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Review Paper

The Structure of Data in Medical Records

Abstract: With the growing complexity of health care, patient data are more and more in demand for purposes such as research, education, post-marketing surveillance, quality assessment, and outcome analysis. Many of these purposes require patient data to be available in a structured, electronic format. Despite the rapid advances in computer technology, which allow patient data to be organized, analyzed, and shared, the majority of physicians still use paper medical records. Apparently, most physicians still perceive the paper record as being more suitable for their task than present day computerized versions. Both the shortcomings and the strengths of paper medical records have been identified and it proves difficult to design a computerized medical record that exploits the strengths of computers without loosing the advantages of the paper chart. The structure of patient data is an area of high interest, since structure determines how physicians, other health care workers, and patients may benefit from these data. An overview of research efforts in structuring patient data will offer insight in the problems that still impede a wide-spread use of the computerized patient record in clinical practice.

Keywords: Computer-based Patient Records, Problem-Oriented Medical Records, Natural Language Processing, Structured Data Entry

1. Introduction

Approximately a quarter of a century ago, researchers began to draw attention to the shortcomings of the paper medical record (PMR). They reported on the poor organization, incompleteness, inaccuracy, and many other drawbacks of the PMR. The increased complexity of health care and information demand, combined with the potential of computer technology, has led to a great enthusiasm for and high expectations of applying that technology to computerize the patient record. Yet, even after 25 years, with some exceptions for primary care, there is still no computer-based patient record (CPR) in wide-spread use that fully replaces the paper chart. Apparently, for physicians, the potential benefits of the CPR do not yet outweigh the strengths of the PMR. This review paper provides a brief overview of the history of the patient record and the attempts of researchers to structure its contents, especially of the part that has proven to be the greatest challenge: the clinical narrative.

2. History of the patient record

The patient record has probably existed ever since people with medical skills were able to report on a patient's course of disease and treatment. The Hippocratic case record was a time-oriented record in the purest sense. It described the condition of the patient prior to his current illness, followed by the sequence of symptoms that led him to seek help. From there, the record contained narratives which related signs and symptoms, till the patient was cured or died. Each narrative mentioned the number of days, that had passed since the patient presented [1].

For centuries, records continued to be written in the Hippocratic style with emphasis on the patient's phrasing of the symptoms. After Laennec's publication on auscultation with the stethoscope, in 1819, the focus of the patient record changes from the observations of the patient to the observations of the doctor. The medical notes were brief comments, used by their author to trigger fuller recollections of the patients involved. In the late 19th century, the expansion of surgical expertise caused new areas of specialization to emerge. After founding St. Mary's Hospital in Rochester in the 1880s, surgeon William Mayo and his sons started a group practice, which was the forerunner of the Mayo Clinic: a cooperative group of physicians with various specialties. From 1885 till 1907 it was customary for physicians in the early Mayo Clinic to record patient information in personal leather-bound ledgers. The attending physician, the surgeon, and the laboratory, kept their own set of ledgers. Each ledger was a chronologic account of the physician's findings and actions. Hence, the contents were time-oriented per physician: the notes pertaining to an individual patient could be on separate pages, depending on the time between subsequent visits. Tracing a patient's case history was a laborious task. Therefore, in 1907, Plummer introduced a single record per patient [2].

In the 1920s missing data and the absence of a standardized method of recording led to a proposal to enforce physicians to note certain essential data. Although this proposal met with a lot of resistance, the standardized portion began to serve as a framework for the record as a whole [3].

Recording essential data did not mean that there was general agreement among physicians as to how these data should be ordered in the record. In many patient records, the notes were a mixture of observations, interpretations, treatment, and test results. Such unstructured notes obscured the underlying motivations and causal relationships. Therefore, Weed introduced the problem-oriented medical record (POMR), in which all notes are recorded in the context of a specific problem [4]. Problems are defined on the basis of an inventory of symptoms and signs. Per problem, the notes are organized conform the SOAP-structure (Subjective, Objective, Assessment, Plan), which helps to elucidate the physician's line of reasoning. Although the POMR offers educational benefit, it requires redundant reporting when findings pertain to more than one problem, and it may obscure relationships between problems [5, 6].

3. Current patient records

What most modern PMRs have in common is a nested ordering: the documents that make up the PMR are ordered by source and within each source by time. In this context, the term 'source' denotes the type of data, not their author. Examples of sources are: letters, progress notes, lab results, X-ray reports, and pathology reports. In a source-oriented patient record trend analysis is much easier than in a strictly time-oriented record for the same reasons as case analysis was difficult in the physician-centered ledgers of the Mayo Clinic. Depending on how the record is used, data within a source are ordered from past to present, or vice versa. Progress notes may further be organized in a problem-oriented SOAP-structure.

A rapid increase in medical knowledge and technology have led to a large diversity in specialties. Although Plummer [2] introduced the patient-centered record, the multi-disciplinary aspect of health care caused the logistic aspects of one PMR per patient to become unacceptable. Although records are no longer physician-centered, there are often as many records as there are specialties involved in the patient's care. As a result, the scattering of patient data impedes the formation of a complete picture of the patient. With the need to share patient data among care providers, the strategy of brief notes to trigger the memory no longer suffices.

Scattering of patient data and too concise notes are not the only problems of the PMR. Physicians and other care providers have to deal with illegible handwriting, poor organization of documents, and missing and ambiguous data. PMRs can only be in one location at a time and when a record cannot be found at all, an extra temporary record is created [3, 7-12].

A fundamental limitation of paper-based data is that they can only play a passive role in the decision-making process. It is not possible to trigger the physician's attention to allergies of a patient, contra-indications for drugs, or abnormal test results. Nor can a paper record actively use treatment guidelines and protocols to comment on its contents. It is virtually impossible, even for a very specialized physician, to have ready all the knowledge relevant to his domain. Hence researchers in medical informatics soon saw a potential for improving the quality of care if patient data could be used to support the decision-making process actively. Retrieval of data from PMRs is cumbersome and what is difficult to interpret for a human reader is even less suitable for scientific analysis [12-15].

In attempting to overcome the disadvantages of PMRs, the strengths of these records for their users tend to be overlooked. The Institute of Medicine identified at least five strengths of PMRs: their use requires no special training, they are portable, they are never "down" like computers, they allow flexibility in data recording, and they can easily be browsed through and scanned [12]. Insufficient understanding of the importance of these aspects proved to be a great barrier to the introduction of its intended successor: the computer-based patient record.

4. The computer-based patient record

The availability of patient data in electronic form already solves part of the mentioned shortcomings: The patient record can be accessed at multiple locations, patient data no longer need to be scattered, and there are no illegible notes. However, easy browsing of the data, presentation in various views, and automated decision support, require that the data are structured and stored in "understandable" chunks which applications can recognize and reason with [16, 17].

In the past 20 years, several systems for the electronic storage of patient data have been developed and used in clinical settings: TMR, COSTAR, RMIS, STOR [7, 18-22]. Early developments involved tasks such as administration, billing, and planning. The early versions of the CPR included categories of patient data that were relatively easy to represent in a structured fashion, such as laboratory data, discharge diagnoses, and medications. The advantages of structured data are obvious: data can be presented in different views and formats, thereby eliminating the need for redundancy. However, the collection of structured progress notes, directly from physicians, was long felt to be an unattainable goal. Many existing applications have adopted an intermediary solution to this problem, using printed encounter forms [23]. These forms serve two goals: the presentation of recent data and the recording of new data by the attending physician. Clerical personnel then enter the data into the computer. Part of the data, such as diagnoses, vital signs, and medications, are usually entered in a coded format. Apart from free-text descriptions, which still remain uncoded, this methodology is sensitive to transcription errors, misinterpretation and delay.

4.1 The structure of data in the CPR

In recent years, the CPR has become a major topic in medical informatics research. This is reflected by the formation of "The Committee on Improving the Patient Record" by the Institute of Medicine of the National Academy of Sciences in the USA. Much research involves the structure of data in CPRs. Prior to discussing research in this field, it is important to realize that one can address the topic "structure" from many different viewpoints: the structure of the CPR as the user perceives it, the structure of the underlying database, and the structure of the conceptual model behind the CPR application. We feel that it is most interesting to focus on conceptual models behind CPRs, as these reflect how their designers think that medical data should be collected and used. When properly implemented, the conceptual model determines the functionality of the resulting application for data entry, consultation, and retrieval [7, 24].

At the level of conceptual models, researchers have focused on a variety of aspects. Some focus on the organization and content of a computerized equivalent of the PMR. Others formulate foundations for the CPR, based on requirements for clinical practice, research and decision support. Again others propose models for the representation and capture of patient data. Figure 1 illustrates how the various research areas fit in the domain as a whole. The cube represents the medical record and symbolizes three important aspects of the medical record structure: (1) the building blocks denote the categories of data in the record, (2) the horizontal plane depicts the temporal organization of the data, and (3) the vertical plane portrays the separation between observations and interpretations. The box enveloping the cube represents the data model, used to store the patient data. Since a box may have several compartments, it is possible to split parts of the cube and put them in different compartments. In other words, depending on the nature of certain data one may use different data models. Finally, the capture and

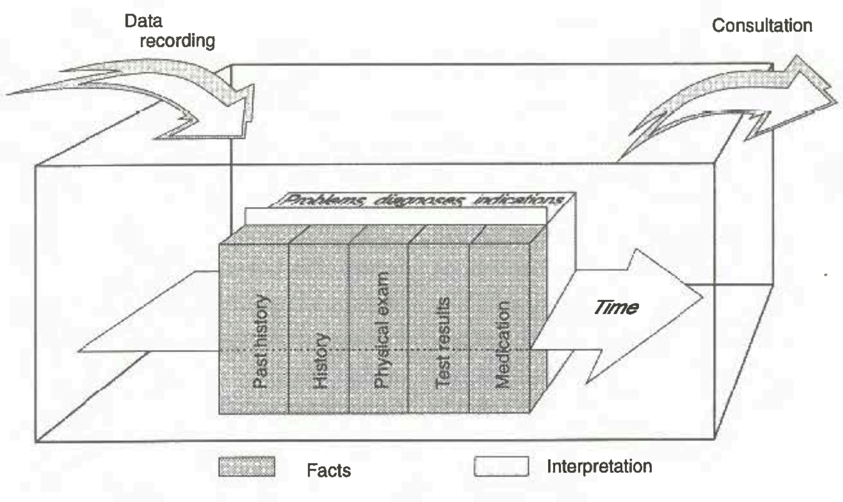

Figure 1. The cube symbolizes the medical record. The 'Time-arrow' depicts the temporal organization of its contents. The categories are the facts that stem from observations, thoughts and actions. The interpretation component represents the semantics of the medical record: how the facts fit in the decision-making process. The box enveloping the cube denotes the data model and interface to enable recording and consultation of patient data.

retrieval of data are symbolized by the opening of the box, through which its contents are put in and taken out. We will subsequently address the categories as depicted in Fig. 1.

4.1.1 The categories of data in the CPR

There are certain categories of data which generally occur in every patient record: demographics, problem lists, signs and symptoms, current medications, test results, assessment, and plan [7, 20, 21]. The presence of these data categories is most variable in PMRs as these permit individual physicians to organize them. CPRs are usually standardized at a departmental or institutional level, resulting in more uniform patient records. Partitioning data in categories creates structure in a patient record at a macro level. The micro level comprises the data within the categories, such as actual complaints and findings. Where the macro level ends and the micro level begins is arbitrary, which is reflected by the fact that some records have more refined categories than others [18, 23, 25]. Allergies and social and family history may be present as separate categories or be lumped as part of the history. In the same way, some records mention diet and referrals explicitly, while others view them as part of the plan section. The question arises: what is a category? What do the pieces of data within one category have in common? A common denominator of categories is that they are related to the procedure with which the data were obtained. The mentioned categories are in fact source-oriented views on the patient record. In contrast, in a problem-oriented view data will be related to a problem or diagnosis across the boundaries of the various sources. Both views are important to the physician, but the fundamental difference between the two is that the source-oriented view is data independent, while the problem-oriented view is not: problem-dependent views can only be supported once the necessary semantic relationships between data have been made explicit by the physician, whereas source-oriented views can be supported as a general structure in a patient record. From the source-oriented viewpoint, we see that the granularity of categories is arbitrary, but their contents are not. Categories can be placed in a tree structure: a branch starting with 'additional tests' may be subdivided into laboratory tests and X-rays. Laboratory tests may be further subdivided into blood tests and urine tests. Hence, differences in the granularity of categories merely correspond to different levels in the same hierarchy.

4.1.2 Temporal aspects of patient data

Since the patient record essentially involves the recording of events over time, the representation of time in these records has been subject of many studies. Time-stamping of patient data is important for a variety of purposes. The physician consulting the record relies on time-stamps to determine whether certain investigations need to be repeated or whether medications need to be renewed. He also uses time-stamps for analyzing trends; when the number of white blood cells decreases, the length of the intervals between the measurements matters. In case of short intervals, the deterioration is faster and may require more aggressive clinical action. Depending on the context and purpose for which data are used, time-stamps differ in nature and precision. Time may be expressed as an absolute expression ("May 5 1994, 4.00 p.m."), as a relative expression ("2 days after"), or as a duration ("lasted 20 minutes"). More precise time-stamps will be needed in an intensive-care setting. Physicians will use all these different types of temporal data in their reasoning, but automated decision support requires a formal representation of time to permit algorithmic reasoning [26]. We will briefly discuss three important issues in the representation of time in the CPR: (1) how time is represented, (2) which data need to be time-stamped, and (3) which moments need to be made explicit.

4.1.2.1 How is time represented?

Relative temporal expressions only have meaning when their relationship to real time is known. Relative time is essential for the expression of knowledge about the general course of a certain disease, or the chronologic order of actions to be taken in a clinical protocol. Once this knowledge needs to be applied, its reference to real time becomes important. Patients often relate the history of their complaints in relative time, but it is usually not difficult to convert this temporal data into real-time expressions. The same applies for expressions of duration. Hence, we will focus on the representation of real time. Depending on the context, time can be of different granularity. A patient may have undergone gastric surgery in 1985, a chest X-ray on June 5, 1994, or the recording of an ECG at 11.10 a.m. on September 3, 1994. The examples given differ in temporal granularity. Human reasoning with such different granularities has been formalized in algorithms. Pinciroli proposed sequential comparison, from large to fine granularity [27]. For example, September 3, 1994 comes after June 5, 1994: comparison at the level of the year provides no solution, but comparison at the level of the month is conclusive. Whether June 5, 1994 is before or after another event time-stamped with June 1994 stays unresolved. Campbell and Das proposed a metric model of time with the same granularity for all time-stamps [28, 29]. Each event is associated with two time-stamps between which it has taken place. These event-related intervals explicitly reflected temporal uncertainty and temporal operations are no longer granularity dependent.

4.1.2.2 Which data need to be time-stamped?

When patient data are recorded, the person taking the notes drastically reduces the amount of data. He does not record everything that has happened or is true, but only that part of the data that he considers relevant. Relevance is an arbitrary issue but Buekens argued that relevance is closely related to causality [30]. The data we record should enable us to make causal and predictive inferences. Time and causality are dense, in the sense that there is an infinite number of moments and events in a chain that leads from state A to state B. However, not every event plays an explanatory role. Buekens gives the example of domino stones: if there are a million stones and the first one is pushed, 999,999 events take place before the 1,000,000th stone falls. However, the activity that has led to the falling of the first stone is considered relevant to the falling of the 1,000,000th stone. Similarly, instead of saying that a patient had no hypoglycemia in 1982 and in 1983 and in 1984 and in 1985, one will write that the patient had no hypoglycemia in the period from 1982-1985. Hence, the essence is the art of identifying and time-stamping those events that are relevant to the medical history [30]. Often, causal insight only comes after a series of events has taken place. The paradox is to decide which events to record when time has to tell us which ones are going to be relevant. In practice, physicians use their training and experience to identify events which are probably relevant [31].

4.1.2.3 Which moments need to be made explicit?

Few patient records provide more than two time-stamps. Most often these instants are: the moment it has been recorded, and the moment it happened. Rector emphasized the importance of the patient record to be both faithful and permanent [32]. This means that the contents of the record should reflect the findings and decisions of the physician, but also that data may not be changed at some later date. Yet, a physician's insight may evolve over time, requiring him to 'overrule' statements made in the past. Similarly, an internist may hear from a colleague in neurology that his patient has been suffering from multiple sclerosis for two years already. Consequently, it must be possible to make statements about the past.

For the given example two time-stamps seem to suffice: on October 10, 1994 the physician records that his patient has suffered from multiple sclerosis since June 1992. However, in some circumstances proper interpretation is only possible when there is a third time-stamp indicating when the data became available or was assessed. A classic example is a laboratory test. There are three time-stamps: the moment the sample was taken, the moment the sample was analyzed, and the moment the result was recorded [33]. If too much time elapsed between sample time and moment of analysis, the result may have become invalid (e.g. sedimentation rate). If there is a large gap between the moment of analysis and the moment of recording, the result may no longer be up-to-date. Another example is the situation in which an internist hears from the pathologist that tissue taken during surgery has proved to be malignant. The internist then starts a certain treatment. The pathology report is made later. The physician can only record the reason for therapy when he can make explicit that he had gained his insight prior to the pathology report. With the examples given, it is clear that the "moment happened" is an ambiguous statement. It should be replaced by two time-stamps: "moment insight gained" and "moment insight applicable" [33, 34]. In case of the laboratory test, the "moment insight gained" corresponds to the time of analysis and the "moment insight applicable" to the time of sampling. In practice, however, the three moments will often coincide, as is the case with a physical examination during a visit.

4.1.3 Observations and interpretations

Data in patient records often pertain to observations, interpretations, and decisions. Observations include complaints, findings, and test results. Examples of interpretations are diagnoses, and the formulation of causal, c.q. explanatory relationships. Decisions encompass test orders, drug prescriptions, referrals, and other components of work-up or treatment plans. Data of these three types often co-occur in patient records. When one is evaluating information for further decision-making or medical audit, it is important how the data in the record is related. Based on medical knowledge, physicians are often able to infer relevant relationships. However, studies have shown that ambiguous descriptions and missing data may hinder proper interpretation [15]. For example, explicit recordings of indications for treatment and diagnostic tests are often lacking. To make the process of care more transparent, semantics need to be added to the data in the record [24].

Weed's problem-oriented medical record (POMR) [4] is an early example in which semantics are added to the patient record. By relating SOAP-codes to a single problem, it becomes clear that observations (S and O), interpretations (A), and decisions (P) are related to each other in the context of that problem. Problems may need to be linked over time, which is especially important when problems are renamed according to evolving insight [35]. However, the expressive power and granularity of the semantics in the

POMR is coarse.

Rector proposed a framework for the patient record in which he distinguished two levels [33]. Level 1 encompasses the facts that stem from the physician's observations, thoughts and actions. Most data in patient records belong to this first level. Level 2 provides the links between the components at the first level to make explicit how they fit in the decision-making process and the clinical dialogue. The explicit recording of indications for tests and treatments [34] would correspond with level 2 semantics. In Rector's model, the boundary between observations and interpretations is not clear-cut, because level 1 includes facts that stem from what physicians thought. The line of reasoning leading to such facts is seldom made explicit. An expression like "bronchitis" would belong to level 1, although it is in fact the interpretation of a set of observations such as rhonchi, fever, and cough. From Rector's point of view it is not important at what level of abstraction a physician phrases his observations.

Buekens correctly observed that interpretations may change over time as insight increases. He advocates that the events to be recorded should serve an explanatory purpose. In order to achieve that goal, events need to be *redescribed*, reflecting the evolving insight regarding the event [30]. For example, the fact that a patient ate mushrooms may later be found to have been the cause of his illness and could be redescribed as ingestion of poison. The danger is that it may become difficult to trace which event underlies the various reformulations. Therefore, observations and interpretations are ideally separated, thereby making explicit to which event a redescription pertains [31]. The author was personally confronted with a patient thought to have bronchitis by one physician and pulmonary edema by another. Recording the interpretation alone, instead of the observation 'basal rhonchi', introduces a bias and may obscure part of the proper differential diagnosis.

4.1.4 Models for the representation of patient data

As has been indicated earlier, analysis of patient data, the creation of multiple views for consultation, and the application of automated decision support, require patient data to be represented in an unambiguous structured format. We will not focus on implementation issues regarding the storage of patient data: the type of database technology used is usually influenced by functional requirements, existing infrastructure, available expertise, and cost.

A straightforward form for the representation of patient data is a table that defines by which attributes a particular entity may be described [7, 19, 20]. However, this approach is rigid: a change to a table requires adjustments in the application and when certain attributes can be used in more than one context, redundancy may be the result. Tables function well if the data set is stable and can meet with consensus of its users. The more users differ in their needs, the more difficult it will be to achieve such consensus.

In search of a larger flexibility, other strategies have been applied for the structured representation of patient data. These strategies involve a knowledge model that consists of a predefined vocabulary and of knowledge about how the terms of that vocabulary may be combined into meaningful expressions. The instantiations of that knowledge constitute the actual patient data. These data often are expressed in triplets [36]. The basic structure of a triplet is "object - attribute - value", for example: "diabetes - control - poor" or "pain - location - leg". For the purpose of maintenance and transparency, terms are often ordered in a hierarchical structure, in such a way that a 'child' in this structure is a specialization of its 'parent'. Based on this hierarchy, children inherit their parent's relations. Hence, a relation may only be defined when it applies to all children of the parent in question. A widely used formalism for the representation of this type of knowledge is the 'conceptual graphs' formalism. Conceptual graphs are an intuitive notation for first-order logic [37]. In this formalism, there is a set of predefined terms and types of relationships between these terms. The core unit of knowledge is a triplet of the form: 'term A - relation B - term C'. For example, "fracture - has location - bone", where "bone" is a high-level term in the hierarchy with children such as 'femur', 'humerus' and 'mandible'. Since a term may have multiple relationships with other terms, these triplets form a large network: the conceptual graph. Actual patient data form a sparse instantiation of this graph. Complex data can be represented by forming new triplets of already existing ones [36, 38].

Conceptual graphs have been used in many clinical applications, most of which are related to natural language processing (NLP) [28, 39-43]. The quality of NLP strongly depends on the ability of the system to represent and interpret medical concepts [44]. Often graphs are chosen to encode the knowledge needed for the parsing process.

Other researchers have proposed strategies that structure patient records with the purpose to facilitate browsing through patient data. In Essin's dynamic data model, the basic elements of the database are items that appear on documents. These elements can be combined to define any type of document [45]. Although this model is very flexible and provides easy access to data, analysis of data requires a detailed semantic model of the documents involved [46]. Another approach to offer structure for an associative way of browsing is the use of Hypertext or Hypercard [47, 48]. Related Hypertext documents are linked together. A highlighted area in a document indicates the presence of a related document and can be used to access it. Unless there is a semantic model defining a mapping to a database, this strategy offers no potential for the generation of different views on the data, nor for data analysis.

4.2 Standardization

Having a formal representation of structured patient data, does not mean yet that data can easily be shared among different institutions. Therefore a variety of terminologies have been developed, intended to promote standardization. Examples are ICD9/10 [49], SNOMED [50], READ [51], and UMLS [52]. Several researchers have tried to map patient data on one or more of these coding schemes [28, 53, 54]. However, no vocabulary exists that can represent all variations of medical terms that appear in natural language [39, 55]. Some have more than one expression for the same concept and others are not granular enough. The Canon group and the Galen project are working towards the possibility of exchanging patient data while retaining maximal expressive power and correct reflection of meaning. These projects involve a formal representation of medical data and knowledge to serve as an interlingua [44, 56-60]. The resulting representation scheme should allow for flexible expansion, unique representation of meaning, support of NLP, sentence generation, and mapping into other languages to create multi-lingual information systems.

4.3 Data entry

Patient data can only be stored in a structured format if they can be obtained as such. Presently, two types of strategies receive most attention: NLP and structured data entry (SDE). The advantage of NLP is that physicians do not have to change the way in which they choose their phrasing. Free text offers maximum expression capability. NLP requires knowledge about the terms and semantics of the domain to which it is applied. The best possible result with NLP - and we are still far from that - is that as much structured data is extracted from a source as a human expert can accomplish. Yet, the disadvantage of not influencing the process of data capture is that this process cannot be improved.

SDE involves the selection of terms from a predefined vocabulary to describe a case. For a long time, data entry directly by physicians was considered an unattainable goal [7]. The earliest applications for data entry by physicians started with electronic equivalents of paper forms [23]. Some studies indicate that data entry on computerized forms produces better results than data entry on paper forms [61-63].

Forms are static in the sense that the contents are not dependent on the context. The static approach is preferred when the domain of application is small and does not involve too many forms. The larger the domain, the more awkward forms become. Another approach involves a more dynamic interface, using menu trees and graphical displays to interact with the user [64-70]. These dynamic applications are based on a model of the domain of application which defines which expressions can be made within that domain. Models that are used for NLP or for the representation of patient data, are also used by applications for the support of SDE. However, using triplets of the form "finding - attribute - value" for data entry, allows only very 'shallow' descriptions or requires the definition of composite terms as findings [55]. Although composite terms such as 'left cervical lymphnodes' may be typical for progress notes, the use of such composite terms introduces redundancy. Domain completeness, non-redundancy, and non-ambiguity are among the criteria that a controlled medical vocabulary should fulfil. Domain completeness means that a terminology should not be restricted in scope, nor should descriptions be restricted in depth [71]. Moorman [32] and Rector [70] achieve non-redundancy by adopting the principle of generating complex expressions from a modest number of primitives.

In the applications for dynamic SDE mentioned above, the underlying knowledge models seem to be directly inspired by the domain of application. Instead of modelling per domain which expressions can be made, Moorman focused on the type of semantic constructs that may need to be made explicit in general. This study led to the identification of description knowledge, that defines when, where, and how concepts can be described. The resulting model is domain-independent and allows for the construction of knowledge bases that are specific for certain domains. The model also allows for the capture of physician-specific meaning of summarizing terms to facilitate SDE [70].

SDE has proven to be an efficient tool to enhance completeness of data [61, 62, 72-75]. Yet, no matter how much detail is supported by SDE, the expression capability is intrinsically limited. Therefore the option to add detail in the form of free text is usually provided. The question is which level of detail is sensible in a structured form. Anecdotal information will have little scientific relevance and may be recorded in a slightly abstracted form, conveying the deeper meaning: instead of saying that "chest pain comes on when the patient walks past a cooling section in a supermarket", the physician will state that "chest pain is induced by cold" [32].

Most SDE applications require more time for data entry than free-text reporting, but there are examples where a gain in time was observed [61]. In fact, typing itself does not seem to be the greatest barrier for physicians [76]. The preference for a static or dynamic approach depends on the circumstances [77]. Versatility is very important for user-acceptance [17]. So far, SDE has only met with relative success when small well-circumscribed domains were involved [78]. Motivation of physicians strongly depends on the benefit that is gained and one should realize that a period of investment is required before benefits can be harvested [76]. Default reasoning and interface technology such as graphics, pointing devices, and voice input may further the efficiency and feasibility of SDE in daily practice.

5. Which way should we go with the CPR?

There are numerous publications explaining why structured and standardized CPR data are valuable and what the potential benefits of such data are. The long list of potential ways of using patient data can be divided in ways that directly benefit patient care and ways that may have a more indirect impact on health care [7, 12, 22, 79-81]. Examples of direct support of patient care are rapid access to data, flexible summary generation, reminders, warnings, support of protocol adherence, and decision support. So called secondary benefits include billing, research, education, post-marketing surveillance, quality assessment, outcome analysis, and health care regulation. Yet physicians have been slow to accept the CPR in their routine practices. Positive exceptions are GPs in The Netherlands and the UK [82]. Researchers have warned that beside benefits there may be distortion of data, or interpretation of data in an improper context [8, 83, 84]. The CPR should promote the explicit recording of data with their context. Still the question remains why the CPR is not readily accepted when its potential benefits are so obvious?

Many researchers and developers have formulated requirements that CPRs should meet [11, 12, 85-87]. These requirements have been formulated on the basis of two main points of view: (1) those that are prerequisites to realize the potential benefits, and (2) those that make CPRs acceptable or attractive to their users.

A CPR in which the conflicting aspects between these two viewpoints have been fully resolved does not exist yet. The question arises whether we still fail in our designs, whether the priorities of clinicians do not match the pursued benefits, or both. The essence of the problem is the tension between effort and benefit. The balance is delicate and further complicated by the fact that physicians vary greatly in specialty and working styles [16, 17]. We believe that the most promising strategy towards acceptance of the CPR is to focus on those benefits that are greatly valued by users. Physicians will find CPRs useful if they support them in billing, correspondence, drug prescription, versatile overviews, access to multi-media data and other sources of information on the same patient, reminders, warnings, retrieval of certain cases, and access to literature sources. Physicians want access to data with a minimum of interaction and, ideally, each view in the CPR is tailored to the situation at hand [17, 87]. Hence requirements following from these benefits should have priority [11], even though they may not be easy to realize. Two requirements deserve to be specifically mentioned. In the first place the CPR should not supplement, but fully replace the PMR and be used directly by the physician; only then can it reach its full potential [86]. Secondly, one cannot sufficiently involve the user in the developmental stages, whereas now too often designers try to convince users of the elegance of their ideas. It requires a thorough understanding of user problems to find proper solutions to them [17].

Perhaps, we should temper our enthusiasm about the potential of the CPR and take smaller steps in its development. User-acceptance should have priority above all. In the mean time, new insights and developments may bring the remaining goals within reach.

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