

The computerized patient record: balancing effort and benefit

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Abstract

Promise and reality: this review addresses two questions. First, why is the introduction of the computerized patient record (CPR) so slow, while its potential for improved quality of care and reduction of cost is well recognized? Second, what, in this respect, is the role of record architecture and standardization? *Barriers:* the impediments for CPR adoption are put in a larger context by addressing the relationship among effort, benefit, and the parties involved. An important financial impediment is insufficient return of investment. Other hurdles related to the use of CPRs are lack of integration and flexibility, which cause clinicians to experience insufficient reward to motivate them for data entry and changes in working style. Effort and benefit have to be balanced for each party involved. *Requirements for improvement:* lack of standardization impedes exchange and sharing of medical data, and new developments cause fear of applications to become outdated. Flexibility in content and use, integration, and adaptability to change, are key requirements for CPR systems. These requirements can most effectively be met through an architecture that separates content and structure, such that the road to standardization is not paved with frequent expensive adaptations. *Strategies for implementation:* successful implementation and acceptance require reliable evaluation of applications by independent professional groups. Users need to be involved in setting priorities and planning for actual implementation. © 2002 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

The vision that the computerized patient record (CPR) is the technology of the future is no longer restricted to a handful of pioneers. It is a generally accepted belief that the

paper record can no longer meet the demands of modern health care. Even clinicians who are not looking forward to change do understand much of the added potential of the CPR.

Despite the fact that so many healthcare professionals understand the benefits of the CPR and that the Institute of Medicine presented it as an essential technology for healthcare in 1991 [1], introduction has been

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slow. The CPRI monitored 225 CPR related projects over 4 years and found only nine to be successful [2]. What is impeding this introduction if the benefits are so evident? First of all, many of the benefits mentioned in the literature, are potential. Most CPR implementations meet at best part of the requirements to harvest these benefits [2,3], which demonstrates that the effort needed to fulfill these requirements is far from trivial.

The obvious question to be asked is: are efforts and benefits balanced? Benefits are the motivation for the efforts. Hence, we need not only a deeper understanding of which efforts are needed to enjoy which benefits, but also which parties are associated with these efforts and benefits.

The paragraphs in the first section of this paper summarize the benefits, as they have been published in the literature, and we outline which efforts are required to realize each of these benefits. From there, we summarize a number of important parties involved, and we provide an overview of how these parties share in these efforts and benefits. This overview puts the expectations of CPR developments in a broader context and shows several imbalances that to our belief clarify much of the current impediments in CPR introduction. Part of these imbalances is financial: some parties do not see their financial investments returned. Other imbalances involve hurdles related to the use of CPRs, such as integration of existing data sources and physician data entry (PDE).

There is no single step solution to alleviate the problems involved in CPR introduction, but it is evident that clinicians play a crucial part in the content, quality, and usability of the CPR. Consequently, many efforts are directed toward CPRs that clinicians find attractive for consultation and data entry. In the second section of this paper we, therefore, highlight requirements for consultation and

recording of data, and we discuss the relation between content and structure of patient records in view of these requirements.

2. Effort and benefit

2.1. The potential benefits of the CPR

Numerous publications explain the potential benefits of the CPR. ‘CPR’, however, is just one of the many terms for non-paper patient records, and these terms cover a wide range of definitions [2,4,5]. Non-paper patient records may range from scanned text to fully coded data, and range in scope from one department to a complete patient record across the borders of one institution. In this paper, we do not want to restrict ourselves to a specific definition, since one of the goals is to clarify the relationship between benefits and requirements: the more requirements a non-paper record fulfills, the more potential benefits it has. The following briefly summarizes the (potential) benefits of CPRs as cited in many recent publications [3,6–10].

2.1.1. Accessibility

Computer-stored data can be viewed at multiple locations at all times. There are two forms of availability that are often mentioned separately.

Shared records: when required permissions and proper infrastructure are present, co-treating clinicians can directly view data in each other’s patient records. Whether stored in one shared database or physically distributed over different systems, such data may be presented as one coherent patient record, also called a virtual patient record [5].

Electronic data interchange (EDI): EDI is necessary when infrastructure or access permissions do not allow direct access of a

co-treating clinician to a patient's record. EDI involves messages that require initiative from their sender, be it with or without explicit request. EDI implies some delay and, therefore, cannot provide instantaneous information to its addressee.

2.1.2. Readability

Scanned documents can be made available at multiple locations, but freehand may be difficult to read. Typed information, often acquired through transcription, is easy to read, but susceptible to errors. Several authors report on studies where the elimination of transcription not only improved reliability, but also saved time and money [11–14].

2.1.3. Reporting

Data in well-organized CPRs can be used to generate reports for institutional, regional or national repositories, and reduces the need for redundant recording. Correspondence, such as progress, referral, and discharge letters can also be generated with data in the CPR.

2.1.4. Completeness

Computers can actively prompt for data. This is useful for improvement of the quality of data in CPRs, especially in the context of decision support, data analysis, and reporting.

2.1.5. Decision support

This is a broad area of functions that support diagnosis making and treatment policy, which often involve both assessment of health parameters and treatment [15]. The mode of advice of a decision support system may be passive or active [16]. A passive system waits for the user to come to it: the clinician enters data and requests response from the system. Active systems can access and interpret data that are provided during

the process of documentation, and provide advice without explicit request. For their reasoning decision support applications may use heuristics, probability theory and neural nets [17–22]. Although there is some overlap in what decision support systems may do for the user, three types of decision support are often mentioned:

2.1.5.1. Diagnostic support. Diagnostic support encompasses all help to solve an open-ended diagnostic problem, or to test a user-defined diagnostic hypothesis. Examples of diagnostic support applications are IL-IAD, quick medical reference (QMR), and DxPlain [17,20,23]. These applications typically support a variety of clinical questions: they can produce a differential diagnosis based on case findings, provide information on the discriminative power of additional tests, and present which evidence counts in favor or against a specific disease. These applications ideally work directly with data in the patient record, but an effort with QMR shows that such integration is far from trivial [24].

2.1.5.2. Treatment policy support. This type encompasses a relatively broad spectrum of systems that have in common that they help to decide what to do with the patient. Many of these systems draw upon health parameters to generate comments. Their response may take the form of warnings on the basis of findings that require medical attention, or reminders to support the flow of care [25,26]. Examples are alerts for abnormal test results, reminders that certain conditions must be met to allow a specific medical procedure, or warnings regarding interactions and contraindications for drugs. Drug management is among the few tangible benefits that have been reported for the CPR [2,10,27]. Hunt et al. view 'drug-dosing as a separate category of decision support [28].

Protocol support: for an increasing number of diseases, the medical community develops guidelines for work-up and treatment [29–31]. Examples are guidelines for hypertension, chronic obstructive pulmonary disease, diabetes, myocardial infarction, and cerebrovascular accidents. There are also protocols for the treatment of a variety of malignant diseases. Protocol support may involve protocol-specific reminders and warnings, whereas the above-mentioned alerts apply to abnormal findings or organizational aspects in general.

Critiquing systems are a form of active protocol support. These systems typically use data in the CPR to generate advice [32–34] since it has been demonstrated that decision support is most effective when directly delivered at the point of care [28,35].

2.1.5.3. Preventive medicine. Screening and preventive medicine are far more efficient when patient records are available in a well-structured computerized form. When patient data for screening or intervention are extracted by automated interpretation of selection criteria, preventive medicine is a special form of decision support. Amatayakul expects that compliance with preventive guidelines will be one of the key benefits of the CPR with respect to cost-effectiveness [2].

2.1.6. Access to external knowledge sources

Searches of databases with reference knowledge can be performed on the basis of CPR contents. Examples are literature databases, such as Medline, but also other healthcare related sites via the Internet, such as HON (Health on the Net), Clinweb, and Medweb.

2.1.7. Data analysis

The aforementioned benefits were mainly

related to one particular patient. Research often involves data extractions beyond the boundaries of one patient. Data analysis can be performed in the context of clinical research, but also for the purpose of quality assessment: what is the outcome of a certain treatment?, which complications have occurred and how often?, which conditions are associated with certain complications?, etc.

Quality assessment, management, and cost control: here, we refer to insight in and management of organizational aspects and cost in its broadest sense. Data in CPRs provide insight into resource utilization in relation to diagnosis and treatment. Morrissey performed a questionnaire in which 44% of respondents mentioned improved outcomes measurement as a tangible benefit of the CPR [13]. Data about complications in relation to certain procedures or treatments provide valuable feedback for improvement. Hence, patient data in combination with results from quality assessment allow decisions to redirect investments. CPRs can reduce cost with regard to paper record handling and storage, transcription, duplicate testing, and billing [9,11,12,36].

3. Efforts required to harvest the benefits

The benefits described above come with a set of requirements. A significant portion of these requirements can roughly be divided into requirements related to consultation of records and requirements related to computer-assisted interpretation of record contents. Other requirements are more related to the barriers for actual implementation of a CPR.

3.1. Requirements for consultation

In the context of this paragraph, consultation denotes the use of a computer to inform oneself about the contents of a patient's record. Consultation encompasses accessibility, readability, and indirectly, reporting. These require data at least to be available electronically, which involves data capture, data transfer, and integration.

Data capture can be achieved through scanning of documents and data entry. Scanning of documents preserves the exact content and look of the original documents. It will cause some delay, as the documents are not available at other locations until they have been scanned. Readability, however, may suffer as the resolution of the scanned documents may make the interpretation of handwriting even harder. Readability is highly increased when data are entered into the CPR. If data entry is performed through transcription, there is some delay involved before data are accessible. Transcription may also cause interpretation errors and requires checking. Transcription is often a supplement to the paper record, and as such, may involve redundant work or may not fully represent the patient data recorded.

Data transfer requires the proper infrastructure of hardware and software in order to capture data at location A, and present it at location B. When data transfer is achieved via messages, data are copied from the sender to the receiver and the communicating systems must share a common message format. For exchange of medical data, Edifact and HL-7 (health level 7) are important standards [37]. Data replication, as implied by messaging, poses problems with keeping the data consistent and up-to-date. Preferably, data resides in one location where it can be updated and consulted via a variety of systems on the network. Problems are the

many data in many different systems and formats. Part of these systems is dedicated for specific tasks, which operate on a stand-alone basis with only paper-based output [7,38].

Integration is more than access to data. A personal computer with separate access to departmental systems, such as the laboratory system, the radiology reporting system, and the ECG management system, represents only desktop integration: each program acts by itself, has its own interface, and does not use information from any of the other programs. Viewing patient data from such different systems requires knowledge of how each of them operates, and the clinician will have to perform redundant activities, such as specifying the patient identifying information over and over again. Further integration achieves presentation of data from different sources via one coherent interface, where data can be exchanged between the underlying applications. With loose integration, however, these applications act independently, each with its own full set of functions. With tight integration, overlapping functionality, such as 'save' and 'print' are made available through shared components, but there may still be different databases involved. Data integration represents the highest level of integration and involves a common data model [39].

3.2. Requirements for computer-assisted interpretation

Benefits, such as completeness, data analysis, and decision support, require that data are stored in a computer understandable format [40]. For a computer to perform sensible actions on data, it needs to know *where* to find *what*. In other words, both representation and meaning of data items must be fully explicit. This requires not only an unambigu-

ous relationship between a concept and the term(s) representing it, but also explicit representation of the context of each concept [10,41–43].

In order to promote completeness, an application must identify what has been already entered, and whether this is valid and detailed enough.

Data analysis requires data extraction based on user-specified criteria that the application must be able to interpret. To retrieve drug therapy information on patients with hypertension and diabetes mellitus, the system must know where to look for the conditions ‘hypertension’ and ‘diabetes mellitus’, and how drug therapy information is represented. Research, quality assessment, and cost control, are all benefits that depend directly on data analysis. Natural prose or free text is not computer understandable as such.

Decision support involves both extraction of and reasoning with data: the applications must assess which conditions are fulfilled to draw certain conclusions. Decision support requires a higher level of integration than presentation of data in one coherent interface. It requires exchange or sharing of more than administrative data between programs: data in the patient record must be understood by the decision support applications to generate warnings, provide diagnostic suggestions, offer treatment advice, or establish links with external knowledge sources.

For this level of integration the terminology for the medical concepts and the model in which information is represented, must be shared among applications [38,44,45]. Therefore, many groups work towards standardization.

Coding systems, such as SNOMED (systematic nomenclature of medicine), ICD (international classification of diseases), Read, and ICPC (international classification for primary care) are important initiatives toward a

standard terminology [46–50]. Projects, such as UMLS (unified medical language System) and GALEN (general architecture for languages, encyclopedias, and nomenclatures in medicine), are large-scale efforts to combine terminologies and to provide a framework that makes the semantic relationships between medical terms explicit [51–53]. The road towards a re-usable terminology is paved with obstacles. This is especially true for a so-called ‘patient-centered’ terminology, where practical use, formal representation, and scale, are difficult to reconcile [54]. A common terminology alone does not yet make integration simple: data conversion is still needed to present data in the format that a certain application can process. CEN (European committee for standardization) TC251 and GEHR (the good European health record) work towards standards for record architectures, i.e. the models in which the CPR data are represented [55,56]. With a common terminology and architecture, developers can build plug-and-play components to expand functionality [39].

It is important to bear in mind that periodic data conversion to a standardized format may suffice for data analysis, but not for decision support: experiments have shown that decision support is most effective when comments are directly generated as data are entered into the record. The learning effect gradually diminishes as decision support is removed [35]. Therefore, real-time decision support is often achieved through dedicated applications.

3.3. Other requirements

Structured data, standardization, and integration are a *conditio sine qua non* for full benefit of a CPR, but they are not sufficient for a successful introduction of the CPR. Other barriers to be overcome involve lack of

infrastructure, the need for behavioral and organizational change, leadership, and training [2,12,57]. There is lack of insight in the pros and cons of products in the market and fear of investing in a partial and temporary solution [58]. These barriers can basically be translated into three additional requirements to facilitate the introduction of the CPR: attitude change and re-organization, legislation, and financial investment.

3.3.1. *Re-organization*

As soon as a CPR is being introduced, clinicians will face a change in their practicing habits [59]. Depending on the functionality of the CPR being introduced, also administrative personnel may be faced with the extra burden of scanning documents and transcribing dictations or handwritten forms [60]. Storage of paper records will gradually be replaced by electronic archiving systems. Computer-based repositories require decisions as to where data reside and who is responsible for their management. Such systems bring great changes to the daily activities of archiving personnel, require expertise for integration and maintenance, and require the application of new rules for access and updates.

Other organizational changes may involve the scheduling of physician time, billing system, and service fees. There are private websites via which patients with chronic diseases electronically communicate with their care providers [3]: they may ask their physician questions, which may help to reduce hospitalization, or there may be a monitoring system using daily input from patients to fine-tune their care. These and other forms of teleconsultation are beginning to involve both clinicians and patients [61]. In other words, new forms of care will develop for which new financial arrangements need to be made.

3.3.2. *Legislation*

Consultation inevitably requires clear protocols and legislation for security, privacy, and confidentiality [62]. In this respect, authentication and verification are crucial for computer-based patient data to be accepted as legal evidence. Interestingly, current legislation for access and use of patient data is often not effectively applied in paper-based environments. In a large institution, a white coat is often sufficient to walk in and leave with several paper records. Computer-based data is not only much better protected against unauthorized use, but via audit trails it is also easier to track the trespasser. On the other hand, when unauthorized access does occur, the consequences can be more serious because of the larger number of patients that can be involved. A complicating factor for legislation in this area is that networks and electronic data transfer, especially over the Internet, are a global achievement. Hence, when patient data needs to be collected and used across the border, different access or exchange rules need to be applied, or these problems need to be tackled at an international level.

3.3.3. *Financial investment*

Financial investment is obviously a big hurdle. Retchin and Wenzel estimate that the introduction of the CPR may require 7.5–13.5% of an institution's total budget [9]. The medical records institute (MRI) estimated the need of \$75 billion to implement the CPR throughout the US, whereas Hodgkins estimates this to cost \$100–\$200 billion. Kaiser Permanente was planning to invest one billion into their information system infrastructure by 1998 [12].

The main problems are: what to invest and how the financial return will be. Although there are claims that the CPR may reduce healthcare cost significantly, most of these

are still based on sensible assumptions, and only few studies report on actual savings in expenditure [58]. Hodgkins mentions a cost reduction of \$7–\$11 per visit and shorter hospital stays [12]. Schubiger and Weber report a more qualitative gain of 10 min less time to create a discharge summary per physician and up to 49 min for a secretary [14]. Sujansky calculates that medication problems account for 8% of US healthcare cost and that these could be reduced by 50% [10]. But even when the potential savings are credible enough, decision makers often remain in the labyrinth of vendor's claims and reality.

Another factor that makes decision makers hesitant to invest is the fear of products becoming outdated [58]. If a vendor does not keep up with new functional requirements, the hospital has to change to a different product with all the complications of converting and transferring the existing data, or is 'stuck' with the old system.

Table 1 shows the potential benefits of the CPR in relation to the efforts needed to harvest these benefits. Note, that electronic text, structured data entry, and integration bring most benefits within reach. In the following paragraph we focus on how these efforts and benefits are distributed over the parties involved.

3.4. *The balance between effort and benefit*

The shortcomings of paper records have been well documented [6,63], and focus on the potential or already achieved advantages of the CPR. Yet, it is not sufficient for the benefits and the efforts to be balanced on a large scale: if party A has to invest and party B enjoys the benefits, than party A will not invest. In other words, effort and benefit must be balanced for each party involved. Such a party may be as small as the individ-

ual clinician, who will only take on the burden of PDE if there is sufficient reward, e.g. in the form of improved access to patient data.

Table 2 provides an overview of the efforts and benefits of a number of parties involved. Table 2 does not pretend to be complete, but is meant to elucidate some discrepancies that may hinder successful introduction and use of CPRs. To make the discussion more transparent, Table 2 is based on the assumption that patients do not directly pay for their benefits: their cost is covered by insurance companies and the government.

Based on the two overviews in Tables 1 and 2, we make the following main observations:

- Clinicians have a lot of potential benefits. Most of these benefits are of a qualitative nature: task facilitation and improvement of documentation for the participants in the care process.
- Clinicians can most effectively harvest these benefits when their CPR contains integrated structured data.
- Clinicians' main effort involves direct structured data entry, which impacts their work style most.
- Institutions' main efforts are financial investment and re-organization.
- Institutions benefit mainly through reporting and data analysis for the purpose of resource management, cost control, and quality assessment.
- Payers, such as insurance companies and the government, may enjoy cost reduction when the CPR leads to fewer medical prescriptions, procedures, complications, and hospitalizations.

3.5. *Discrepancies at the financial level*

In most specialized care settings, clinicians view CPRs as an infrastructure that the orga-

Table 1
Potential benefits and requirements to achieve them

	Infra-structure	Inte-gration	Standar-dization	Electronic text	SDE	Legis-lation	Adaptation workflow	Reorga-nization
Benefits								
Accessibility	X	X		X		X	X	
Readability				X			X	X
Completeness		X	X?	X	X		X	X
Shared records	X	X	X	X			X	X
Decision support		X	X	X	X			
Correspon-dence	X	X		X		X	X	
Reports		X	X	X	X	X	X	
Preventive medicine				X	X		X	
cost control		X		X	X			

X? = desirable, but not mandatory.

Table 2
Benefits and efforts in relation to parties involved

	Institution	Clinicians	GPs	Prof. groups	Resear- chers	Educa- tors	Patients	Payers	Govern- ment	Vendors
Benefits										
Accessi- bility	X	X	X		X	X	x			
Readability	X	X	X		X	X	x			
Comple- tness	X	X	X		X	X	x			
Shared records		X	X				x			
Decision support		X	X			X	x			
Corres- pondence	X	X	X				x			
Reports	X	X	X		X	X	x			
Preventive medicine		X	X				X	X		
cost control	X?							X	X	
sales										X
Efforts										
Financial investment	X	X?	X							X
Integration	X									X
Standar- dization	X			X	X			X	X	X
Validation				X						X
Data entry		X	X		X		X?			
Training	X	X	X							X
Adaptation workflow	X	X	X							
Re-orga- nization	X	X	X				X?		X	
Legislation									X	

x = indirect benefit. X? = may or may not be applicable, depending on organizational factors.

nization should provide. This is understandable, as clinicians' benefits are mainly of a qualitative nature. Hence, it seems that hospital management faces a big investment, whereas insurance companies (payers) seem to have many benefits and little or no investment. So who should pay for what?

It is important to realize that especially the financial aspects strongly depend on the organization of healthcare [12]. In a managed care setting, the hospital may find return money for its investments if it can save on expenditure without facing a budget cut until a new financial balance is reached. In a fee-for-service model, only certain types of expenditure can be reduced to save money: reduction in administrative personnel will save cost for the hospital, but a reduction of tests and hospital stays will reduce income necessary to pay staff, and save money only for the government and insurance companies. If one party plays more than one role, however, the associated efforts and benefits can be merged, producing a, probably, more favorable balance. Because of this, there are large organizations, in which medical insurance and the provision of health care are combined. Such constructs are common in the US (health management organizations), but non-existent in many European countries.

When large investments are involved, vendors may be willing to make concessions towards the customer [9]. On the other hand, one must be aware that investing parties, such as insurance companies or the government, may use their position to negotiate functional priorities to their own benefit.

The message here is that cost reduction or added revenues must return to those who invested for that benefit. In the Netherlands, each primary care physician who uses an information system receives supplements to their fees which amount to an equivalent of \$7500 per annum for an average practice of

2500 patients. In combination with professional groups for testing of products and user-groups, this was a strong incentive for the GPs to adopt the CPR in their practices [64,65].

3.6. Discrepancies at the user level

Cost plays a role for decision makers to introduce the CPR in their institution. Clinician's acceptance and commitment, however, is crucial for success: after all, they are the primary users [58]. Table 1 shows that PDE at the point of care is a crucial requirement for many benefits of the CPR. Therefore, PDE is one of the major challenges for CPR developers. In the past, PDE was considered an unattainable goal [66], and many still believe that PDE is too big a step for clinicians who have yet to be introduced to the use of computers [57–59]. In the last decade the number of initiatives to tackle this problem has been increasing. Some attribute this enthusiasm to possible 'youthful carelessness, due to a lack of experience of maintaining an electronic medical record in an operational environment with a broad range of medical domains' [67]. What reasons caused this renewed interest in PDE? Have new technologies emerged? Is the attitude of physicians changing? Do we have more insight into how physicians work? Does natural language processing (NLP) not meet the requirements? All these factors apply to some extent. In addition, there is increasing pressure from society and governments for improved documentation of patient care and evidence-based medicine. Bates et al. provide recommendations for health care information systems to reduce error in medical practice. In combination with well-documented patient data, decision support at the point of care, is a powerful mechanism to support evidence-based medicine [68].

Networking and internet technology do increasingly bridge the gaps between different platforms; younger clinicians tend to be more familiar with computers than older ones and are increasingly aware of new facilities; studies have shed more light on how clinicians use patient records and have identified recommendations for CPR functionality and interface [11,69,70]. NLP has made considerable progress and is coming close to human performance in limited domains, but it is associated with delay, requires verification, and cannot stimulate better record keeping [10,38,67]. Furthermore, when NLP is not applied instantaneously, decision support cannot be delivered at the point of care. Speech recognition is becoming more sophisticated and performs best in combination with a limited vocabulary. It is a technique, however, that is more easy to implement in a setting where reporting does not take place in the presence of the patient, for example, in radiology and pathology.

Although we focused here on efforts to reduce user effort, it is important to realize that meeting the CPR-related requirements for a benefit does not automatically imply that benefit. Shared records, for example, require infrastructure and integration, while decision support requires dedicated implementation of inference, or integration with a decision support system via a common vocabulary and exchange format.

No matter how committed policy makers and healthcare executives are, the CPR will not be used if clinicians do not accept it. Functionality and user interface are crucial for clinician's acceptance. Kalra states that a system, no matter how brilliant, will not be used if it has an awkward user interface [71]. The second section of this paper will, therefore, address bottlenecks in clinician acceptance and use of CPRs.

4. The challenge: making the CPR attractive

4.1. The CPR for clinical use

Most early CPR systems that have found acceptance in daily clinical practice combine the advantages of on-line patient information with minimal impact on the patient-clinician encounter: data are recorded on clinical encounter forms, which contents are later transcribed and made available electronically [72–76]. Progress notes often remained in free text. This approach is based on the experience that clinicians are far more accepting of computer-use for consultation purposes than for data entry [77]. It is not surprising for the time-pressured clinician to be more motivated for the benefits of the CPR than for the efforts. Even more, many benefits of CPRs are not in effect because their requirements are not met or the functionality is not offered. But for what benefits are clinicians really motivated? In fact, clinicians get used to missing information to such an extent that they do not depend on patient records. If necessary, they do without [78]. When clinicians experience current shortcomings of paper records barely as a problem [79], they certainly do not miss the extra benefits that a CPR might provide. Hence, there is a catch-22: a good experience with extra functionality fuels motivation, but the positive experience requires effort and effort requires motivation. The problem is that the majority of clinicians do not *miss* anything. In the absence of an obvious incentive, clinicians are reluctant to change. So how to break this catch-22 problem?

To date, most successful strategies have been based on providing as many benefits as possible with as little effort as possible. Access to patient data at multiple sites and from multiple sources provides benefits for which clinicians have relatively little to invest.

Therefore, such access is often the first functionality offered in the process of acquainting clinicians with computer-based patient data [59]. Yet, as explained earlier, the benefits that can be achieved this way are limited. PDE remains a difficult goal. Other than negative [58] or positive reinforcement of PDE on a financial basis, the only other option is reduction of the required effort, which is the great challenge in making PDE more attractive.

The starting point here is the philosophy that the CPR should fully replace the paper record. Use of either one as a supplement to the other introduces extra work and the constant need to check both sources because the user cannot rely on the coverage of either one. Hence, the clinician will be using the record both for recording and consultation. In the context of this paper, we will not review all attempts towards PDE, but focus on specific insights with respect to consultation and data entry, which are crucial in the challenge of successfully supporting these two tasks in one CPR.

4.2. Consultation and data entry

Consultation and recording of patient data are two different activities that require different types of support in a CPR. Consultation requires minimal search-time, whereas data entry must accommodate the ‘jumpy’, associative nature of history taking. Wyatt and Wright mention that designs often focus too much on data entry at the expense of how data are used [80].

4.2.1. Consultation

Nygren et al. made a thorough study of how physicians obtain information from paper records and used the results to make recommendations for interfaces for the consultation of data in the CPR [81,82]. Clinicians skip, skim, and read paper records to answer a variety of clinical questions. Their needs may range from the look-up of simple facts to the assessment of a patient’s health status or course of disease. Such tasks also must be supported by the CPR. A variety of publications provide criteria for an efficient interface for data consultation, especially a recent series in the Lancet [69,70,80,83].

The main messages in papers on patient record consultation are *overview*, *predictable presentation* and *clinically relevant presentation* of data.

Overview means seeing what there is to find and where to find it at a glance, but also seeing a combination of relevant data in one view. This implies that information is not limited to the notes of one care provider, but covers the patient as a whole [4,45,84]. Overview, in fact, encompasses both sufficient coverage and straightforward positioning of data. The latter implies predictable presentation of data, which can be achieved by a layout with consistent positioning of data items, predictable ordering of topics, use of headings and subheadings, and outline display [70,83]. Quantitative data are preferably presented in tables with consequent rows and columns, or graphs with consequent axes and scales [69]. Tange et al. found a significant correlation between granularity of data and search time [85]. Clinicians search faster through problem-oriented progress notes than one piece of prose. The same holds for history and physical examination when ordered by organ system. More refined granularity increases search time again, probably because too many labels are distracting or because the scope of information per label is too small to be clinically relevant.

Patient data cannot fit on one screen and necessarily need to be divided among a number of computerized documents. Contents of each document type must be clear and docu-

ments must be easily accessible and recognizable, e.g. by the use of icons or thumbnails.

Besides predictable presentation, however, the information presented is preferably relevant to the clinical situation. Nygren et al. advocate highlighting, and positioning of urgent data where easily seen [70]. Whereas highlighting can be combined with predictable ordering, positioning of data as a function of urgency seems to conflict with predictability. Furthermore, since information requirements vary highly among specialties and clinical questions, the CPR must support views on the record contents that are tailored to specific needs. Strictly speaking a clinically relevant view depends on the combination of a clinical question and a case, but a case-specific view is not definable beforehand. Views are necessarily based on disease types or categories in combination with specific clinical tasks: for trend analysis one would prefer a source oriented presentation of data, whereas a time-oriented presentation may help assessment of current health status.

Custom-defined views may improve efficiency and serve as reminder, but they also carry the risk of reducing the clinician's creativity and associative thinking. Therefore, as Nygren stresses, the general predictable ordering of the CPR is more important than different views. Such views must always be regarded add-on functionality, and may not obscure the main ordering.

4.2.2. *Data entry*

Data entry directly by clinicians is the most challenging part of CPR usage. Main bottlenecks are clinician typing, time-consumption, limited coverage, and concerns about the impact on the clinician–patient encounter. Although the younger generation of clinicians is increasingly more computer literate and more accepting of typing [86], SDE is often more time-consuming than entering prose [2,83,87].

Navigation through the interface and selection of the applicable items is time-consuming [10]. Therefore, the interface ideally anticipates what the user needs to enter. In a routine setting where a very predictable set of data is collected, such anticipation is straightforward: fixed forms with a predefined number of items and layout are most effective. Such situations mainly occur in research settings and in highly specialized environments tailored to specific medical procedures. Examples can be found in eye clinics, child health centers, departments for function tests, etc.

For broad specialties, such as internal medicine and pediatrics, anticipation of data entry is less trivial: a fixed-form approach involves a large number of forms to sufficiently cover the domain. As a consequence, navigation through the forms would become cumbersome and overview is lost: the user only sees the data in the form on display. Apart from limitations on the part of the user, maintenance and customization of fixed forms is labor intensive.

Because of the relative rigidity of fixed forms, several CPR applications have adopted a more dynamic approach with predefined descriptive options in the form of menus or a set of templates. 'Dynamic' applies to the fact that the descriptive options apply to the context at hand. Examples are PEN&PAD, IMR-E, Ivory, Pure MD, Purkinje, and ORCA-SDE [67,88–94]. IMR-E offers templates with descriptors based on a selected complaint; Purkinje uses a hierarchical approach in the form of a tree of medical concepts that expands as more detail is entered; ORCA-SDE offers an expanding tree of concepts in combination with standard and custom forms that offer descriptors for the selected concept in the tree [95]. The scope and amount of detail that such systems support vary. Yet, the more flexibility and

expressiveness, the more time is needed for navigation and selection. Time, however, is such a critical factor in clinical practice that many applications offer limited flexibility and do not cope well with the unexpected [67].

Although there are examples of time-gain with SDE [11,90], there are several opinions about how to apply SDE. McDonald advocates that careful analysis is needed to determine the data sets for which SDE is most useful [38]. In analogy, Rector et al. states that anecdotal information, although relevant for patient care, should not be captured via SDE unless it can be represented at some level of abstraction. For example when ‘chest pain comes on when passing the cooling section of a supermarket’, one could record that ‘chest pain is induced by cold’ [41]. The general opinion is not to fully replace free text with SDE, but to apply a combination of both [11,38,67].

Free text can be obtained via dictation or direct data entry. Aydin and Forsythe found that dictation is only faster than typing for long notes, and provides a qualitatively better result when done during the patient encounter [60]. In general, versatility increases the acceptance of SDE: the more options, such as forms and trees in combination with keyboard, mouse, pen, or voice-recognition, the more chance there is something to the user’s liking [11,42].

Fear of a negative impact of computer-use on the clinician–patient encounter is gradually decreasing. Patients become more accustomed to computer-use [7,96–98]. Acceptance by clinicians of computer-use or dictation during the encounter is positively related with the degree to which the clinician is familiar with the application [60]. An interface must put a minimal cognitive load on its user in order to help perform a task instead of disrupting it and distracting the clinician away from the patient [99].

4.2.3. *Conclusions*

We come to the following main conclusions for consultation and data entry:

- CPR content and detail must be tailored to specific domains.
- Data presentation must be highly predictable, be relevant to the clinical situation and the task at hand, and also support customized views.
- Structured data entry requires both custom forms and flexible dynamic entry modes with a variety of data entry tools.

4.3. *Considerations for a CPR structure*

User acceptance of a CPR is one major concern for decision makers regarding IT in healthcare institutions. It is important to select a CPR application that strikes a good balance between flexible and efficient support of consultation and data entry, and that permits gradual introduction of its functionality. The number of vendors claiming their products to do so is increasing, but the best choice is not always transparent for decision makers [13]. Another major concern is how well a product can cope with changing demands, and what the consequences of such changes are for existing patient data.

In view of flexibility and adaptability, many strengths and weaknesses of CPR applications can be explained by the design of the underlying data model. The conventional relational database is characterized by the fact that each parameter to be described is represented by a separate column in a table. Tables with related data are linked via common keys or ‘bridge’ tables. Context is often represented via one-to-many relationships that put tables in a referential hierarchy.

The conventional database is well known, can be queried with a standard query language, and contains or exports data in a format that can be processed by external

applications, e.g. for statistical analysis. On the other hand, structure and content are strongly related: a change in the set of parameters that can be stored requires a change in the database structure and the associated forms and queries. The structure of a database, however, cannot always be changed without loss of data, and conversion of patient data to a new database version may involve data manipulations, which are in conflict with the requirement that the patient record be permanent [41]. Maintaining different versions of a database has the problem that data have to be accessed per version.

As the database grows, maintenance becomes progressively labor intensive. Therefore, end-users are often confronted with rigid forms, too many or too restricted forms, inflexible navigation, and lack of overview [70,80]. Furthermore, when new tasks are accommodated with a variety of dedicated tables, inconsistencies can easily occur in the form of different representations of the same medical concept [100].

Specialists, working in broad domains such as internal medicine and pediatrics, typically encounter a large variety of medical findings of which only a few apply per patient contact. Large tables with numerous attributes are then very sparsely filled. The conventional database is not efficient for storing a large amount of variable heterogeneous data items.

Whereas consultation and data entry require flexibility in content and data presentation, evolving insight, new tasks, and changing user requirements, make adaptability to cope with change an equally important issue for policy makers. Flexibility and adaptability, however, are very limited for CPR applications where structure and content are strongly related.

Abstraction is a powerful mechanism to achieve separation of structure and content.

This separation makes a database and application operating on that database domain-independent, and applicable across the boundaries of medical specialties. The essence of abstraction is that findings and observations, i.e. the parameters of interest, are no longer directly represented by columns in tables, but as content of a table. The columns of such an abstract table reflect common properties of these parameters: a name or code, state of presence, a time-stamp, and a numeric value or range of values. A table with a higher level of abstraction could be named ‘medical entity’ with columns ‘item name’, ‘presence’, ‘time-stamp’, and ‘value’. Instead of ‘severity’ and ‘frequency’ being columns of a table ‘chest pain’ in a conventional model, the concepts ‘chest pain’, ‘severity’, and ‘frequency’ are presented as rows of the column ‘item name’. This column-to-row transformation is applied in so-called entity-attribute-value (EAV) models, where the entity usually represents a patient event [101].

The main advantages of abstraction are:

- *Flexibility*: as long as parameters share the same generic properties, a change in the set of parameters to be covered does not require a change in the database design. Hence, abstraction represents a strategy to accommodate not only the content requirements of different medical specialties, but also changes of content over time.
- *Integration*: abstraction applied to a relational database still produces tables with columns, which can be combined with conventional tables and columns into one database.
- *Efficient storage*: only data actually entered require space, instead of tables with thousands of attributes of which only a few apply at a time.

- *Patient-centered queries* are usually more efficient than in a conventional model, where such queries require data to be extracted from a large number of tables.
- *Maintenance*: abstraction separates content and structure, such that content can be expanded and adapted without the need to change the database structure, nor the software operating on that database.

The main drawbacks of abstraction are:

- *Criteria-based queries*: queries involving multiple patients and conditions can be very complex, especially when nesting occurs within tables. This is typical for hierarchical or network structures.
- *Compatibility*: the contents of abstract tables cannot be interpreted directly by external systems, such as applications for billing or statistical analysis. Dedicated extraction and conversion is necessary.

When abstraction is applied to both the definition of *what* can be recorded in *which context*, as well as to the actually recorded patient data, interactive software can be developed for the maintenance of the content model and for the construction of custom views for consultation and data entry [95].

It is important to realize that abstraction should not replace conventional data models in CPR applications, but be applied in combination with a conventional data model for optimal representation of various kinds of data [102].

Another aspect of CPR architecture, relevant to flexibility, is the separation of process (work flow) modeling and programmatic design. When the execution of different software units can be controlled by process definitions, the institution can tailor the program execution sequence to accommodate a variety of work environments. With such architecture, the organization implementing the CPR has a much more flexible environment

for meeting specific work needs. Flexibility of both content and workflow support are relevant to the ease of installation, maintenance and task support.

5. Moving towards the CPR

Implementation of the CPR requires commitment of the management, whether it is a small group practice or a large healthcare institution. Hence, there are two important aspects concerning the implementation of CPRs: (1) factors that promote commitment, and (2) factors that facilitate implementation following this commitment.

One of the most important stimuli for a management to commit to the implementation of the CPR is the motivation of users. This motivation often comes from pioneers within the institution, who often have created their own dedicated systems, or frequently explore products in the market. The ability of these pioneers to propagate their vision plays an important part. Another factor facilitating decision making is reliable information about existing systems, but trustworthy evaluations per product are hard to find or not available. Although up to 39% of the vendors seem to live up to their own claims regarding system benefits [13], such information is ideally provided by professional groups, who represent the user community [64]. Although Morrissey and coworkers report on the best-documented benefits—improved outcomes, less administrative labor, drug management, guideline adherence, and preventive care—this documentation is still scarce and often based on questionnaire results [13,27]. Kibbe and coworkers stress the importance of benefit measurement, because one cannot manage what one cannot measure. Such measurements, however, require a vocabulary to express interventions, health status, and outcomes [45,57].

Other aspects that will positively influence decision-making is risk-sharing by vendors to deliver priority promises [13], and the fact that vendors are willing to tune a product to customer preferences when the number of users is large enough.

In view of the financial discrepancies, financial incentives must come from those who are expected to benefit from future cost reduction: the government and third party payers, specifically health insurance companies [9,44].

Once management has committed to the introduction of the CPR, a variety of factors influence the success of implementation. Questions to be answered are: start where?, start with what?, and start how?

Retchin and Wenzel advise to start in academic centers, which already have a relatively high level of computerization, technical expertise, and a medical staff who is used to change [9]. There is a relatively large influx of young doctors, who 'grow up' with new technology. Furthermore, academic centers value the benefits for research.

Most successful strategies have started the implementation of the CPR by offering their users access to existing patient data. Although consultation of computer-based patient data does not necessarily replace the paper chart, it is an immediate benefit that requires relatively little effort. It is, however, essential to offer clinicians a critical mass of electronically available patient data, otherwise clinicians will not be motivated enough to acquaint themselves with the system and use it [58]. Offering such a critical mass is far from trivial as there are many data in many different systems in very different formats [7,36,38,44]. Standards for terminology and exchange formats have to pave the way to interconnectivity and sharing of records. Much work is needed before we have a common vocabulary and architecture that allows

developers to build plug-and-play components, such that institutions can obtain 'parts' from different 'brands' (vendors) to compose their CPR system. Currently, it is worthwhile for large organizations to embark on a migration path by providing access to different sources of data, such as 'Results Reporting' in EpicCare, and by gradually replacing or adding new components [59].

There are differences in opinion on how functionality should be introduced. Some advocate the introduction of a simple and practical system with stepwise addition of new functionality in order not to overwhelm the users [57,58]. Hodgkins, on the other hand, would rather introduce all functionality locally, and spread from there, rather than step-wise introduction of functionality institution-wide, as the latter involves too long a time of change within a particular department [12]. These seemingly conflicting opinions may stem from different views on guiding learning processes. Change in working style is inevitably incremental as the process of learning is inherently incremental. Stepwise introduction of new functionality, however, implies responsibility and planning of the learning process by the organization, whereas introduction of all functionality at once leaves the initiative in the learning process primarily to the user.

Ash stresses the importance of visibility, i.e. the degree to which users see others use a system [103]. Visibility both promotes the diffusion (spread) and infusion (depth) of use. Likewise, McDonald et al. are in favor of introducing new functionality throughout the institution [77]. In view of visibility, institution-wide implementation may be more effective, but the logistic challenges of training and reorganization may require a strategic plan to phase it in, with temporary use of both the old and new procedures.

Learning takes time, even more so for data entry than for consultation. Introduction of data entry is a logical step following consultation, but because of its impact on working style, it is not realistic to solely rely on willingness to learn. The organization must actively invest in the learning process by training clinicians on-line [58], by involving everyone in training, and by offering ‘protected time’ to adopt a new working style [104]. Protected time means that the workload is substantially reduced to allow time for learning in a real practice setting. Chin and Krall report a reduction of 50% of scheduled patient encounters, which was gradually phased out. After 4 months, 89% of the users did not want to return to the old system, despite an average increase of 130 s per encounter [59].

No matter which strategy the management decides to adopt, enthusiastic initiators are few and the majority of future users still needs to be motivated to cooperate. Before actually introducing change in the working environment, it is crucial to involve users in the selection of priorities, the implementation plan, and to achieve consensus on goals [27]. In addition, each change must include a clearly identifiable benefit for every user. Furthermore, feedback and turn-around time are critical in the implementation process. If months pass by before clinicians see any response to their remarks or requests, the interest will dwindle fast and may even turn into loss of faith in the technology and a negative attitude. This does not mean that clinicians can expect to have every wish or suggestion satisfied within days. Therefore, one cannot be careful enough to set and manage user expectations [104]. The majority of clinicians will be realistic enough not to expect a multitude of benefits at once, but a short turn-around time is especially important when clinicians’ daily tasks are involved: they will

not accept a CPR application to be an obstacle in daily practice for very long....

6. Conclusions

Flexibility in content and use, integration, and adaptability to change, are key requirements for CPR systems. These requirements can most effectively be met through a common architecture and vocabulary in combination with the development of plug-and-play components. Seamless integration of functionality and content is not the only advantage. Vendors no longer need to provide total solutions, but can concentrate their resources on specific functional components. The advantage for users and policy-makers is more choice from a market with a variety of products, and less fear of being stuck with a suboptimal system. Financial stimuli from third party payers and support from professional groups are pivotal in overcoming the barriers of introducing the CPR.

Predictions about the adoption of the CPR in health care have been disappointing because they were too heavily based on technological advancement. The key challenge is *consensus* and a record that allows gradual migration towards the emerging standards. Once consensus is reached on terminology, architecture, reimbursement, and legislation, the CPR will become as established as the Hippocratic record was for centuries.

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