and inconsistency in where data were documented (Chao, 2016; Kossman and Scheidenhelm, 2008; Stevenson and Nilsson, 2012), leading to frustration and possibly overlooked information (Kossman and Scheidenhelm, 2008). Input fields that were grouped in related sections in the paper chart were missing in certain EHR-generated forms or were difficult to find. This caused nurses to document in text boxes, often in different places throughout the record (Chao, 2016). Nurses avoided the use of templates because they were difficult to use, leading to inconsistency in where certain data were charted. Nurses were concerned about missing or overlooking important information because it was complex to input and locate (Stevenson and Nilsson, 2012). Preconfigured checklists or templates did not always contain details that matched the clinical situation; for example, a screen may have a drop down for staples, when the patient instead had sutures (Kossman and Scheidenhelm, 2008). In such cases, nurses had to decide whether to chart inaccurately, take time to navigate to another part of the record to enter a note, or not to document the finding (Kossman and Scheidenhelm, 2008).

Clinicians found it difficult to navigate the EHR and to locate relevant information in cluttered screens (Embi et al., 2013). They coped with this by selectively reading narrative notes which left them concerned that they had missed or overlooked important information (Embi et al., 2013). Nurses' notes were not read by other disciplines (Kossman and Scheidenhelm, 2008), because their formats required too much work to navigate and understand (Weir et al., 2011). This led to increased verbal exchanges or loss of information (Kossman and Scheidenhelm, 2008; Weir et al., 2011). Nurses reported a delay in being able to access and read physician notes from the emergency department and notes from morning

rounds reflecting team decisions made during that time (Embi et al., 2013).

Certain care activities were not found in the EHR, such as patient safety double-checks and the evaluation of goals (Collins et al., 2011). Alerts and notifications about laboratory findings changed from a linear process managed by ward clerks to a continuous notification process embedded in the EHR. While critical laboratory results were more readily flagged, other results were overlooked or lost in the record (Vikkelsø, 2005). When a patient had numerous abnormal findings, nurses found it difficult to navigate the medical record to find where to document various findings, potentially leading to lost or overlooked information (Schenk et al., 2016).

There was no centralized overview function accessible by all clinical team members. Given the rarity of interdisciplinary communication and very limited time spent on the units by non-nursing members of the team, it was unlikely that nursing knowledge was accessed and used by other disciplines (Keenan et al., 2013). While nurses' autonomous actions and decision-making were apparent during observations, these were not represented in the EHR (Collins et al., 2011). Another study reported a shift in focus to the medical versus nursing or patient-centered aspects of care when using the EHR, leading to loss of nurses' and patients' perspectives (Vikkelsø, 2005).

4. Discussion

This review summarized the literature on the EHR's impact on nurses' cognitive work. Five themes were identified that described how nurses and other clinicians perceived and used the EHR. These were 1) forming and maintaining an overview of the patient, 2) the cognitive work of navigating the EHR, 3) the use of cognitive tools, 4) forming and maintaining common ground and a shared understanding of the patient, and 5) loss of information and professional domain knowledge.

Most findings indicated that forming and maintaining an overview of the patient at both the individual and team level were difficult when using the EHR. The work of navigating the vast volumes of information in the EHR to locate, contextualize, and synthesize relevant clinical information was challenging and increased clinicians' cognitive work. The EHR scattered and fragmented information, making it difficult for clinicians to see the chronology of events and to situate and understand the clinical implications of various data. The template-driven nature of documentation and limited narrative note functions in the EHR created difficulties and increased cognitive work for clinicians as they attempted to express their clinical thinking and reasoning, and decipher that of colleagues. The EHR-generated cognitive tools such as summary reports and handoff tools were insufficient as stand-alone tools to support nurses' work throughout the shift and during handoff, resulting in reliance on self-made paper forms or augmented or tailored EHR-generated tools. Nurses needed tools that helped them individualize and contextualize information to make it clinically meaningful. These were dynamic tools used throughout the shift, representing synthesized information across data sources. Information overload caused clinicians to selectively read narrative notes, usually bypassing those written by nurses, suggesting that certain professional domain knowledge and perspective may be lost or buried in the medical record. In addition, nurses' reliance on paper forms or scraps of paper may lead to clinically important information not being transferred into the record.

These findings suggest that the increased collection, aggregation and storage of information in the EHR have not led to increased access to clinically meaningful information. The challenges that nurses and other clinicians encounter when attempting to contextualize and synthesize information have important implications for the ability to achieve and maintain clinical grasp and situation awareness, which are clearly defined cognitive processes that affect how clinicians maintain safety (Benner et al., 1999, 2009; Endsley, 1995). Information retrieved from the EHR represents one of many important data sources used by clinicians to continually update their individual and shared perceptual and mental models of the clinical situation. Mental models represent rich, dynamic knowledge structures that clinicians use to understand and anticipate evolving clinical situations and are a vital driver of patient safety (McComb and Simpson, 2014). A novel finding in this review is that clinicians relied on seeing and understanding others' clinical reasoning, interpretations, and intentions as part of their understanding of a patient's clinical status—a process they found more challenging when using the EHR. The EHR's focus on template-driven documentation, data completeness, and serving as an information repository does not provide the types of information exchanges that support effective communication. Coiera (2000) posited that information access and communication are different processes, and certain communication cannot be executed using information technology. Clinicians look to each other when working through their interpretations and deciding on a course of action and this interaction is part of an ongoing and iterative process of updating a dynamic understanding of the situation at hand (Coiera, 2000).

Studies of physicians' perceptions of the EHR and computerized physician order entry have reported findings that align with the main themes in this review including loss of overview, fragmentation of data, increased cognitive work when navigating the EHR, and difficulty deciphering colleagues' clinical reasoning or intent (Ash et al., 2004; Ash et al., 2009; Holden, 2011). Workflows in the clinical environment and EHR use in real life are rarely linear and predictable (Hazlehurst et al., 2003); therefore, effectively evaluating EHR impact requires consideration of the interactions between clinician, technology, the environment, and the social system (Harrison et al., 2007; Karsh et al., 2006).

Some findings in this review suggest that the EHR enhances or improves some aspects of cognitive work. In most cases, the conclusion is based on the assumption that increased visibility of or access to information, having information available to multiple users, data completeness, readability or legibility, or automated data entry enhanced cognition (Ammenwerth et al., 2011; Chao, 2016; Embi et al., 2013; Kossman and Scheidenhelm, 2008; Staggers et al., 2012; Stevenson and Nilsson, 2012; Ward et al., 2011). In most cases these were a small part of overall findings suggesting that use of the EHR creates cognitive challenges (Chao, 2016; Embi et al., 2013; Kossman and Scheidenhelm, 2008; Staggers et al., 2012; Stevenson and Nilsson, 2012). Studies that use immersive data collection methods such as interviews, observations and artifact analysis suggest that access to and visibility of information in the medical record do not enhance an overview or ready access to the information needed to support clinicians' cognitive work (Chao, 2016; Collins et al., 2011; Embi et al., 2013; Keenan et al., 2013; Staggers et al., 2011, 2012; Varpio et al., 2015; Vikkelsø, 2005; Weir et al., 2011).

One study sought to evaluate mental workload directly using the NASA-TLX: Task Load Index (Colligan et al., 2015), a tool that measures the operator's subjective assessments of workload using six questions focused on the mental, physical and temporal demand of a task, how much effort was required, its perceived effect on performance, and the level of frustration experienced (Hart and Staveland, 1988). This tool was used to measure narrowly defined aspects of cognitive work during and shortly after the EHR implementation period. When viewing cognitive work through the lenses of clinical grasp and situation awareness (Benner et al., 1999, 2009; Endsley, 1995), a tool such as the NASA-TLX as a stand-alone measure is likely incapable of capturing the complexity of cognitive work.

4.1. Limitations

Most of the studies in this review sought to evaluate nurses' or clinicians' overall perspectives about the EHR or its effect on work, communication, or collaboration. Aside from the study using the NASA-TLX to measure cognitive/mental workload (Colligan et al., 2015), and a mixed-methods study that measured the quality of information processing using an unvalidated HIS-monitor instrument (Ammenwerth et al., 2011), few studies set out to explore the impact of the EHR on a clearly defined aspect of clinicians' cognitive work (Kossman et al., 2013; Staggers et al., 2011, 2012; Varpio et al., 2015). Several studies using immersive qualitative methods reported incidental findings related to cognition supported by rich and substantive data elements (Chao, 2016; Embi et al., 2013; Keenan et al., 2013; Weir et al., 2011). In the remaining studies, cognitive work was reported as an incidental finding, and in some cases the report lacked substantive data elements to support such conclusions (Collins et al., 2011; Darbyshire, 2004; Kossman and Scheidenhelm, 2008; Schenk et al., 2016; Stevenson and Nilsson, 2012; Vikkelsø, 2005; Zadvinskis et al., 2014). While rigor was enhanced by a comprehensive search of the literature in five databases, all phases of data evaluation, extraction and analysis were conducted by one researcher, which may have led to bias.

4.2. Strengths

This comprehensive review of the literature is the first to attempt to summarize and evaluate how EHR use affects nurses' cognitive work. Concepts from clinical grasp (Benner et al., 1999, 2009) and situation awareness (Endsley, 1995) were used to conceptualize cognitive work as a higher order, dynamic, and evolving understanding of the patient's status, situated in a particular clinical context, and dependent on the clinician's ability to continually contextualize and synthesize data across information sources. This review identified only a few studies that have focused on clearly defined aspects of cognitive work using immersive qualitative methods, representing a gap in the literature.

5. Implications for future research

Using a human factors and sociotechnical systems framework, future research should focus on understanding how nurses retrieve, organize, synthesize, and communicate information; how they achieve and maintain clinical grasp and situation awareness when using the EHR; and exploring information technology design that supports cognitive work. Practical research applications might include how to effectively integrate narrative notes in the EHR as an organizing aspect of clinical practice; evaluate handoff and tracking tools and align them with how nurses think and work; and focus on best practices for clinician input on information technology design to ensure content in preconfigured templates is clinically meaningful and organized in ways that support clinical work.

6. Conclusion

Findings from this review challenge the assumption that EHRs have improved communication, access to information, and assisted with clinical decision-making (Aspden et al., 2004; Page, 2004). Instead, findings suggest that EHR use has generated numerous cognitive challenges for clinicians that may have important safety implications. The EHR's focus on data completeness, aggregation, and storage has produced vast volumes of information that clinicians find difficult to navigate and synthesize, making clinically meaningful information less accessible and available. Nurses found that the structure of the EHR did not always match how they thought and worked, which generated additional work to integrate EHR use into their complex and dynamic workflows. The EHR's focus on data completeness needs to be balanced with design features and structures that make relevant clinical information readily accessible for clinicians without creating undue cognitive burden.

Author contributions

Study design: KW, AL, CC.
Data collection: KW.
Data analysis: KW.
Study supervision: KW, AL, CC.
Manuscript writing: KW.
Critical revisions for important intellectual content: KW, AL, CC.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijnurstu.2019.03.003.

References

Ammenwerth, E., Rauchegger, F., Ehlers, F., Hirsch, B., Schaubmayr, C., 2011. Effect of a nursing information system on the quality of information processing in nursing: an evaluation study using the HIS-monitor instrument. Int. J. Med. Inform. 80 (1), 25–38. doi:http://dx.doi.org/10.1016/j.ijmedinf.2010.10.010.

Ash, J.S., Berg, M., Coiera, E., 2004. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. J. Am. Med. Inform. Assoc. 11 (2), 104–112. doi:http://dx.doi.org/10.1197/jamia.M1471.

Ash, J.S., Sittig, D.F., Dykstra, R., Campbell, E., Guappone, K., 2009. The unintended consequences of computerized provider order entry: findings from a mixed methods exploration. Int. J. Med. Inform. 78, S69–S76.

Aspden, P., Corrigan, J.M., Wolcott, J., Erickson, S. (Eds.), 2004. Patient Safety: Achieving a New Standard for Care. National Academies Press, Washington, D.C. . Retrieved from http://www.nap.edu/download.php?record_id=10863.

Benner, P.E., Hooper-Kyriakidis, Stannard, D., 1999. Clinical Wisdom and Interventions in Critical Care: A Thinking-in-Action Approach. W.B. Saunders, Philadelphia.

Benner, P., Tanner, C.A., Chesla, C.A., 2009. Expertise in Nursing Practice: Caring, Clinical Judgment, and Ethics. Springer Publishing Company, New York.

Bristol, A.A., Nibbelink, C.W., Gephart, S.M., Carrington, J.M., 2018. Nurses' use of positive deviance when encountering electronic health records-related unintended consequences. Nurs. Adm. Q. 42 (1), E1–E11.

Campbell, E.M., Sittig, D.F., Ash, J.S., Guappone, K.P., Dykstra, R.H., 2006. Types of unintended consequences related to computerized provider order entry. J. Am. Med. Inform. Assoc. 13 (5), 547–556.

Chao, C.A., 2016. The impact of electronic health records on collaborative work routines: a narrative network analysis. Int. J. Med. Inform. 94, 100–111. doi:http://dx.doi.org/10.1016/j.ijmedinf.2016.06.019.

Coiera, E., 2000. When conversation is better than computation. J. Am. Med. Inform. Assoc. 7 (3), 277–286.

Colligan, L., Potts, H.W., Finn, C.T., Sinkin, R.A., 2015. Cognitive workload changes for nurses transitioning from a legacy system with paper documentation to a commercial electronic health record. Int. J. Med. Inform. 84 (7), 469–476. doi:http://dx.doi.org/10.1016/j.ijmedinf.2015.03.003.

Collins, S.A., Bakken, S., Vawdrey, D.K., Coiera, E., Currie, L., 2011. Model development for EHR interdisciplinary information exchange of ICU common goals. Int. J. Med. Inform. 80 (8), e141–149. doi:http://dx.doi.org/10.1016/j.ijmedinf.2010.09.009.

Cresswell, K.M., Worth, A., Sheikh, A., 2012. Integration of a nationally procured electronic health record system into user work practices. BMC Med. Inform. Decis. Mak. 12 (1), 1–12.

Darbyshire, P., 2004. 'Rage against the machine?': nurses' and midwives' experiences of using computerized patient information systems for clinical information. J. Clin. Nurs. 13, 17–25.

Dekker, S., 2015. Safety Differently: Human Factors for a New Era. CRC Press, Boca Raton, FL.

Embi, P.J., Weir, C., Efthimiadis, E.N., Thielke, S.M., Hedeen, A.N., Hammond, K.W., 2013. Computerized provider documentation: findings and implications of a

multisite study of clinicians and administrators. J. Am. Med. Inform. Assoc. 20 (4), 718–726. doi:http://dx.doi.org/10.1136/amiajnl-2012-000946.
Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. Hum. Factors 37 (1), 32–64. doi:http://dx.doi.org/10.1080/00140130600612762.
Harrington, L., Kennerly, D., Johnson, C., 2011. Safety issues related to the electronic medical record (EMR): synthesis of the literature from the last decade, 2000–2009. J. Healthc. Manag. 56 (1), 31–44.
Harrison, M.I., Koppel, R., Bar-Lev, S., 2007. Unintended consequences of information technologies in health care—an interactive sociotechnical analysis. J. Am. Med. Inform. Assoc. 14 (5), 542–549. doi:http://dx.doi.org/10.1197/jamia.M2384.
Hart, S.G., Staveland, L.E., 1988. Development of NASA-TLX (Task Load Index): results of empirical and theoretical research. Adv. Psychol. 52, 139–183.
Hazlehurst, B., McMullen, C., Gorman, P., Sittig, D., 2003. How the ICU follows orders: care delivery as a complex activity system. AMIA Annual Symposium Proceedings, , pp. 284–288.
HealthIT.gov, 2014. EHR Incentives and Certification Retrieved October 18, 2014 from. . http://www.healthit.gov/providers-professionals/meaningful-use-definition-objectives.
Holden, R.J., 2011. Cognitive performance-altering effects of electronic medical records: an application of the human factors paradigm for patient safety. Cogn. Technol. Work 13 (1), 11–29. doi:http://dx.doi.org/10.1007/s10111-010-0141-8.
Karsh, B.T., Holden, R.J., Alper, S.J., Or, C.K., 2006. A human factors engineering paradigm for patient safety: designing to support the performance of the healthcare professional. Qual. Saf. Health Care 15 (Suppl. 1), i59–i65. doi:http://dx.doi.org/10.1136/qshc.2005.015974.
Keenan, G., Yakel, E., Dunn Lopez, K., Tschannen, D., Ford, Y.B., 2013. Challenges to nurses' efforts of retrieving, documenting, and communicating patient care information. J. Am. Med. Inform. Assoc. 20 (2), 245–251. doi:http://dx.doi.org/10.1136/amiajnl-2012-000894.
Koppel, R., Metlay, J.P., Cohen, A., Abaluck, B., Localio, A.R., Kimmel, S.E., Strom, B.L., 2005. Role of computerized physician order entry systems in facilitating medication errors. JAMA 293 (10), 1197–1203. doi:http://dx.doi.org/10.1001/jama.293.10.1197.
Kossman, S.P., Scheidenhelm, S.L., 2008. Nurses' perceptions of the impact of electronic health records on work and patient outcomes. CIN: Comput. Inform. Nurs. 26 (2), 69–77. doi:http://dx.doi.org/10.1097/01.NCN.0000304775.40531.67.
Kossman, S.P., Bonney, L.A., Kim, M.J., 2013. Electronic health record tools' support of nurses' clinical judgment and team communication. CIN: Comput. Inform. Nurs. 31 (11), 539–544. doi:http://dx.doi.org/10.1097/01.NCN.0000432122.79452.7b.
McComb, S., Simpson, V., 2014. The concept of shared mental models in healthcare collaboration. J. Adv. Nurs. 70 (7), 1479–1488. doi:http://dx.doi.org/10.1111/jan.12307.
Page, A. (Ed.), 2004. Keeping Patients Safe: Transforming the Work Environment of Nurses. National Academies Press, Washington, D.C. . Retrieved from http://www.nap.edu/download.php?record_id=10851.
Perrow, C., 1999. Normal Accidents: Living with High-Risk Technologies. Princeton University Press, Princeton, New Jersey.
Pluye, P., Robert, E., Cargo, M., Bartlett, G., O'Cathain, A., Griffiths, F., et al., 2011. Proposal: A Mixed Methods Appraisal Tool for Systematic Mixed Studies Reviews Retrieved from. . http://mixedmethodsappraisaltoolpublic.pbworks.com.
Schenk, E.C., Mayer, D.M., Ward-Barney, E., Estill, P., Goss, L., Shreffler-Grant, J., 2016. RN perceptions of a newly adopted electronic health record. J. Nurs. Adm. 46 (3), 139–145. doi:http://dx.doi.org/10.1097/NNA.0000000000000313.
Staggers, N., Clark, L., Blaz, J.W., Kapsandoy, S., 2011. Why patient summaries in electronic health records do not provide the cognitive support necessary for nurses' handoffs on medical and surgical units: insights from interviews and observations. Health Inform. J. 17 (3), 209–223. doi:http://dx.doi.org/10.1177/1460458211405809.
Staggers, N., Clark, L., Blaz, J.W., Kapsandoy, S., 2012. Nurses' information management and use of electronic tools during acute care handoffs. West. J. Nurs. Res. 34 (2), 153–173. doi:http://dx.doi.org/10.1177/0193945911407089.
Stevenson, J.E., Nilsson, G., 2012. Nurses' perceptions of an electronic patient record from a patient safety perspective: a qualitative study. J. Adv. Nurs. 68 (3), 667–676. doi:http://dx.doi.org/10.1111/j.1365-2648.2011.05786.x.
Varpio, L., Rashotte, J., Day, K., King, J., Kuziemsky, C., Parush, A., 2015. The EHR and building the patient's story: a qualitative investigation of how EHR use obstructs a vital clinical activity. Int. J. Med. Inform. 84 (12), 1019–1028. doi:http://dx.doi.org/10.1016/j.ijmedinf.2015.09.004.
Vikkelsø, S., 2005. Subtle redistribution of work, attention and risks: Electronic patient records and organisational consequences. Scand. J. Inform. Syst. 17 (1), 1–28.
Ward, M.M., Vartak, S., Schwichtenberg, T., Wakefield, D.S., 2011. Nurses' perceptions of how clinical information system implementation affects workflow and patient care. CIN: Comput. Inform. Nurs. 29 (9), 502–511. doi:http://dx.doi.org/10.1097/NCN.0b013e31822b8798.
Weir, C.R., Hammond, K.W., Embi, P.J., Efthimiadis, E.N., Thielke, S.M., Hedeen, A.N., 2011. An exploration of the impact of computerized patient documentation on clinical collaboration. Int. J. Med. Inform. 80 (8), e62–e71. doi:http://dx.doi.org/10.1016/j.ijmedinf.2011.01.003.
Whittemore, R., Knafl, K., 2005. The integrative review: updated methodology. J. Adv. Nurs. 52, 546–553. doi:http://dx.doi.org/10.1111/j.1365-2648.2005.03621.x.
Zadvinskis, I.M., Chipps, E., Yen, P.Y., 2014. Exploring nurses' confirmed expectations regarding health IT: a phenomenological study. Int. J. Med. Inform. 83 (2), 89–98. doi:http://dx.doi.org/10.1016/j.ijmedinf.2013.11.001.