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The mantra of modeling and the forgotten powers of paper: a sociotechnical view on the development of process-oriented ICT in health care

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Abstract

The recognition that restructuring care processes is central to effective and efficient health care will result in the emergence of process-oriented electronic patient records (EPRs). How will these technologies come into being? Within informatics, it is often stated that to informate something, we should first model it. This paper queries whether a detailed modeling of work processes and data flows is the primary step that needs to be completed before such EPRs can be developed or tailored. Building upon a sociotechnical understanding of ICT development, we argue for a reinterpretation of 'models' in such development processes. We do so through a reverse engineering of parts of the paper-based medical record, which has received little attention in medical informatics. In process-oriented EPR design, we argue, modeling should not be conceived as the crucial first step in this design, but rather as an intervention in the organizational change-processes that constitute proper ICT development.

Keywords: Medical records systems; Computerized information systems; Order–communication systems; Software design; Modeling; Computer system development; Organizational innovation; Sociotechnical system development

1. Introduction

In the medical informatics literature as well as within health care organizations, the electronic patient record (EPR) has so far mainly been conceptualized and designed as a data-repository. In such a view, its advantages over the paper record lies first and foremost in its enhanced storage and retrieval functionality, including the ability to provide smart search functions, instantaneous and multi-location access, and the virtual integration of data elements stored in geographically disperse

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databases. In recent years, however, changes in the health care context and in ICT developments have led to a gradual shift in this conceptualization [1]. The move towards integrated care, in which care processes are redesigned around patients' needs, the emergence of evidence-based medicine, and the development of guidelines and carepaths that more and more incorporate efficiency considerations all have led to an increased interest in *process*-oriented ICT [2]. Likewise, the recent popularity of ERP and workflow systems as models for health care systems development reflects the increased tendency to see the 'core business' of future EPRs to structure and support the 'core business process' of health care: the primary care process [3]. (As yet, this is more visible in the changing trends in commercial and in-house EPR developments than in the medical informatics literature). Although the importance of this new orientation is widely shared, it cannot be said that it has already led to unequivocally successful systems [4,5].

Within the field of Informatics, a powerful, received tradition says that in order to informate something, we should first *model* it. We should abstract from the messiness and the concrete forms of the work practices for which the ICT application has to be designed, and capture its essence. This serves at least two interrelated purposes: it facilitates the interaction with the users in the process of requirements elicitation, and it is a necessary step in the generation of system requirements [6,7]. In the case of process-oriented ICT, the essential core that the models aim to capture generally lies in the information flows between actors and/or the distribution of the actors' responsibilities. Once these are mapped in flow diagrams, activity models, and/or data models, the 'environment' within which the information system is to operate is charted, and the work of designing (or 'buying' or 'tailoring') the system itself may begin[1].

In this paper, we would like to ask the question whether a detailed modeling of ('business') processes is indeed the primary step we need to complete before we can hope to design a process-oriented EPR, or to acquire or tailor such a system. Building upon a sociotechnical understanding of ICT development, we will argue for a thorough reinterpretation and repositioning of 'models' in such development processes [8,9]. We will do so through a *reverse engineering* of (some elements of) the paper predecessor of the EPR: the paper-based medical record. Scorned by many EPR enthusiasts, an understanding of its powerful (albeit indeed rusty and heavily burdened) role in making primary care processes possible can nevertheless help us to understand what models underlie its functioning, and how these models came about. Doing so, we will question another often repeated starting point within medical informatics: the claim that ICT will revolutionize health care, and that it will bring light into the darkness of current 'paper-based' practices [10,11]. Since the overall view is that the EPR will 'finally' get rid of the messy and inadequate paper records that imprison data, that get lost and that are unreadable, serious analyses of the powers of *paper* records are hard to find [12–14].

2. What does the record do

As one of us has argued in detail elsewhere, record systems (whether paper-based or electronic) fulfill two functions that are crucial for current medical practice [15,16]. First of all,

[1] This design process itself requires many models—of the information system functions, of its components and their interrelation, and so forth [6].

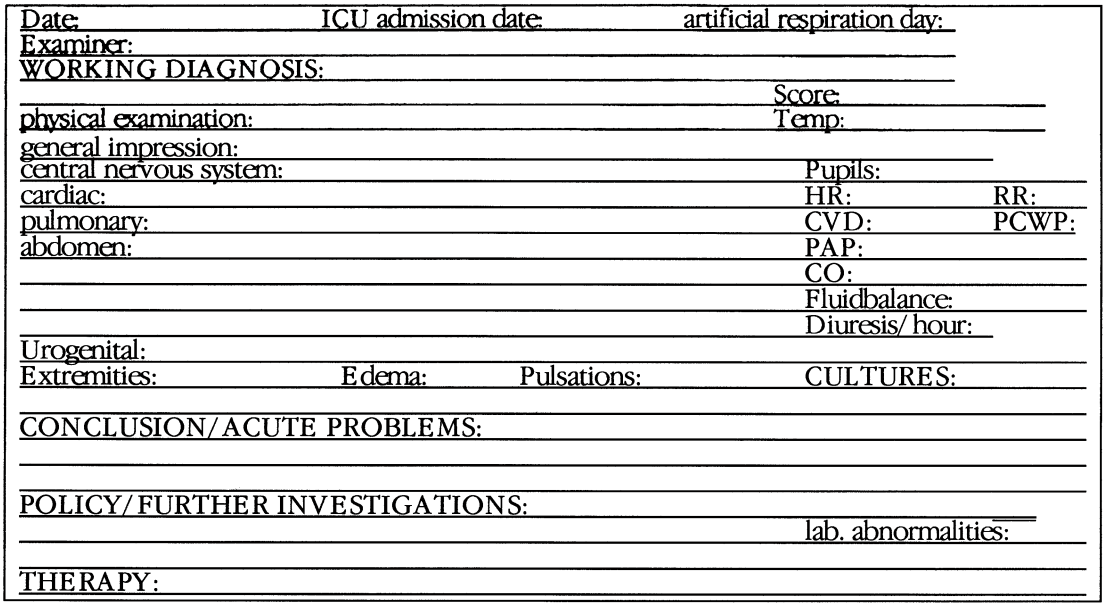

Fig. 1. A paper progress form from an ICU. (HR, heart rate; RR, tension; CVD, central venous pressure; PWAP, pulmonary wedge arterial pressure; PAP, pulmonary arterial pressure. Some details not important for the discussion are omitted).

record systems *accumulate* the data gathered during the course of a patient trajectory, resulting in a powerful 'external memory' [17]. This external memory is not a mere passive repository: by providing a specific structure and context to the data accumulated, the record's *form enhances the information content* of these data. A brief description written after a ward's round becomes step x in this patient's medical history, and a blood test result becomes part and parcel of a whole array of data whose overall evolution is vastly more informative than each individual measurement. In the progress notes form shown in Fig. 1, for example, the entered data automatically become placed in a larger systematic reasoning process: the data gathered all become part of an overall pattern of data leading to a 'conclusion' and a 'policy'. When such a form is re-read later, this implied reasoning process thoroughly structures the reading process, and the isolated data entries will be interpreted in this framework [18].

Second, through structuring and sequencing the *work* of health care workers, the record *coordinates* activities and events at various locations and times. The standard headings in the ICU progress form structure the questions that physicians ask and the examinations that they perform, and make their notes comparable to each other. Likewise, as a workflow-system avant-la-lettre, structured forms that are used by several people, at different moments (such as an order-form), help to link the activities of doctors and nurses without the need for real-time, 'face-to-face' interaction [19][2].

[2] The medical record, it is obvious, it intertwined with medical work on many layers. Its complex functionality is reflected in the difficulty in classifying an (electronic) patient record: is it merely a database, or maybe a knowledge-work system? Or is it part and parcel of a management information system, or primarily a decision-support system, or again maybe predominantly a workflow system? Elsewhere, we have used the term 'patient care information systems' (PCIS) to prevent confusion [16].

Both functions are pivotal to Western medical work: they make the complicated care processes that characterize current health care possible. They help handle hundreds of people with increasingly long and elaborated medical histories, and help link the actions of the increasing number of care givers working with a single patient.

3. What model, what modeling

Within the fields of study designated *Software Engineering* and *Information Systems Science*, much discussion has focused on what constitutes the 'best' modeling approaches, to be used in the analysis and design of software systems. Data Flow Diagrams (for modeling the functionality of a system), Entity Relationship Diagrams (for modeling the information structures of a system) and Class Diagrams (for modeling the objects a system deals with) are but a few of the manifold, often competing modeling techniques that have been proposed. In recent years, attention has shifted to modeling techniques that encompass several viewpoints, such as e.g. the enterprise viewpoint (modeling the business environment in which the system has to operate), the information viewpoint (modeling the information structure), the use case view (modeling the systems' behavior with respect to its environment) and several viewpoints that model the components, mechanisms, hardware architecture and so forth of the information system itself [6,7].

Within medical informatics, modeling efforts have been directed mostly at getting a grasp on the building blocks of medical knowledge, or at the essence of medical decision making (conceptualized as an individual, cognitive process). Whenever 'modeling' is discussed in relation to the EPR, these are the realms that are usually implied [11,20]. This approach, although dominant within medical informatics, has never been without its critics. They argued, for example, that 'medical interpretation is not so much a function of cognitive structures as one of social processes that take the form of discourse and argumentation' [21]. That is to say: medical work, including the interpretation of signs and symptoms, is based as much on communication and negotiation between health care professionals and between professionals and patients, as on the cognitive thought processes of an individual physician [22]. Likewise, the view of medical knowledge that underlies much modeling activity within medical informatics has been criticized as being founded in an overly positivist, atomistic conception of knowledge, which has already been proven fallacious by the later Wittgenstein [23,44,24]. As we will argue later, 'medical knowledge' is a much more *fluid* category, which is constantly adapted to local needs and changing circumstances [25]. In this light, then, the move away from thinking processes, and away from trying to 'found' informatics in an illusive essence of medical language is crucial. Modeling *processes*, at the very least, turns us towards the interactive and unfolding nature of health care work (Coiera, this volume).

Yet what is, in fact, 'modeled' in the (design of the) *paper* record? What, in other words, needs to be 'modeled' to bring a smoothly operating, indispensable information system into being? Interestingly, the paper medical record models a bit of everything out of the 'field of work' in which it operates [26]—medical knowledge, decision making processes, business processes—, but in a very sketchy, highly uneven and utterly eclectic way. Let us reconsider the progress form shown in Fig. 1. In this form, the medical decision making process is modeled: data are gathered, which lead up to a conclusion,

which lead up to a policy which might consist of further investigations and/or therapeutic action. This is clearly reminiscent of the classic 'hypothetico-deductive method' that cognitivist psychologists see as typifying the medical reasoning of medical professionals ever since the seminal work of Elstein et al. [27]. Likewise, however, medical knowledge can be said to be modeled, although in a rather rough sense: the body is split up in several systems (central nervous system, pulmonary, abdomen), and certain key-indicators for ICU patients are singled out. There is no relation made between these indicators, but for a rough grouping and the—implicit—suggestion that these are indeed core-parameters, somehow more universally relevant for this category of patients than others.

Finally, the process of ICU work is sketchily and partially modeled: the admission date and the 'artificial respiration day' are designated as important markers in this work, for instance. Likewise, the items listed all refer to distinct activities that are performed as a part of this process. Items such as 'fluidbalance', 'cultures' and 'PAP' can be seen to be medical knowledge entities, but they also point to the concrete nursing routines and instruments that result in the data filled in after 'fluidbalance', 'cultures' and 'PAP'. For an insider, in addition, the form as a whole clearly models ICU physicians' working routines as a part of the overall ICU practice: they gather some information themselves (through investigating the patient, for example); read other information from monitors or from the nurses' notes, make a list of further investigations and therapeutic activities to be arranged and executed by the nursing staff, and so forth.

Order forms similarly model the work relationship of doctors and nurses (one giving orders; the other executing them). Depending on their specific form and content, they can be seen to model medical knowledge and decision processes as well. Test result tables model knowledge more clearly and explicitly than the progress form does. Their chronological structure models the importance of temporal dimension in medical knowledge and decision making processes, and the clustering of blood tests on such forms represents the structure of knowledge within laboratory medicine.

Yet when browsed through like this, the models are highly partial and eclectic, seemingly both about 'process' and 'medical knowledge', and most of the times highly implicit. Why is this the case? Importantly, what does this teach us about the place and role of modeling in the design of new information systems?

First of all, the information system (whether paper or electronic) is only one element active in doing the accumulation and coordination. Physicians, nurses, patients, organizational routines, paper forms, electronic records: all play their roles in constituting memory and coordinating the work. The health care workers are not only responsible for writing into and reading from the record: they are also themselves rich sources of memory (for themselves and for each other), and they also themselves spend much time ensuring that their activities are and remain coordinated [28,29]. Since the record only needs to cover its part, it follows that it is simply not *necessary* to have more than a very partial model of the process. A lot of separate activities and thinking steps are covered by the simple heading 'central nervous system' on the ICU progress form—but these steps are known by physicians and executed by them. The form plays no role in these subtasks—only in accumulating the overall outcome of these activities, and in coordinating this group of activities with other (groups of) activities. Similarly, the form does not need to embed a more elaborate model of medical knowledge, since that is part and parcel of the intelligence

that the health care professional brings to the scene. Finally, the form does not need to be more precise in listing who has to arrange which 'further investigation' or 'therapy' where, and with which department: the nurses will do that part of the coordination work, activating organizational routines and using additional forms for every single intervention.

Second, this seemingly peculiar status of models in the existing information systems is related to the specific nature of professional work. Social studies of professional work have shown repeatedly that professional 'knowledge' and 'information' cannot be conceptualized as atomic bits and pieces that can be 'stored' and 'retrieved' at will, and that can be unequivocally mapped on simple, universal schemata. In professional work contexts, 'knowledge' and 'information' should rather be conceptualized as highly dynamic and context-dependent entities; as 'flow' rather than as 'stock', and as 'tacit' and 'embodied' rather than as 'explicit' and instantly codifiable [30,31]. This does not mean that it is impossible to explicate and codify such knowledge, and that one cannot attempt to create atomistic schemata: the numerous existing coding systems and thesauri show that this is indeed possible [32–34]. Yet moving from the fluid professional knowledge and information as it exists in everyday work-practices to these static schemes is an active act of translation. This might be very useful for e.g. epidemiological, statistical, administrative or financial purposes, but in which aspects of what made a local situation typical and recognizable are inevitably deleted [35]. Such translations decontextualize, are partial, and risk to be rapidly outdated. Systematic, and logically structured medical knowledge, in other words, may be very useable for purposes that involve the gathering of similar information from very different sources—but such static and reified terminology does not suit the everyday communication amongst caregivers about their cases [25,36].

With regards to the nature of the 'workflows' in health care, similar remarks can be made. Many sociological studies of health care work have emphasized the 'situated' and 'interactive' nature of workflows. Although there are important routines and protocols, no one patient follows an identical course [28,37]. This is a simple consequence of the combined complexity of the professional problem that has to be tackled and the organizational structures set up to tackle it. In other words, the way a human organism reacts to a disease, to a combination of afflictions, and to interventions upon these is hard to predict, and the complexity of the organizational routines that come to play around this human organism also defies predictability. In such contexts, the work is inevitably improvisational, ad hoc, and reactive. Although there are definite routines and rules that bring structure, *none* of these are in principle exempt from reinterpretation in the light of unforeseen or unfamiliar circumstances. As above, making workflows, guidelines and/or carepaths is possible—as the enormous attention to 'evidence-based medicine' illustrates. Yet here again, such models will remain always partial, will always be in need of interpretation rather than prescribing interpretation, and will always run the risk to become rapidly outdated [38].

The models in our paper information systems, then, are so partial and eclectic because their functionality covers only a small part of the accumulation and coordination tasks. In addition, they have evolved to such a point that the granularity with which they structure and standardize the communication and worktasks of professionals forms a perfect match with the working needs of these professionals. In other words: they standardize the work—through providing headings and

sequences—so that reports become comparable and scientifically structured, yet they refrain from imposing additional structure there were that would go against the communication and working needs of professionals within the primary care process. Embedding fully-fledged and logically refined models in these tools, then, is not necessary. Worse, they would more likely than not obstruct the work they are intended to 'support' [39].

We can understand these phenomena better if we look at a third and last point, which is related to the way the models came about. What did we do, in our 'reverse engineering' exercise? Did we deduce, from the forms, the models that the forms' designers had made of the work practice (or the related knowledge or decision making processes)? If so, these were poor modelers indeed. If we take another look at these forms, however, and especially if we also look at the forms that preceded or succeeded them, a rather different interpretation becomes evident. The 'models' that we witnessed were never the result of conscious design: rather, they resulted from attempts to improve upon the physician's practice of history taking, for example, or attempts to improve data storage, or to enhance the cooperation between doctors and nurses [40].

Let us look once more at the progress form. The primary goal of listing the individual entries is to ensure uniformity and completeness of data collection, and thereby to prevent that important data items are not gathered because they do not seem vital at the moment of their gathering. Its predecessor was a form, which listed less subheadings, and in its (electronic) successor, each subheading (such as 'cardiac') was divided up further (for 'cardiac' for example including new fields about 'murmurs' and 'rhythm' (see [40] for a further analysis). The designers' aim, then, was to improve, in this case, the data gathering process: it was an attempt to *change* the practice, *not* to 'model' it. The order form, likewise, was created as a simple tool to afford more efficient and error-free doctor–nurse communication, and results tables are constantly improved to enhance readability and retrievability. In electronic systems, the order forms may start to create automatic links between distinctive parts in the record, and actively coordinate work by sending messages and controlling whether tasks have been executed within an allotted time frame. Tables might become more 'active' by automatically adding rows and columns, and by automatically importing and/or checking data from other parts of the record. In all these forms, the 'models' embedded in them were never 'designed' as such: what was designed was a tool that would take up a larger or more powerful accumulating and/or coordinating task. 'Modeling' was not either a step *towards* change, as one might counter: the admittedly patchy model that the record indeed contains was a *secondary by-product* of an attempt of *process-improvement*. An accumulating and/or coordinating tool inevitably embeds a model of the field of work in which it operates—but this does not imply that this 'model' was ever consciously designed. In fact, in the cases we studied here, it would be hard to imagine how such feeble 'models' ('feeble', that is, when looked at from a modeling-perspective) could be arrived at when 'modeling' would have been an aim somewhere in the process.

4. Discussion

What does the above argument mean for process-oriented EPR design and implementation? One could still argue that there is a *non sequitur* here: from the insight that models sometimes do not seem to play a great role in the design of paper or electronic records, we can hardly conclude that adequate modeling

should not play a role. We have spoken about order forms and progress notes, and that is surely something else than an integrated information system underlying the care process? These objections, however, are highly problematic. Of course, as long as we speak about single order forms and isolated progress notes sheets, the comparison with an integrated, process-oriented EPR is moot. But as soon as we consider the whole assembly of forms and paper slips that travel within and between health care organizations every day in massive numbers, and that all end up in the overall paper medical record, this comparison becomes very relevant. More importantly, however, these objections reinstall the view that there is a large discontinuity between the 'old and messy' days of paper, and the bright, shiny and rational future of ICT. Our argument is that we should rather attempt to learn from what the paper medical record *has* achieved over the last century [41]. A detailed discussion of its particular strengths and weaknesses, we argue, and a comparison with the particular strengths and weaknesses of ICT is a much more fruitful road towards successful EPR design than the all too current drive to 'eradicate' paper. In addition, we can learn much from the way it has *evolved* over the years: as an implementation story, it has been successful to a degree that no health care ICT application to date has been able to match.

In addition, an analysis of a variety of operational EPR systems would not reveal a different picture. The stories behind the choices for certain fields and headings would be much like the story told above: either they are simply copied from earlier paper forms, or they are, as was the case here, seen as an attempt to improve record keeping practices. The most obviously process-oriented EPR systems currently in use, those that pivot around physician order entry, are a case in point. In such systems, physicians directly enter their orders for e.g. laboratory and radiology tests into a computer system, and the results of these tests are directly communicated back to the ordering physician. Almost invariably, an important rationale of implementing these systems is that they *change* pre-existing work practices, where it is usually the nurses and/or ward secretaries who are the ones responsible for the paperwork of ordering tests [4]. Taking them 'out of the loop' is generally expected to reduce costs and, importantly, to reduce the chance of errors [42]. A close investigation of the implementation stories of such applications reveals that, again, elaborate 'modeling' was never undertaken. The models that can be 'read' in these tools are byproducts of these change-processes—and not vice versa [43].

Another objection that might be raised is that although you might not find systematic and logically consistent models of medical knowledge, cognitive processes or workflows in the information system, this does not mean that you do not still need adequate modeling methods in the process of designing and constructing such tools. One caveat that we need to put in place, indeed, is that in system design terms, we are here discussing the need and practice of modeling the *environment* of the information system as a step in designing the system. We are not contesting the need to model information system functionalities and components as crucial steps in proper software development [6]—that is a discussion that we do not address here. We do, however, contest that exhaustively modeling the information flows and/or actors' responsibilities is a necessary first step in *either* the process of interacting with future users and the design of the information system itself.

Process improvement is the task of conjointly restructuring human worktasks, rearranging organizational routines, redesigning

paper forms, and introducing new ICT functionalities. The aim of all this is to improve the overall quality of the process on one or more of several dimensions: patients' outcomes, patient satisfaction and empowerment, efficiency, but also, importantly, the satisfaction and empowerment of the health care professional [44]. The role ICT plays in all this is that its accumulation and coordination powers may go much further than its paper predecessors' capacities. When well designed and implemented, therefore, it has the potential to increase the mutual coherence of work-tasks executed in different times and places, to enhance the health care professional's responsibilities and introduce new capabilities, to bring the patient closer to the center of the collective decision making process around his/her own trajectory, and so forth.

To embark on such a process improvement project, it is indeed useful to acquire a rough view of the overall work practice one is confronted with—its core actors, their core tasks, the 'standard' flow of the work, the most prominent flows of data, and so forth. Of equal interest, however, is to get a grasp on the actor's main motivations, their possibly conflicting interests and drives, and the strengths, weaknesses and modifiability of the existing paper and ICT infrastructure. Indeed, from the very first moment on, the drive is towards initiating change and towards finding a fruitful starting point from which to *grow* an information system [45]. Even the first activity of acquiring an overall view of the workpractice, however, is not a process of 'modeling', no matter how rough, if by that we mean making a *description* or elucidating the 'essential core' of the workpractice's information flows or organizational structure or aims. When properly executed, this activity is already itself a process of transformation: forcing the workpractice's actors to rethink what it is they do, and why they do it, and creating a shared opinion on where the major weaknesses of the practice's current functioning lie [cf. [46]]. Put in other terms, we can call this activity 'modeling' if with that we imply that every *representation* we create (whether it is a 'workflow diagram' or a 'rich picture') is simultaneously always immediately an *intervention* in the practice that is represented [cf. [47,48]]. The innate drive in these representations can not be the desire to be systematic or logically coherent *within the framework of the model itself*—it should, rather, be the desire to *pragmatically use representational techniques* to bring meaningful change to the work practice involved. In this sense, long winded discussions about modeling techniques are moot—each modeling technique will bring out different details and responses, and it is the actual situation at hand that should determine *which* details and responses matter.

After this first step, a fruitful starting point for growing the information system should be selected. This is a crucial step, which cannot be but highly pragmatic: it should take into account the drives and motivations of the work practice's different actors, the peculiarities of the existing paper and electronic (components of an) system, the potentiality to achieve a gain in quality in at least some of the dimensions mentioned above, the technical, economical and political feasibility of the potential change, and so forth. With all this, it should be taken at heart that the organizational processes that will emerge once the first information system kernel is in place are highly unpredictable [49,50]. Unexpected reactions will occur (both negative and positive), and organizational dynamics outside of the project's reach can interfere in many different ways. The information system's 'requirements', in other words, will *necessarily* evolve; if they remain unchanged during the implementation process the implementation will be suboptimal or fail [51,52]. Managing

this uncertainty, stimulating organizational improvisation [53], mutual growth of the organization with the information system [45] and organizational learning [54,55] are the central challenges here. Put in different words, a core challenge is to fruitfully use the ICT as simultaneously a coordinating and accumulating tool-in-development, and *drawing* upon these functionalities as a change agent (never fully predictable!) in an ongoing process of organizational development. Especially in the beginning of a project, the latter function of ICT might even be more important than the former.

The EPR that will emerge from such a development will contain an eclectic medley of models just like the paper medical record does—and this will be a sign of its practical usability rather than an indication of methodological sloppiness. The models will be patchy, and only there where the EPR's functionality requires it will we see the use of standardized terminology or clearly defined workflows specifically geared towards the fulfillment of this functionality. Generating statistical data for health care policy purposes from an EPR requires a different terminological standard, with a different orientation, a different level of detail, and focused on different data in the record than generating data for reimbursement purposes, for instance. These models will have come about, again, largely as a by-product of the actual work of process-improvement and ICT-facilitated organizational change[3].

[3] For this argument, it does not matter whether we are speaking about EPR's developed in-house, or about information systems that are acquired and that are tailored to the specific needs and demands of specific health care institutions.

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