Review

Definition, structure, content, use and impacts of electronic health records: A review of the research literature

Kristiina Häyrinen[a,*], *Kaija Saranto*[a], *Pirkko Nykänen*[b]

[a] *University of Kuopio, Department of Health Policy and Management, Finland*
[b] *University of Tampere, Department of Computer Sciences, Finland*

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ABSTRACT

Purpose: This paper reviews the research literature on electronic health record (EHR) systems. The aim is to find out (1) how electronic health records are defined, (2) how the structure of these records is described, (3) in what contexts EHRs are used, (4) who has access to EHRs, (5) which data components of the EHRs are used and studied, (6) what is the purpose of research in this field, (7) what methods of data collection have been used in the studies reviewed and (8) what are the results of these studies.

Methods: A systematic review was carried out of the research dealing with the content of EHRs. A literature search was conducted on four electronic databases: Pubmed/Medline, Cinalh, Eval and Cochrane.

Results: The concept of EHR comprised a wide range of information systems, from files compiled in single departments to longitudinal collections of patient data. Only very few papers offered descriptions of the structure of EHRs or the terminologies used. EHRs were used in primary, secondary and tertiary care. Data were recorded in EHRs by different groups of health care professionals. Secretarial staff also recorded data from dictation or nurses' or physicians' manual notes. Some information was also recorded by patients themselves; this information is validated by physicians. It is important that the needs and requirements of different users are taken into account in the future development of information systems.

Several data components were documented in EHRs: daily charting, medication administration, physical assessment, admission nursing note, nursing care plan, referral, present complaint (e.g. symptoms), past medical history, life style, physical examination, diagnoses, tests, procedures, treatment, medication, discharge, history, diaries, problems, findings and immunization. In the future it will be necessary to incorporate different kinds of standardized instruments, electronic interviews and nursing documentation systems in EHR systems.

The aspects of information quality most often explored in the studies reviewed were the completeness and accuracy of different data components. It has been shown in several studies that the use of an information system was conducive to more complete and

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* *Corresponding author at*: University of Kuopio, Department of Health Policy and Management, P.O. Box 1627, FIN-70211 Kuopio, Finland. Tel.: +358 17162604.
E-mail address: kristiina.hayrinen@uku.fi (K. Häyrinen).

accurate documentation by health care professionals. The quality of information is particularly important in patient care, but EHRs also provide important information for secondary purposes, such as health policy planning. Studies focusing on the content of EHRs are needed, especially studies of nursing documentation or patient self-documentation. One future research area is to compare the documentation of different health care professionals with the core information about EHRs which has been determined in national health projects. The challenge for ongoing national health record projects around the world is to take into account all the different types of EHRs and the needs and requirements of different health care professionals and consumers in the development of EHRs. A further challenge is the use of international terminologies in order to achieve semantic interoperability.

Contents

1.   Introduction

Research and development projects are ongoing in several countries around the world to develop an infrastructure for national health information; examples include Canada [1], Australia [2], England [3], the United States [4] and Finland [5]. These projects share in common a number of elements, including (1) the aim of involving patients in the use of their own health records; (2) the need to define the core information of these records; (3) the choice and implementation of standards, nomenclatures, codes and vocabularies; (4) the need to develop the necessary data security infrastructure and policies; (5) the aim of producing open, standardized and interoperable EHR systems for data exchange and information management. Besides national projects, the European Union launched the European eHealth Action Plan in 2004. One challenge is to standardize health information systems, which also means standardization of the content and structure of EHRs [6]. In particular, a patient summary has been seen as the most appropriate way to establish eHealth interoperability. A patient summary includes patient history, allergies, active problems, test results, and medications. However, further information can be included, depending on the intended purpose of the summary and the anticipated context of use. Additionally, investigation into the amount of structured data of the patient summary is needed [7]. EHRs are a major focus

for current research in the field of health informatics [8,9] but the need for research from different approaches has also been noticed [10] The focus of recent studies concerning EHR has been on the possibilities of current technologies and underlying architecture (cf. [11–13]) and on exploring the health care registers as a source for evidence-based medicine [14].

According to the literature, the meaning of EHR is unstable. EHR has many functions and includes many kinds of data, and it is obvious that there is a need to determine explicitly what EHR means. Once that has been done, common ways to develop EHRs will be found, along with common viewpoints on what kind of research focusing on the content of EHR can be done in the future. The aim of this study is to determine what an electronic health record is and how far its content is standardized. An EHR is used primarily for purposes of setting objectives and planning patient care, documenting the delivery of care and assessing the outcomes of care. It includes information regarding patient needs during episodes of care provided by different health care professionals [15,16]. The amount and quality of information available to health care professionals in patient care has an impact both on the outcomes of patient care and the continuity of care. The information included in EHRs has several different functions in the decision-making process in patient care, and it also supports decision-making in management and in health policy. EHRs have so far consisted of unstructured, narrative text but also structured coded data. In the future it will be necessary to

implement more systematic terminologies and codes so that the data contained in these records can be put to better use in clinical research, health care management, health services planning, and government reporting [8,9,15,16]. Thiru et al. have reviewed the literature assessing the quality of data in EHRs in primary care. They report that the main focus has been on structured data elements, i.e. codes, classifications and nomenclatures. Most of the studies included in their review were descriptive surveys. Thiru et al. also draw attention to the lack of standardized methods for the assessment of data quality [17].

The present review focuses on research that is concerned with the structure and content of EHR systems. It aims to answer the following questions: (1) how is the EHR defined in earlier research, (2) how is the structure of EHRs described, (3) in which contexts is the EHR used, (4) who has access to EHRs, (5) what data components of the record system are used by end-users and studied, (6) what is the purpose of these studies, (7) what methods of data collection are used in the studies and (8) what are the results of these studies.

2. Materials and methods

An automated literature search was conducted on four databases with the assistance of a librarian. The databases were PubMed/Medline (National Library of Medicine, Bethesda, MD, USA), Cinalh (Cinahl Information Systems, Glendale, CA, USA), Inventory of Evaluation Publications (University for Health Informatics and Technology, Tirol Research Group Assessment of Health Information Systems) and Cochrane (The Cochrane Collaboration). On the *Cumulative Index of Nursing and Allied Health Literature* (Cinahl), the search was performed using thesaurus terms and free text words, combining them in an appropriate way. The terms used were: content analysis, content validity, evaluation research, computerized patient record, documentation, validation, utilization, classification, nomenclature, vocabulary, controlled and nursing classification. In addition, free text words were ANDed with the appropriate thesaurus terms and ORed with other search statements. The search was then restricted to journal articles. As it was expected that much of the research literature within the scope of the review would not be indexed, no time limits were applied.

On *PubMed/Medline*, the search was carried out in a similar way by using both the MeSH terms and free text words. The terms used were medical records systems, computerized, content, assess and evaluate, classification, vocabulary, controlled, coding and nursing classification. On *Cochrane*, the search was carried out using the same terms as on Pubmed/Medline.

On the *Inventory of Health Information Evaluation Studies* 1982–2002 database (evaldb), the search was based on the criteria that are used to classify studies [18]. In this study the search was performed using two criteria of the database classification: the focus of the evaluation study and the type of information system. The focus of evaluation study criterion is classified further; one criterion is the quality of the documented and processed information, i.e. completeness and correctness of documentation. The other database criterion

is the type of information system. Information systems are classified into several types, of which 12 were chosen for the present study: CIS (general or unspecified clinical information or documentation system) OR ANAEST (anaesthesia information and documentation system) OR CPOE (physician order entry system) OR GP (GP information system) OR LAB (laboratory management system) OR NURSE (nursing information and documentation system) OR OP (operation unit planning and management system) OR PACS (picture archiving and communication system) OR PDMS (patient data management system) OR PHARM (pharmacy information system) OR PIS (patient information systems) OR RIS (radiological information system).

The search yielded 299 papers. These papers were reviewed to exclude articles that did not meet the selection criteria: (1) focus on electronic rather than paper-based health record, (2) data content of EHR assessed or analysed, (3) paper written in English, and (4) articles electronically retrievable as full texts or available locally. Following this initial review, 180 papers were retrieved for more detailed evaluation. Forty eight papers were not available electronically or could not be obtained locally. Three studies had been published both in journals and in conference proceedings, and the latter were excluded. A total of 37 papers were excluded on the basis of the criteria specified for this review. The final number of papers included in the review was thus 89 (Fig. 1). The review paper by Thiru [17] is included in this review, but it is only considered under the items of time period, publishers and countries of research.

3. Results

The papers included in the present review were published between 1982 and 2004 in 52 different journals; three of them were published in conference proceedings. The top four journals with the largest number of articles were the *Journal of the American Medical Informatics Association* (n = 11), *Methods of Information in Medicine* (n = 6), *Computers in Nursing* (n = 6) and the *International Journal of Medical Informatics* (n = 4).

Most of the studies had been done in the United States (n = 43). A total of 37 papers were from European countries (United Kingdom, Germany, Sweden, Netherlands, Norway, Hungary, Italy and Finland); the remainder were from Hong Kong (2), Australia (1), Taiwan (1), and Canada (5) (Table 1).

The discussion below deals in order with each of the research questions. The themes in the articles were examined by means of content analysis. Each section begins with a description of the criteria informing the analysis. This is followed by a presentation of the results, which are finally summarized in tables.

3.1. How is the EHR defined?

EHRs were classified on the basis of the International Organization for Standardization (ISO) definition [19]. According to this definition, the EHR means a repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health
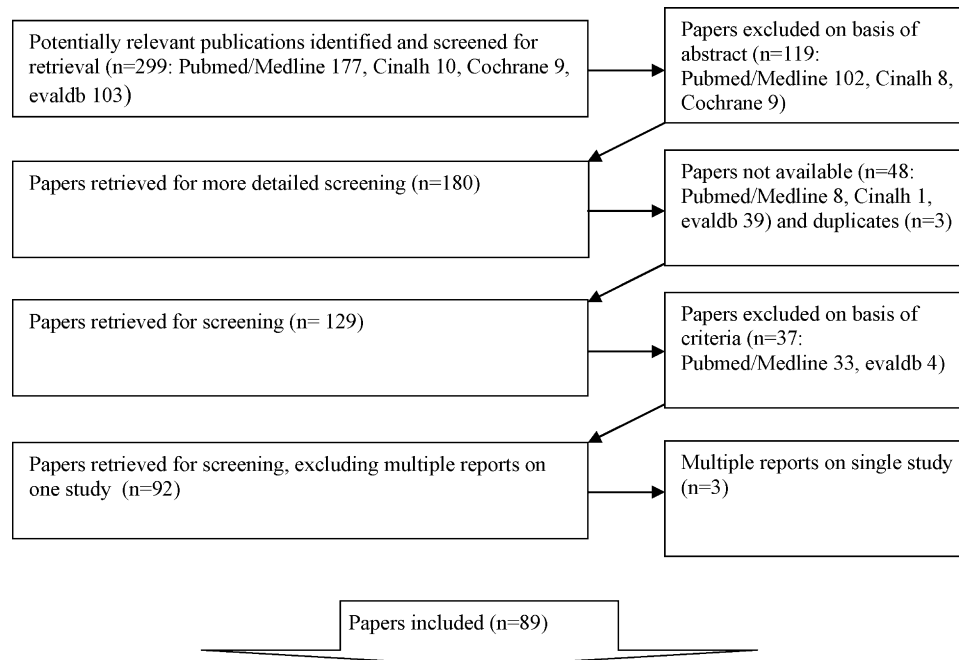
Fig. 1 – Flow diagram of review.

care. ISO also gives a number of other terms commonly used to describe different types of EHRs (Table 2).

The different types of EHR introduced in the articles reviewed are shown in Table 2. Electronic patient records were used both in hospitals [59–63] and in general practice [64–71]. Patients could use electronic interviews concerning their medical history [79–84] or enter information concerning their diabetes [85,86]. There were also computerized diaries that patients could use to control their medication [87], urinary voiding [88] or food intake [89] and to assess pain intensity [90]. The concept of computerized medical record was used in seven studies [91–97], but its meaning was the same as for computerized patient record. Furthermore, a separate or integrated computer-based nursing information system had been developed to support nursing documentation [29,53,55,56,64,98–104]. Standard computerized instruments have also been used by health professionals among other things to assess activities of daily living (ADL) [105] or pain [106]. One study provided no information on the type of information system assessed [107].

3.2. How is the structure of EHRs described?

The structure and content of EHRs has varied over time. Using earlier classifications of the structure of EHRs [108,109], we made a distinction between time-oriented, problem-oriented and source-oriented EHRs. Nowadays EHRs combine all three elements. In the time-oriented electronic medical record, the data are presented in chronological order. In the problem-oriented medical record (POMR), notes are taken for each problem assigned to the patient, and each problem is described according to the subjective information, objective information, assessments and plan (SOAP). In the source-oriented record, the content of the record is arranged according to the method by which the information was obtained, e.g. notes of visits, X-ray reports and blood tests. Within each section, the data are reported in chrono-

Time period	n = 89	Publisher	Country of origin
Table 1 – The time period covered, publishers and countries of origin of research papers included in this review			
1982–1989	7	Various medical and medical informatics journals (n = 7)	USA (n = 3); Europe (n = 3); others (n = 1)
1990–1999	34	Computers in Nursing (n = 4); Journal of the American Medical Informatics Association (n = 2); Methods of Information in Medicine (n = 1); International Journal of Medical Informatics (n = 2); various medical and medical informatics journals (n = 25)	USA (n = 22); Europe (n = 9); others (n = 3)
2000–2004	48	Computers in Nursing (n = 2); Journal of the American Medical Informatics Association (n = 9); Methods of Information in Medicine (n = 5); International Journal of Medical Informatics (n = 2); various, e.g. medical, nursing, medical informatics or nursing informatics journals (n = 30)	USA (n = 18); Europe (n = 25); others (n = 5)

Table 2 – Types of EHR		
Type of EHR (ISO)	Definition	Reference number
Electronic medical record (EMR)	Generally focused on medical care	
Departmental EMR ($n = 29$)	Contains information entered by a single hospital department	
Picture archiving and communication system (PACS)		[20–22]
Anaesthesia records		[23–26]
Intensive care records		[27–30]
Ambulatory records		[31]
Emergency department systems		[32–36]
Pathology laboratory system		[37]
Oncology records		[38]
Cardiology records		[39]
Operation theatre records		[40]
Gynaecology records		[41]
Internal medicine records		[42]
Pharmacy systems		[43,44]
Geriatric centre records		[45]
Diabetes clinic records		[46]
Radiology reporting system		[47,48]
Inter-departmental EMR ($n = 2$)	Contains information from two or more hospital departments	
Obstetric records for inpatient and outpatient clinics		[49]
Prescribing system		[50]
Hospital EMR ($n = 8$)	Contains all or most of patient's clinical information from a particular hospital	[51–58]
Inter-hospital EMR	Contains patient's medical information from two or more hospitals	–
Electronic patient record (EPR) ($n = 13$)	Contains all or most of patient's clinical information from a particular hospital	[59–71]
Computerized patient record (CPR) ($n = 13$)	Contains all or most of patient's clinical information from a particular hospital	[72–77,91–97]
Electronic health care record (EHCR) ($n = 1$)	Contains all patient health information	[78]
Personal health record ($n = 8$)	Controlled by the patient and contains information at least partly entered by the patient	[79–86]
Computerized medical record	Created by image scanning of a paper-based health record	–
Digital medical record	A web-based record maintained by a health care provider	–
Clinical data repository	An operational data store that holds and manages clinical data collected from health service providers	–
Electronic client record	Scope is defined by health care professionals other than physicians, e.g. by physiotherapists or social workers	–
Virtual EHR	No authoritative definition	–
Population health record	Contains aggregated and usually de-identified data	–

logical order [108]. The American Nurses Association (ANA) has developed a framework for nursing documentation which also corresponds with the SOAP structure for medical documentation. The nursing process had four stages: assessment, diagnosis, planned or delivered interventions and outcomes [109]. In addition to the structure of narrative text in EHRs, classifications are needed [108,109].

The structure of the EHR is described in only 15 of the papers reviewed. The SOAP structure appears in five papers [65,66,71,74,95], while computerized nursing documentation is structured around the nursing process in nine papers [29,55,56,64,100–104]. The steps included in the nursing process varied. Nursing documentation included at least assessment, the identification of nursing problems and nursing care aims, planning and delivering nursing interventions, and the evaluation of outcomes [29,56,64,94,100–103]. Further-

more in one paper the structure of EHR is episode of care oriented [67].

EHRs include both unstructured free text and coded data. Twenty-eight papers also described the terminologies used in these records, i.e. their classifications, vocabularies, nomenclatures or codes (Table 3).

Various other national classifications were also used in medical information documentation, including the Operationenschlüssel nach §301 SGB-V (OPS-301) [63,76] coding for procedures, the Swedish coding system [71], the problem list vocabulary [91], the controlled terminology medical entities dictionary [31] for problems, medications and adverse reactions and the drug dictionary for coding medication [50]. Different classifications were also used for purposes of nursing documentation (see Table 3). Outcomes were also described by means of unstructured statements, such as expressions

Table 3 – The international terminologies used in EHRs

Data component	International terminology	Reference
Diagnoses	International Classification of Diseases (ICD)	[27,46,48,49,54,57,59,63,65–67,72,76,78,94]
	Read codes	[68,92,93]
	International Classification of Primary Care (ICPC)	[67]
Procedures	Current Procedural Terminology (CPT)	[27,48,49]
Medication	Anatomical Therapeutic Chemical Classification Index (ATC)	[54,78]
Pathological findings	Systematized Nomenclature of Medicine (Snomed)	[37]
Nursing problems	North American Nursing Diagnoses (NANDA)	[100,101,103,104]
	International Classification of Nursing Practice (ICNP)	[101]
Nursing interventions	Iowa Nursing Intervention Classification (NIC)	[100,103,104]
	ICNP	[101]
Nursing outcomes	Iowa Nursing Outcome Classification (NOC)	[104]

of pain [103]. In Sweden the content of nursing documentation had a common structure based on the key words of the Swedish model for the documentation of nursing care, VIPS. The key concepts for nursing were Well-being, Integrity, Prevention and Safety. This use of key words from the VIPS model as headings for both assessment and interventions is one way to standardize documentation [64,101].

Standardized instruments for purposes of structuring patient information include the mini-nutritional assessment (MNA) and a modified version of the Norton scale [101], an assessment instrument about the patients' medical condition, activities of daily living (ADL), skills, behaviour, nursing care needs and rehabilitation potential, RUG II, assessment of patient functioning category (letter code) and Daily living score [105].

3.3. Where is the EHR used?

Health services are organised in different ways in different countries, but most typically they are divided between primary, secondary and tertiary care. Primary care is health care provided in the community by the staff of a general practice. Secondary care is medical attention provided by a specialist facility upon referral by a primary care physician, and tertiary care is provided by a team of specialists in a major hospital [110]. The context of the studies is represented in Table 4. A few of the studies were concerned with self-monitoring by

Table 4 – The context of the studies reviewed (n = 89)[a]

Tertiary care (n = 35)	Inpatient [21,23,27,28,30,32,35–37,44,47,50,53, 57,58,60,61,62,72,76,80–82,84,95,98,99, 101,103,104]; outpatient [24,38,42,45,52]
Secondary care (n = 34)	Inpatient [20,22,25,26,29,31,33,34,37,40,43,48,49,51, 54,55,56,59,63,74,75,79,91,102,106,107]; outpatient [39,41,46,73,77,78,83,87]
Primary care (n = 14)	[64–71,92–94,96,97,100]; home health care [105]
Home care (n = 1)	[85,86,88–90]

[a] In one study the context was both tertiary and secondary care.

patients in their homes (n = 5). Nine of the studies were conducted in more than one organisation, for example in two hospitals in one context (Table 4).

3.4. Users of the EHR system

The EHR is used by different health care professionals and also by administrative staff. Among the various health care professionals who use different components of the EHR are physicians, nurses, radiologists, pharmacists, laboratory technicians and radiographers. Furthermore, EHRs are also used by patients or their parents (Table 5).

3.5. Studied and used components of EHR system

The medical data components recorded in the EHRs are here categorized on the basis of the classifications used in the papers reviewed [32,36,71,74,75,93,95]. The following data components are identified: referral, present complaint (e.g. symptoms), past medical history, life style, physical examination, diagnoses, tests, e.g. laboratory and radiology, procedures, treatment, medication and discharge.

The classification of nursing data components is based on the components of nursing charting areas identified by Marr et al. [53] and on the nursing care plan. The components are medication administration, daily charting, physical assessments and admission nursing notes. Daily charting includes patients' daily functional activities such as vital signs, food, elimination, mobility and patient teaching. Physical assessment comprises all kinds of status assessments (e.g. skin status or respiratory status). Admission nursing note contains information on allergies, health behaviour (e.g. physical activity or smoking or sleep patterns), physical assessment (e.g. temperature and neurological status), discharge planning and initial care plan.

According to this review the area of the EHR that is studied most often is medical data (n = 37). Various medical data components have been analysed. Some studies have focused on just one data component such as tests; others have looked at almost all data components of the EHR. Several papers (n = 22) said that the documentation systems were used by different health care professionals and that secretarial staff typed the dictation of nurses or physicians and

Table 5 – Users of EHR systems and data components studied	
User (number of papers)	Component of EHR
Nurse ($n = 16$)	Daily charting [29,53,56,64,98,101]; medication administration [53,98]; physical assessment [53,100,105]; admission nursing note [41,53,101,107]; nursing care plan [29,53,55,56,64,98–104]
Physician ($n = 37$)	Referral [68,69,71,93]; present complaint, e.g. symptoms [30,31,65–67,70,71,73–75,77,91,93]; past medical history [32,36,62,75]; life style [68,75,93]; physical examination [23–27,36,62,68,71,75,93,106]; diagnoses [36,58,63,66,67,75,76,92–94]; tests [21,26,32,36,37,42,48,60,67,75,93]; procedures [58,63,67,76,93]; treatment [27,32,36,61,75,93]; medication [31,68–71,77,93]; discharge [32,36,54,59–61]
Patient ($n = 9$)	History [79,83,84]; diaries [85–90]; test [85]
Parents ($n = 3$)	History [80–82]
Secretarial staff ($n = 3$)	Procedures [40]; problems [96]; diagnoses [96]; findings [96]; immunization [97]
Pharmacists ($n = 2$)	Medication [43,44]
Multiprofessional ($n = 22$): nurse [28,31,33,34,49–51,68,72,78,95]; physician [20,22,31,33–35,38,45,49,50,52,68,72,78,95]; laboratory staff [28,72]; radiology staff [20,22,47,72]; clerk or administrative staff [22,33,35,38,47,49,51,52]; pharmacy personnel [78]; health care professionals [39,46,57]	Referral [46]; present complaint, e.g. symptoms [33,46,72,78,95]; past medical history [33,34,38,46,49,52,72,78,95]; life style [46,97]; physical examination [33,38,46,49,52,95]; diagnoses [31,34,46,51,68]; tests [20,22,28,33,38,39,46,47,52,72,95]; procedures [35,49]; treatment [31,34,49,57,95]; medication [31,34,43,45,46,50,68,72,95]; discharge [51,52]; administration of medication [78]; admission nursing note [34,38,51,72,95]; daily charting [28,33,34,46,72]

stored it in the information system. Nursing documentation has been studied in 16 papers, and 12 of these have focused on the documentation of nursing care plans. Patient self-documentation has been investigated in only a minority of the papers.

3.6. Purpose, data collection methods and results of these studies

To explore the purpose of the studies reviewed, we used the framework of DeLone and McLean [111]. van der Meijden has also used the same classification to study the success factors of information system implementation [112]. According to DeLone and McLean [111] information system success can be considered on six different dimensions, where the output of information systems is measured at the technical, semantic and effectiveness level. These dimensions are information quality, system quality, information use, user satisfaction, individual impact and organizational impact. System quality refers to the technical level, information quality to the semantic level and information use, user satisfaction, individual impact and organizational Impact to the effectiveness level. In their more advanced model [113] DeLone and MacLean added a third major dimension, service quality, for e-commerce purposes. Service quality refers to the service provided to the customer. Furthermore, in the advanced model, the success dimension information use has an alternative measure in intention to use, and individual and organizational impact has been combined in the single variable of net benefits. DeLone and McLean have also proposed that these dimensions are interrelated, which is why it is important to measure the possible interactions between the different success dimensions.

Each major dimension can be measured by various different success criteria. *System quality* assesses the information processing system itself, and its attributes (in the original model, 18) include ease of use, ease of learning or usefulness of system. *Information quality* measures both the output and input of the information system; attributes (23) here include completeness, accuracy, legibility, reliability and format. *Information use* measures end-users' consumption of the output of an information system, with attributes (12) including amount of use and number of queries. *User satisfaction* measures the end-users' response to the use of the output of an information system, and attributes (8) include overall satisfaction and decision-making satisfaction. *Individual impact* measures the effect of information on the behaviour of the end-user, and attributes (15) include improved individual productivity and information understanding. *Organizational impact* measures the effect of information on organizational performance, and its attributes (18) include return on investment and increased work volume [111].

The discussion below presents the results of our content analysis, classifying the purposes and results of the studies according to the original framework of DeLone and McLean. The data collection methods used in these studies were also analysed means by content analysis.

3.6.1. Impact of EHR on information quality
All of the studies included in the review analysed one or more of the information quality criteria mentioned above (Tables 6 and 7). In this analysis the most frequently used criteria were completeness and accuracy. The *completeness* of documentation was addressed in 55 papers. In this analysis completeness serves as a measure of the prevalence of missing information. Several studies indicated that the use of an information system was conducive to more complete documentation by health care professionals [24,27,29,31–34,36,38,39, 41,42,45–48,56–59,63,67,68,73,74,77,78,93,96,99,100], although

Table 6 – Research focusing on information quality and data collection methods used

Research focus	Quality of documented information: completeness ($n = 55$) [24,27,29–34,36,38,39,41,42,44–48,51,53,56–59,63,64,66,67,68,71,73,74,77,78,80–86,88,89,91–93,95,96,98–104]; accuracy ($n = 29$) [20,23,25,26,28,35,37,40,43,45,49–51,54,56,59,66,69,70,72,73,76,77,79,90,93,94,105,107]; legibility ($n = 2$) [64,99]; comprehensiveness ($n = 8$) [32,36,46,55,64,75,97,106]; consistency ($n = 3$) [61,62,87]; reliability ($n = 5$) [57,65,76,90,95]; relevant ($n = 1$) [60]; format ($n = 3$) [66,75,95]; timeliness ($n = 2$) [29,53]; availability ($n = 4$) [20,21,22,72]
Data collection method	Data review ($n = 66$) [20,23,25–30,32,34–43,45–49,51,53,55–60,62–66,68,71–75,77,80–84,88–91,93–103,105,106]; analyze database ($n = 22$) [23–26,28,33,50,54,59,63,67,76,78,85,86,87,89,90,92,97,104,106,107]; computer clock ($n = 1$) [53]; scanning documents and categorize ($n = 1$) [61]; interview ($n = 5$) [69,70,79,80,81]; videotaping ($n = 2$) [31,93]; observation ($n = 3$) [21,22,44]; focus group ($n = 1$) [98]; questionnaire ($n = 4$) [20,52,57,99]; search method ($n = 1$) [60]

the completeness of records does vary between different data components [34,38,46,77,93]. Furthermore, the documentation seems to include more detailed data [24,27,41,100,102]. In two studies it has been shown that structured data entry improves data completeness [59,74], and further in three studies that completeness improves with time [33,68,103]. Attention has also been drawn to differences between end-users [66]. Documentation by patients or their parents has also been reported to be good [80–86,88,89]. In one study, a mixed structured or directed text entry seems to be conducive to more in-depth documentation by patients [80]. The completeness of different terminologies varies. Some terminologies cover all or almost all necessary terms or statements [30,31,71,91,104].

Table 7 – Research focusing on aspects of information system quality other than information quality and data collection methods used

Research focus	Data collection method
System quality ($n = 32$)	Self-reporting [22,44,47,52,56,79,99,105]; questionnaire [21,44,50,65,69,81,99]; observation [21,27,29,35,44,47,73,80,98,100,107]; videotaping [31,42]; automatically by computer [20,24,41,52,65,106]; focus group [69,98]; interview [65,69,79]; log files [65]
Ease of use (record keeping time) [20,21,24,27,29,35,41,42,44,47,56,65,73,79,80, 98–100,105–107] Ease of learning [44,99] Usability [31,50,65,69] Timesaving [22,52,56,81,98]	
Individual impact attributes ($n = 4$) Changed clinical work patterns [98] Changed documentation habits [56] Decision effectiveness Speed of clinical decision-making [29] Changed habits [70]	Observation [98]; focus group [98]; data review [56]; audit charts [29]; interview [70]
User satisfaction ($n = 12$) Attitude [74] User satisfaction [35,44] User acceptance [28,47,73,80,84,87,88,90,99]	Interviews [74,80,87,90,99]; questionnaire [28,35,44,73,80,84,87,88,99]; observation [47]
Information use ($n = 6$) Frequency of use [21,92,104] Retrievability [28,62,74]	Analyze database [92]; requiring time [74]; interview [28]; semantic tagging search method [62]; usage data [104]; observation [21]
Organizational impact ($n = 17$) Communication and collaboration [27,29,56,99] Impact on patient care Patient satisfaction [55] Physician–patient interaction [24,42,73,75] Length of patient stay [31] Effects on patient care [21,102] Consumer reactions [41] Advantages of glucose meters [86] Satisfaction with radiology services [20]	Questionnaire [21,27,29,31,33,41,55,56,99]; interview [20,73,86]; videotaping [42,75]; audiotaping [75]; statistical analysis [20,105]; observation [24]; self-rating [102]
Training time [105]	
Cost (budget) [20]	

Data *accuracy* is analysed in 29 papers. Documentation was accurate according several studies [26,43,49,50,56,73,105,107]. In two studies, data entries by patients have also proved to be valid [79,90]. Structured data entries improved the accuracy of documentation [35,59]. Analyses of the *legality* of documentation found that the requirements of the law had been met in one study [99] but otherwise in one study there were shortcomings in this respect [64]. Eight studies focused on *comprehensiveness*. For the present purposes comprehensiveness was understood in terms of documentation in accordance with the regulations and guidelines. In this regard shortcomings were observed in a number of studies [46,55,64,75,97]. The use of an information system has also proved to provide more comprehensive data [32,36,106].

Consistency has been the focus of interest in three studies. These studies have drawn attention to inconsistencies [61,62,87]. Reliability has been explored in five studies. *Reliability* is defined as the extent to which measurements yield the same results on repeated trials. It has been shown that data from EHRs are reliable [90,95] when compared to manual records. One study addressed the issue of *relevance* [60]. In this analysis relevance is defined as the ability to retrieve material that satisfies the user's needs. The medical documents which were sent from hospital to general practice were relevant as input to the medical record [60]. The *format* of EHRs was analysed in three papers. Records have been SOAP structured [66,75], in one paper the record format POMR of EHRs has been preferred by physicians [95]. *Timeliness* was the focus of interest in two papers. No significant differences were observed in timeliness between desktop and hand-held computers [53]. One paper drew attention to a significant delay in the delivery of medication documentation [29]. Data availability was analysed in four studies. Availability means that the data were actually recorded and accessible to the end-user. Data *availability* was found to be sufficiently good for the data to be used in decision-making [72], and image availability was improved in systems using PACS [20,21]. Another study showed that there is no difference between conventional film and PACS [22].

3.6.2. Impact of EHR on other aspects of information system success factors

As was pointed out, the model proposed by DeLone and McLean consists of six dimensions of information system success. The main interest in the studies reviewed was on information quality, but other aspects of information system success were also addressed (Table 7). System quality has been analysed in 27 studies. The main concern has been with ease of use, which in this analysis means the amount of time taken up by recording-keeping (n = 21). There was no evidence that an information system can help to save time [29,35,42,99,100], or that documentations take more time [41,47,53,56,100,105]. Less time was spent on documentation when information systems were used [20,21,24,27,44,65,73,98,106,107]. Self-administered electronic interviews by patients take up as much time as conducting a full interview [79]. It has been reported in one study that unstructured text is more time-consuming than using structured questions [80]. The use of an information system for documentation takes more time, but on the other hand it was also reported to help save time for example in the search for paper documentation [22,99].

Four papers have also explored *individual impact attributes* such as changed clinical work patterns, changed documentation habits, decision effectiveness or altered policies to allow patients to see their own records. No changes have been observed in clinical work patterns. Bedside documentation was not successful [98], but improved quality of documentation was also reported [56]. The use of an information system had no impact on the speed of decision-making. Surprisingly, information system use gave rise to an increased delay in the delivery of medication [29]. Patients themselves thought they had a very limited role in reading their EHR summaries [70].

User satisfaction was the focus of interest in 12 papers. Physicians accept the new structured dictation procedure. In their view structured notes have no direct impact on patient care, but they recognize that they might facilitate research. The advantage of using a computerized system is that it makes it much easier to locate cases according to diagnosis codes instead of having to scan the whole record [74]. Physicians [35] and pharmacists [44] preferred the electronic documentation system over manual systems, but in one paper physicians preferred typewritten notes over a computerized system [73]. There is broad user acceptance of computers [28,47,84,99]. Information system use significantly increased acceptance of computers for documentation purposes based on the nursing process [99]. Computers were also readily accepted by patients [80,87,88,90].

Information use was the focus of interest in six studies. The frequency of use has been studied in three papers. The use of Read Codes to code diabetes varied between different practices from 14% to 98% [92]. A significant increase was reported in the average number of radiology images reviewed by clinicians [21]. It also shows that information was more easily retrievable from structured notes [74]. Physicians' ability to recall patient data was better when an information system was used [28], and semantic tagging of information significantly improved information retrieval from narrative notes [62].

Organizational impact attributes was the focus of interest in 16 studies. Attention has been drawn to the effects of information system use on communication and collaboration between different stakeholders. Computerized nursing documentation improved communication between physicians and nurses [99]. Communication between primary and secondary care based on a computer system has been described as be useful, and it has been reported to improve the readability of documentation [27]. Significant better experiences were reported of shift reporting when a computer system was used [29]. The nursing charting system also affects the work of other health care practitioners. Four-fifths of physicians indicated that it was very easy to review patient data on terminals [56].

The use of EHRs and its impacts on patient care was investigated in 10 studies. Bedside technology did not seem to affect patient satisfaction with the nurse–patient relationship [55]. The computer system did not affect physician–patient interaction [24,42,73]. Some negative effects were also reported [42,73]. Monitoring of diabetes at home has a positive impact on patient care [86]. The level of user IT-literacy was reported to influence physician–patient interaction [75].

The use of an information system had no bearing on patients' length of stay in hospital [20], and the computer system had no effects on patient care [21,102]. Patients have shown no serious reactions to the adoption of electronic systems, such as objections to the electronic interview [41].

No improvements were identified in the quality of radiology reporting service [20]. Training periods were long and more costly than expected [105]. The implementation of PACS has driven up costs, but outside radiology the system had also produced savings [20].

Methods of data collection varied, but most studies used qualitative methods (Tables 6 and 7). System quality was assessed by means of observation and time use by means of self-report, by computer or observation. In many cases the quality of the information documented was studied by means of content analysis against standards or guidelines, or by counting data items included in the documents or by quantitative analysis. Information use has been studied among other things by analysing databases. Among the methods of data collection used in studies concerning organizational impact or individual impact are semi-structured, in-depth or open-ended interviews, videotaping and questionnaires.

Comparisons of EHRs with manual paper records were presented in 45 studies [20–23,25,27–29,34–36,38–41,44,46,47,50, 51,53,55,56,58,61,63,67,69,72–75,77,93,95,97–100,102,103,105, 106]. Patient self-documentation was also compared with documentation by health care professionals, or patient documentation was validated by health care professionals [80,83,87–90].

4.   Discussion

A number of factors need to be considered in assessing the reliability and validity of this review. First of all, finding the right key words for the database search was extremely difficult, and therefore a librarian was consulted. Secondly, the papers were reviewed by just one researcher. Furthermore, the review was confined to papers that could be accessed locally and to English language papers. The classification of the studies according to their purpose was also extremely difficult, not least because they rarely provided explicit accounts of that purposes and therefore the inference had to be made by the author (KH).

The concept of EHR covers a wide range of different information systems from departmental systems to comprehensive electronic health care records. Various kinds of departmental EHRs such as intensive care records, emergency department records or ambulatory records have now been in use for a long time, but hospital-wide EHRs, primary care or personal health records are less common. A patient-centred electronic health care record was introduced in only one study, and personal health records in eight studies. Interestingly, the definition of EHR does not include nursing information systems or computerized instruments; however, descriptions of these systems or instruments were provided in the articles.

Few studies offered descriptions of the structure of EHRs, i.e. whether they were based on SOAP or the nursing process, even though studies from the 1980s in which the structure has been described were included in this review. The focus

of the studies has rather been on the use of different nursing and medical classifications, and international, national and local classifications have been applied. Furthermore, patient information has been structured by using different kinds of standardized instruments. Most EHRs are still primarily based on narrative text. Reuse of the data recorded in EHRs requires the use of different terminologies.

Most of the studies reviewed had been conducted in the context of tertiary or secondary care, which is where the first information systems were introduced. However some work has also been done in the context of home care. Research got under way in the early 1990s, and in the future patients will be even more closely involved in their own care. This means that patients will also be using EHRs both in health care organisations and at home.

EHRs are used by many different health care professionals, and the needs and requirements of all these professionals must be taken into account in the development of the information systems. EHR systems in multiprofessional use are precisely the information systems in such departments as intensive care unit or emergency department where the work by nature involves closer teamwork. On the wards, nurses and doctors record patient data in their own separate information systems, and the use of the other's documentation is difficult, which might also have an effect on patient care. Almost half of the papers concerned research into medical data components. However, nursing documentation, or documentation by other health care professionals such as physiotherapists, is an important part of the EHR and must not be excluded from medical documentation. Different kinds of standardized instruments are also an integral part of EHRs. Patients can also do parts of the documentation themselves. Patient self-documentation also reduces the workload of health care professionals, but it is obviously important that self-documented data components are validated by professionals. In a few studies, the documentation was done by secretarial staff according to the physician's dictation. However, the accuracy of documentation suffered when it was done by another person. It is important that all health care professionals who provide information record it themselves.

According to this review, the dimension of Information Quality in information systems was most typically measured by two criteria: completeness and accuracy. However, other dimensions relevant to the success of information systems were also analysed. The aspect of System Quality most frequently addressed was ease of use. Some studies also looked at the dimensions of user satisfaction, information use, individual and organizational impact. Both qualitative and quantitative methods of data collection were used.

The data included in paper-based patient records has provided the golden standard against which the reliability of EHRs has been assessed. The quality of the information recorded in EHRs is extremely important. The success of EHRs depends on the quality of the information available to health care professionals in making decisions about patient care and in the communication between health care professionals during patient care. Good quality of documentation improves the quality of patient care. It is important therefore to assess the quality of information entered in electronic systems by different health care professionals. Decision-making tools can

Summary points

What was already known before this study:

- The EHR has been developed for a long time.
- The content of EHR consists of unstructured narrative text but also structured coded data.

What this study has added to our knowledge:

- An overview of all the varieties of information systems included in EHR.
- An overview of the content of EHR.
- The finding that in EHR development work, nursing information systems and the patient's role in producing data for EHR have not been taken into account.

be integrated in EHRs if the record is structured and defined terminologies are used; however if the data are inaccurate or incomplete, they will have no worth for decision-making, research, statistical or health policy purposes. It is not at all clear and undisputed that record-keeping saves time, but it must also be taken into account that the use of computer systems improves the quality of documentation and reduces other tasks. The structured data could also have other uses. If patients could enter data on their own health history, physicians could use their own time more efficiently and concentrate more on communication with patients, for example.

5. Conclusion

On the basis of this review, it is obvious that studies focusing on the content of EHR are needed, especially studies of nursing documentation or patient self-documentation. Comparison of the documentation of different health care professionals with the core information of EHRs as determined in national health projects is one possible focus of future research. The challenge for ongoing national health record projects around the world is to take into account all the different types of EHRs and the needs and requirements of different health care professionals and consumers in the development of EHRs. A further challenge is the use of international terminologies in order to achieve semantic interoperability.

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