The Computerized Patient Record: Where Do We Stand?

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Summary

Objectives: To provide an overview of trends in research, developments and implementations of the computerized patient record (CPR) of the last two years.
Methods: We surveyed the medical informatics literature, spanning the years 2004-2005, focusing on publications on CPRs.
Results: The main trends revealed were: 1) the development of technologies to realize privacy and security goals or remote data entry and access to CPRs; 2) investigations into how to enhance the quality and reuse of CPR data; 3) the development and evaluation of decision support functions to be integrated with CPRs; 4) evaluations of the impact of CPRs on clinicians, patients, clinical work settings and patient outcomes; and 5) the further development and use of standards to move towards shared electronic health records (EHRs).
Conclusion: The CPR is playing a growing part in medical informatics research and evaluation studies, but the goal of establishing a comprehensive lifelong EHR is still a long way off. In moving forward to EHRs, convergence of EHR standards seems required to realize true interoperability of health care applications. User acceptance of present-day CPRs (for all categories of users) and compatibility with work patterns has not been achieved yet, and can only be realized by giving these goals high priority. This will require substantial resources for in-depth work flow analysis, development and evaluation of CPRs. Besides this, the implementation of effective CPRs asks for health care organizations that are willing to invest in new developments and to contribute to evaluation studies, to further improve CPRs' functionalities and enhance their use in practice.
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Keywords

Medical records systems, computerized; Computer security; Decision support systems, clinical; Evaluation studies; Health informatics, standardization

1. Introduction

Computerized patient records (CPRs) are considered to offer great potential for improving the quality and efficiency of health care services. The Institute of Medicine regards the implementation of CPRs as an essential technology for health care and one of the principal ways to improve it on a world wide scale [1]. In the past, some CPR implementations such as COSTAR [2], VistA [3] and the HELP system [4] have indeed been enduring successes, CPRs have proven to advance the quality of care and patient safety, facilitate work flow, decrease medical errors and reduce costs [5], and to improve communication among physicians [6, 7]. High system speed, integration of order-entry systems and decision support further enhance their use [8, 9].

However, CPRs in general have slowly disseminated and the EHR is still under discussion [10]. And yet health care organizations and their professionals and patients nowadays make high demands upon CPRs, and we are far from realizing CPRs that fulfill all these requirements.

But there are promising approaches to cope with the worldwide trend of aging societies and the accompanying growth in chronic diseases and multi-morbidity. These require an even higher level of specialization than present day health care, and hence progressively more shared care [11], which necessitates co-ordination of health care activities through communication [12], information handling and exchange [13]. CPRs should support this by facilitating effective communication among clinicians, which in turn may have a great impact on the quality and safety of health care delivery. Patient data have thus to be shared by multiple care providers, preferably simultaneously and with wide geographical availability of CPRs. In order to realize shared-community based CPRs, typified as EHRs, a variety of standards are under development to enhance information exchange and communication among health care providers through interoperability of health care applications. Besides that, CPR data have to be shared by multiple care providers; computer applications use this data to support these care providers in decision making [14].

Yet, patients regard the information concerning their health as private and expect access to their CPRs to be controlled [15], yet relevant information to be accessible for all their care providers. Consent-based, fine-tuned privacy rules on individual patient information use are needed to regulate access to CPRs' contents [14]. This leads to the demand to develop technologies to realize privacy and security goals.

Then, the role of the patient is changing from a passive receiver of care to an active participant who wants to be informed on his prospects as regards his health status, and involved in the medical decision making process. This is one of several areas in which telematics is becoming increasingly important in connection with CPRs [16-18]. Involving the patient as an active participant in the care process, including access to and development of her/his CPR, opens up new avenues, triggering demand for more remote data entry and access to CPRs.
Other demands in the development of CPRs stem from the requirements that medical decision support, operations and quality management pose on the structuring and standardization of medical data to enable reuse and processing of these data by other computer applications. Furthermore, evidence-based medical practice imposes heavy demands on the quality of health care services. This necessitates investigation of how to enhance the quality and reuse of CPR data as well as development and evaluation of decision support functions integrated with the CPR.
Last but not least, it only makes sense for CPRs to spread in health care organizations if their users value these systems, because a CPR's usability may in turn have an impact on the quality of the data entered. Apart from their technical and functional features, CPRs' acceptance is also highly influenced by smooth integration into the clinical work settings, so they should be designed with explicit consideration of the working practices of their ultimate users. This leads to the demand to evaluate the impact of CPRs on health care workers.
In this contribution, we provide an overview of those trends in CPR research, development and implementation studies of the last two years which address the requirements named above: With the help of examples we describe new technologies designed to realize privacy and security goals, remote data entry and (mobile) access of CPRs by patients and clinicians, studies that have focused on the quality and reuse of CPR data, or on decision support functions to be integrated with CPRs, on the impact of CPRs on clinicians, patients, clinical work settings and patient care, and the state-of-the-art of health care standards developed for realizing interoperability of CPRs.
Finally, we give an overview of the lessons learned from CPR implementations in different national settings.

2. Results

2.1 Developing Technologies to Realize Privacy and Security Goals

Electronic signatures based on a public key infrastructure (PKI) using asymmetric cryptographic algorithms can be important both for privacy (confidentiality of content) and security (integrity and authenticity of content) of CPRs.
However, PKI technology has proved expensive and also too complex for end users. So Sax et al. and Jelekäinen [19, 20] suggest that the health care industry should harness existing cell phone infrastructure rather than trying to set up its own. Obvious advantages are that cell phones are widely distributed, have high user acceptance and offer advanced security protocols.
Electronic signatures have a limited lifetime (up to 5 years), whereas some health-related regulations require the storage of patient information for 30 years and more. This problem can be solved by re-signing data items – i.e. providing them with a new signature whenever the current signature is nearing the end of its lifetime. Pharow and Blobel [21] discuss and compare different re-signing mechanisms.

2.2 Developing Technologies to Realize Remote Data Entry and Access to CPRs

The Patient as an Active Participant

An important and little-researched question is how to make e-consent (electronic consent) systems that really sup port the patient's interests, balancing patient privacy against patient safety and offering flexibility for differing health sectors and patient wishes. Patients may use these kinds of systems intensively as they truly accommodate their needs [22].
Coiera [16] identifies different dimensions of possible models of e-consent and considers the impact on different clinical working patterns, concluding that a good e-consent model should take account of patient preferences, clinical safety and the impact on physicians' workloads, and sketches an accordingly flexible information architecture to support an e-consent system.
The actively participating patient should ideally have secure access to, and storage of, an integrated lifelong health record, generally known as an EHR. Simons et al. [18] designed and implemented the architecture of such a record system, in which each patient personally controls access to his or her record. This system is managed by free, open source software. It avoids some of the problems that beset EHR projects, owing to the fact that it is not designed to be the primary record of the health care system: It is a comprehensive copy of all medical data in the patient's history. A further dimension of active patient

participation involves enabling patients to enter certain health status data into the CPR system themselves, preferably from home, thus saving health workers' time for other tasks and themselves from disruptions of their lives by visits to care providers. Giorgino et al. [23] report on an intelligent phone dialogue system via which hypertensive patients can deliver health status data by phone: The CPR which stores the data thus collected is also used to analyze this data in order to tailor the flow of the dialogue to the patient's health status and to his preferred dialogue style in previous interactions.

Mobile Access to CPRs within a Hospital

The growth of handheld computer use in clinical practice has occurred largely without plans or extensive budgets; physicians use them for a variety of purposes, often buying them themselves and connecting them up to the hospital network [24]. Thus a considerable proportion of physicians seem to be interested in using this technology to improve their working environment, to gain mobile access to the hospital CPR system [24-29] wherever and whenever it is needed in the hospital. However, usability evaluations should precede their implementation, because interface problems are closely associated with the occurrence of errors in using these systems [30].

A pilot project with wireless handhelds furnished with software to give physicians reading access to the hospital CPR system [27] has shown that wireless handhelds have the potential to alleviate the problem of inadequate access to clinical information. Given the limitations of handheld devices, Reuss et al. [26] investigated the frequencies, patterns and time frame of physicians' accessing of patient records during their ward rounds. They concluded that a mobile CPR system designed to reflect these access frequencies and patterns should improve the efficiency of data entry and retrieval, and thus result in a system with high acceptance among physicians in the demanding environment during hospital rounds. For example, the most frequently used functions of the system should require the shortest, easiest input to select them; and if a certain action is very often followed by a particular further action, then the input necessary to trigger this sequence of actions should be optimized.

On the other hand, as regards writing access to CPRs, using handheld computers rather than handwriting to record data at the point of care produced only a modest reduction of the number of documentation discrepancies [25].

2.3 How to Enhance the Quality and Reuse of CPR Data

The Impact of CPRs on Data Quality

Today, CPRs are used first and foremost to support patient care, and are thus judged by their end users on their value for direct patient care [31, 32]. However, advancing CPRs' value so as to prompt better care, coordinate care, and support medical decision making and operations and quality management, requires sufficient reuse of pre-entered patient data for multiple purposes [33]. Thus, the accuracy of CPR data is of vital importance for all health care areas [32], and measuring, characterizing and finding ways to improve the accuracy of data in CPRs is essential [34]. It has been shown that CPR data is more likely to be of high quality when the provider regards that information as important and relevant for future reuse. Time-pressured, frequently interrupted clinicians consider information that bears no direct significance to tasks related to routine patient care as of little importance [34], and thus may be reluctant to enter this data. So enhancing clinicians' awareness of the importance of appropriate multi-purpose documentation and automated functions for patient monitoring and decision support is essential to improve the quality of CPR data [34, 35].

Considerable efforts have been expended on ensuring high data quality by tuning the structure of CPRs. Different ways of organizing patient records to fully support health care professionals have different effects on the accuracy of data relevant for navigation and information retrieval [34]. Of these, the problem-oriented structure is considered a good way of describing the care process, but is as yet not broadly accepted, possibly due to the increased work load involved in the recording of data. The recently proposed Problem-Driven Health Record (PDHR), an advanced interdisciplinary problem-oriented view of the CPR [36], does not require redundant recording of patient data and may be more acceptable to its users in recording routine care data.

A major concern of clinicians is that CPRs could sacrifice some of the richness of data quality inherent in the written medical record. But overall, greater completeness of CPR contents compared to paper-based records is reported [31, 37]. CPRs used in primary care seem to contain more details of patient diagnoses, advice given to patients and drugs prescribed, and are therefore more understandable than paper-based records [38]. A vast majority of patient problems is coded in general practice CPRs with a high level of completeness and accuracy of diagnostic codes [32]. The quality of coded clinical data in CPRs used in general practice can be enhanced even more by offering a program of repeated assessments, feedback and training of its users [39]. Use of bedside nursing documentation systems has been shown to increase the number of CPR data entries by nurses [31]. As described, besides clinicians, and patients themselves may contribute to the documentation of their own medical data via various computer supported systems. Patients indeed seem compliant with following the reminders to enter data at preset times, and apparently make few errors or omissions if guided by the system [40, 41]. Patients' parents likewise provide high quality data on the medications of their children, and their reports seemingly improve on the validity of current documentation by physicians and nurses [42].

Reuse of CPR Contents

In the 90s, the need to integrate decision support into hospital information systems was already being emphasized [43]. Nowadays, the reuse of CPR data for multiple purposes, including decision support, is still regarded as a key factor for success [44, 45].

As an example, Hazlehurst et al. [46] describe a knowledge-based system which processes clinical narratives as well as structured data, to subsequently encode these automatically for further analyses. This system does not limit the expressiveness of physicians' notes, but nevertheless the data can be processed for other purposes such as quality management or research.

Rosenbloom et al. [47] look at a different aspect of integration: They observed that clinicians resisted using a clinical note capture tool when it was not sufficiently integrated into the clinical workflow. Since a CPOE system was already established, the tool was integrated into this, whereupon its usage increased substantially.

It can be helpful to use knowledge as well as data for multiple purposes. Therefore, Hulse et al. [48] describe a knowledge authoring tool which can easily be used by physicians to create structured clinical knowledge documents represented in XML. These knowledge documents are collected in an enterprise-wide knowledge repository whose content can be used in a variety of applications. As current application areas, they mention knowledge about order sets for CPOE and an online clinical reference for interdisciplinary patient care standards.

There are several other examples of successful integration of clinical decision support into CPRs, e.g. [49-52].

The structuring of CPR data entered by clinicians is essential for applications that are to process these data. Structured data entry tools have failed their expectations mainly because the manner of data entry differs significantly from present routines. Solutions such as OpenSDE - an application that supports structured data entry in and extraction from CPRs in diverse medical settings and avoids redundant recording - make CPR contents available for both routine care and research [53-55] and may help to structure medical narrative data in CPRs in a way that can accommodate unforeseeable and varying data.

2.4 Decision Support Functions Integrated with CPRs

CPR and Guideline Knowledge

The focus on implementation of clinical guidelines in medical practice has already resulted in numerous approaches to make them evidence-based, semantically right, customized to the individual patient, available, sharable and maintainable [56-59].

Sharing and maintaining guideline knowledge has been the motivation for developing a sharable language that could serve as a standard for modelling computer interpretable guidelines [60]. Peleg et al. [61] describe lessons learned from the collaborative development process that may be useful for other decision support systems.

If there are no guidelines available, the best evidence for a current clinical problem normally comes from external resources. In Aphinyanaphongs et al. [62] the performance of machine learning techniques basing on text categorization is compared with Boolean-based approaches for automatically identifying high-quality, content-specific articles providing best scientific evidence that applies to a patient problem.

CPR and Adverse Events

Another CPR application area for machine learning techniques is the automatic analysis of medical reports to identify adverse drug events (ADE) for quality management purposes.

A term searching strategy to detect adverse events in discharge letters was evaluated with a rather low sensitivity (0.23) but a rather high specificity (0.92) [63]. A strategy based on natural language processing showed comparable results on a slightly higher level (sensitivity about 0.28, specificity 0.985) [64].

According to Field et al. [65], usage of spontaneous reporting to detect ADEs leads to underestimation of the incidence of these events, whereas systematic chart review is very time consuming. It is shown that a combination of several manual and computer-supported strategies may be helpful in detecting ADEs with an acceptable positive predictive value. This is also true in the case of adverse events caused by medical devices [66].

In the setting of general practitioners in the Netherlands, Vandenberghe et al. [67] tested a semi-automatic method for collecting prescription information from the electronic medical records, realized by five different software systems, in comparison to a paper based data collection. In their opinion the approach proved suitable for assessing the quality of prescribing, although the results were heterogeneous among the different software systems.

Computerized Physician Order Entry

Computerized Physician Order Entry (CPOE) systems have a role in preventing medication errors and adverse drug events by offering clinicians support in prescribing medication or by alerting them on adverse events.

This is one of the most discussed aspects of using decision support in clinical routine in recent years. In particular, Koppel et al. [68] induced a controversial discussion by analyzing the role of CPOE in facilitating prescription errors. Using multiple qualitative and survey methods, they found 22 types of prescription errors that could be caused by CPOE, and which are said to occur at least weekly. They conclude that, when introducing CPOE systems, the errors they may cause have to be considered as well as those they may prevent.

The basic functionality for CPOE is electronic prescribing of medication. An expert panel developed a set of 60 recommendations for capabilities of electronic prescribing systems that would lead to improvements related to patient safety, health outcomes or patients' costs [69]. Wang et al. [70] found that on average, available systems fully implemented only 50% of these capabilities. In addition, Bell et al. [71] developed a conceptual framework for evaluating potential effects of e-prescribing systems based on their functional capabilities. It is based on a process model for medication management which is applicable to both handwritten and electronic prescribing. Each step of the model is regarded as introducing a potential source of error. It has to be taken into account that a functional capability which is expected to have a positive effect can be implemented in a way that creates unintended hazards.

CPOE enhances electronic prescribing with decision support functions. An example of a useful application area is antimicrobial prescribing, because there is the risk of prescribing an antimicrobial which is not active against the given disease, causing an adverse drug event, and potentially increasing microbial resistance. Sellman et al. [72] found that only half of the physicians they interviewed used external resources to aid the prescription process, although about 80% would have welcomed recommendations if they had been conveniently available within the CPR system.

The study reported in [73] showed a considerable change in physician behaviour related to digoxin use, when potential risks were alerted. These physicians felt that the alerts resulted in a safer use of digoxin. Alerting on contraindicated medication also proved helpful for patients suffering from renal insufficiency [74]. CPOE is expected to be better accepted by physicians if predefined problem-specific order lists appropriate for a given clinical situation or suggestions for alternate tests are presented to them [75-76]. Nevertheless, physician adoption of decision support remains a difficult task and wide variability in adoption and usage of these systems is reported [44, 77-81].

The consensus white paper of Teich et al. [82] describes recommendations and action plans to fully realize the potential benefits of CPOE. These include advances in system capabilities, uniform standards and appropriate incentives to promote adoption. Clinical decision support systems' "…impact increases as more types of data and workflow are combined together in a single system or interoperable set of systems… progression to (or close interoperability with) a more comprehensive EHR is necessary to reap the full spectrum of benefits" [82].

2.5 Evaluations of the Impact of CPRs

Clinician and Patient Satisfaction/ Acceptance

A critical factor in the slow spread of CPRs has been low physician acceptance [60], whereas physician acceptance is an important component of a CPR's success and proclaimed as essential to the survival of a system [9, 83]. User satisfaction with CPRs has been proven to be related to multiple factors such as computer literacy, age, gender and previous exposure to other CPRs [83], but also ease of use, work efficiency and effectiveness and the impact on patient care [83-85]. Recent studies on physicians' and nurses' acceptance of CPRs show favorable results, with user satisfaction mainly positive [6, 86-87] despite some concerns about data confidentiality and medical record security [6, 66], loss of professional privacy and judgment [86] and the additional work load [86, 88].

Physicians may be more likely to perceive a decision support system as useful when the new technology is smoothly integrated into their clinical work setting [89]. According to Goldstein et al. [90], integration of decision support systems requires careful analysis of the organizational context. The authors introduce an approach to integrating a decision support system for hypertension that automates clinical guideline knowledge into the clinical setting by addressing technical/informatics aspects and social/organizational aspects in an integrated manner.

But the most important barriers to user acceptance of CPRs are all time related: Low system speed, long waits for a computer to become available, time spent on documenting care and retrieving documents have all had a strong negative impact on acceptance of CPRs by their users [6, 7, 9]. Results of two recent reviews [9, 86] suggest that nurses are more likely to gain time efficiencies by documenting patient information than physicians.

Though study results on the time spent in documenting patient information using a CPR are not conclusive, the availability of and access to patient documentation and communication between physicians seems enhanced by CPR usage [6, 7], and may even outweigh negative impacts of CPR [7].

But while patient documentation may in principle be more available and accessible when created directly in a CPR, this is not to say that the comprehensiveness of this data is enhanced by computerization alone. Clinicians have expressed concerns about the comprehensibility of CPR data and even feel that CPR use might contribute to mistakes [7]. In many instances, navigation and orientation problems in the CPR make it hard for clinicians to gain a rapid overview of the patient's clinical problems [6, 91]. Since reviewing patient data in the context of a patient visit is time-limited, it is of great importance that CPRs support clinicians in retrieving data relevant for the clinical context in an understandable and efficient way [91].

Patients are the final group to be affected by CPRs. They seem to have positive opinions of CPRs, but have expressed some fear concerning their privacy and the confidentiality of their data [86, 92-93]. Though physicians themselves worry that computers may negatively affect their role as care provider [83], these concerns are not confirmed by research findings. Whereas physicians perceive CPRs as a physical barrier that could reduce eye contact with their patients [87], patients themselves do not report any such reduction and have even found medical consultations more satisfactory [94] and more effective [86] after CPR introduction, mainly because of improved physicians' familiarity with them, improved communication on medical issues, and comprehension of decisions made by their physicians. Physicians also fear that CPR usage during their patient encounters may leave less time for patient needs [7, 94], but studies have found no reduction in time spent with patients [7, 31] or in patients' satisfaction with available visit time [94] as a consequence of CPR use.

CPRs in Different National Settings

The map of CPR development and usage worldwide is changing continuously, and the papers published in any one year represent local snapshots.

There is as yet very little statistical information on the diffusion and quality of CPRs. Nøhr et al. [95] report that in Denmark 7% of all hospital beds are covered by a CPR system, whereas 19% of German acute hospitals employ a CPR [96]. These figures may seem low, but is probably fairly typical of the situation in developed countries. However, mere comparisons of the CPR coverage in different nations or areas would in any case be of little practical value unless they were based on a precise definition of what is to be regarded as a CPR. Jaana et al. [97] illustrate the importance of developing meaningful metrics for CPRs, by revealing differences in clinical IT sophistication between hospital CPRs in Iowa and Canada: Although hospitals in Iowa appear to have more technologies, they have fewer computerized processes and less integration of patient management applications than hospitals in Canada.

CPR reports from the developing world are of particular interest: These are the geographical areas in which to expect the most change relative to the status quo and the greatest human benefit. And these CPRs can be useful as prototypes, to be adapted to, or provide ideas for, local situations elsewhere. Rotich et al. [85], and Siika et al. [98] report on pioneering CPR systems in sub-Saharan Africa: "A simple, inexpensive and effective electronic medical record system can be established and *work* in a resource-poor developing country."

2.6 Health Care Standards

In order to move forwards towards the goal of EHRs - integrated, longitudinal, cross-institutional digital health care records - standardization in health information and communication technology is required to realize interoperability of independent health care system applications. Currently, several standards are under development to address the EHR interoperability issue of which DICOM [99], the CEN ENV13606 EHR standard [100], the HL7 standard including its CDA [101] and OpenEHR [102], are the most discussed. Data structures and services for software independent medical image-exchange are provided by DICOM, which has been extended into a standard (SR) using a tag-based data model for the structured encoding of medical reports and other clinical data. Another extension to the DICOM standard is WADO, a standard for web-based retrieval of DICOM objects via HTTP or HTTPR from web servers [99].

The CEN/TC 251 provided a first fully

implementable EHR standard with ENV13606, a message-based standard to enable communication between EHRs, which allows for a more fine grained exchange of information than documents do. First experiences with this standard revealed some weaknesses limiting its usefulness which let to a near completed revision of this communication standard [100].

At present, the HL 7 standard- version 2 is the most widely implemented standard for the exchange of health care messages. Its great flexibility however had a negative impact on achieving interoperability between health care information systems. To further enhance health care applications - interoperability, its version 2 is converted into a new version based on a Reference Information Model (RIM), a comprehensive non-discipline specific, object-oriented information model of patient care and of the providers, institutions and activities involved. RIM is thus a shared model between all medical subdomains and, as such, all these subdomains have to create their messages from this model [see for example 103]. Moreover, this HL 7 version-3 provides a document mark up standard - CDA, to define the structure and semantics of medical documents which are subsequently encoded in XML specifications and derive their meaning from the RIM [101, 104]. HL7's version-3 is now being used in a number of projects to share electronic health care data across institutions and seems a promising method to enhance data exchange across institutional borders [see for example 105].

OpenEHR, though officially not a standard, provides a generic EHR reference model and was the first to introduce the notion of "archetypes" - constraint rules and ontological definitions that specialize and define the generic data structures that can be implemented using the reference model, and a formal language ADL (Archetype Definition Language) to express these archetypes [102].

The common goal of achieving interoperability of health care applications is addressed by these standards and many requirements for health data exchange are yet covered by these standards. Besides, these standards are very similar in trying to achieve this goal; All combine a general reference model with rules of how to map clinical data onto this reference model. A somewhat negative by-effect of the large number of EHR standards under development may be that health care institutions that conform to one of these standards will not directly achieve interoperability between their systems and systems of other health care institutions that may have decided to use another, incompatible EHR standard. Fortunately, the major parties in the area have decided to collaborate in different ways to obtain unification of their set of standards. In this respect, the collaboration between CEN TC/251, HL 7 and OpenEHR is worth mentioning. Both CEN TC/215 and HL 7 have adopted the technology of archetypes and templates developed by the OpenEHR foundation.

3. Discussion and Future Perspectives

Discussion of the Results

The tremendous complexity of developing and implementing fully functional systems and the high costs associated with CPR development [9] in the past decades have often resulted in immature products and consequently low acceptance of these systems [6], and CPR failures have increased awareness of the investment risks of a CPR that may not be accepted in the long term [83]. Fortunately, the CPR is playing a growing part in medical informatics research and evaluation studies.

New and not-so-new but increasingly mature and widespread telematics technologies are enabling us to set our sights on new, ambitious targets concerning CPRs, with a great potential for improving the quality and efficiency of health care services. The most ambitious of these is the establishment of interoperable, open source CPRs within a distributed security infrastructure which supports sharing of their contents by multiple health care enterprises. Particularly in this context, the technical realization of privacy and security goals and the further development and convergence of EHR standards is still a challenge.

Two further telematics-based goals, both with many independent projects running, are those of improving physicians' access to CPRs in the hospital using wireless handhelds [24-29], and improving patients' access to their own records from home. The field of telehome monitoring is the older and more mature one, and is now at the stage at which the focus is not on transmission technology but on user interfaces and improving patient acceptance and adherence (e.g. [23]); projects to access CPRs in the hospital via wireless handhelds seem to stand a good chance of acceptance by physicians.

The comprehensiveness and quality of the data in CPRs is still not warranted, and should be enhanced by better presentation, using presentation formats that support clinical practice.

Decision support systems that are integrated into a CPR are much better adopted than the earlier stand alone versions. Computerized physician order systems are now in routine clinical use and alerts are integrated with routine clinical documentation, but adoption of these systems by physicians is still a significant challenge. The main goal here is to deepen our insight into how these systems may change work practices, to evaluate whether and how they are being used and finally to understand why they may or may not be adopted into routine practice [91, 106-107] Besides, clinical work flows should be taken into account when designing CPR systems so as to enhance full integration of these systems into routine clinical practice [8, 107-109].

We reported on several approaches to realize automatic encoding and processing of routine clinical data, with the aim of using the acquired information for additional purposes, including decision support for physicians. Although the approaches are said to be promising, we have to be aware that the output of these tools is still a long way from the optimum of structured data based on a standard terminology. The results are promising with regard to specificity, but it has not yet been specified what level of precision and recall is really required for effective quality management of, for example, ADEs. We have to consider carefully, to what extent these results can motivate the use of automatic approaches for coding and/or detecting adverse events and how these automatic tools perform in comparison with the gold standard of manual review. The examination of Friedman et al. [110] has shown that even among experts, precision and recall can range between 0.61 and 0.91.

CPRs' impact is still widely assessed from their users' and patients' perspectives by evaluating single processes. But whereas a CPR may have a negative effect on a single factor which is measured, it may have a favorable effect on another factor which is not assessed in the study. Recent reviews have shown that evaluation studies that focus on a variety of factors are indeed more informative [9, 31, 86]. These factors cannot all be measured quantitatively and statistically analyzed. If we are to reveal the impact of CPRs on multiple, often related processes, we also need qualitative methods to acquire a more complete picture of the causes underlying a CPR's success or failure. Moreover, most evaluation studies are summative in nature, conducted with a CPR already in use. Summative evaluations allow adaptation of a CPR only after its introduction, whereas formative evaluations would allow CPR improvement during its development or pilot implementation. Formative evaluations may be of great help during CPR system design and may prevent some potential problems before a CPR is introduced in practice. Finally, these kinds of evaluation studies allow research interests to emerge over time as evaluation results become intermediately available. Overall, this suggests that a shift in our evaluation methods is needed, including longitudinal assessment of multiple factors in an ensemble of processes, quantitative and qualitative methods to get a grasp of the influence of a CPR on each of these factors, combinations of both summative and formative approaches, and study designs that allow adaptation to the research findings [91, 111-114].

The effect of CPRs on patient outcomes has not often been considered in evaluation studies and is thus less clear. Evidence of positive impacts of CPRs on preventive care are noted, but improvements in medical practice and better adherence to guidelines are less certain [86]. CPRs could decrease prescription errors, although most of these studies have produced indefinite results [115]. So whereas clinicians acknowledge the usefulness of CPRs in improving the quality of care [87], the results on clinical performance or patient outcomes are not always conclusive.

Future Perspectives

The most important challenge for future CPRs is to establish an EHR to support the shared care paradigm. Yet the goal of establishing a comprehensive longitudinal, cross-institutional EHR that is the primary record of the health system is still a long way off. For example, in Denmark different approaches are being developed in different counties [17]. Ultimately, CPRs will have to be interoperable in order to cope with patient mobility, but parallel development of independent regional systems is a way to gain experience in this new field, in preparation for attempts at agreeing on data content and information models [17]. Patient acceptance is particularly important for the EHR, and depends strongly on earning the confidence of the general public that the system ensures the privacy and security of their data in spite of making it more easily accessible – no easy task. Another challenge is how to compile and sustain a coherent EHR across the life-time of a patient. It has recently be argued that a non-centric, independent and regulated approach can ensure the objectivity of the life-time EHR service, which is crucial to most parties in providing high quality patient data, reducing costs of record-keeping, and better support of patient privacy [116].

And, last but emphatically not least, for any CPR system, user acceptance (for all categories of users) and compatibility with work patterns (of health care workers) and with overall circumstances (of patients) can only be achieved by giving them high priority right from the start. This will require early and continuing involvement of all user groups, and substantial resources for in-depth work flow analysis, development and evaluation of CPRs. Besides these investments in research and development of CPRs, the implementation of effective CPRs asks for health care organizations that are willing and able to invest in new developments and to contribute to evaluation studies, so that we all can learn from these experiences to further improve CPRs' functionalities and enhance their use in practice.

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