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Positive Effects of Electronic Patient Records on Three Clinical Activities

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Abstract

Purpose: To investigate the effects of a fully functional electronic patient record (EPR) system on clinicians' work during team conferences, ward rounds, and nursing handovers.

Method: In collaboration with clinicians an EPR system was configured for a stroke unit and in trial use for five days, 24 hours a day. During the trial period the EPR system was used by all clinicians at the stroke unit and it replaced all paper records. The EPR system simulated a fully integrated clinical process EPR where the clinicians experienced the system as if all transactions were IT supported. Such systems are not to be expected to be in operational use in Denmark until at least two years from now. The EPR system was evaluated with respect to its effects on clinicians' mental workload, overview, and need for exchanging information. Effects were measured by comparing the use of electronic records with the use of paper records prior to the trial period. The data comprise measurements from 11 team conferences, 7 ward rounds, and 10 nursing handovers.

Results: During team conferences the clinicians experienced a reduction on five of six subscales of mental workload, and the physicians experienced an overall reduction in mental workload. The physician in charge also experienced increased clarity about the importance of and responsibilities for work tasks, and reduced mental workload during ward rounds. During nursing handovers the nurses experienced fewer missing pieces of information and fewer messages to pass on after the handover. Further, the status of the nursing plans for each patient was clearer for all nurses at the nursing handovers except the nurse team leader, who experienced less clarity about the status of the plans.

Conclusion: The clinicians experienced positive effects of electronic records over paper records for the three clinical activities involved in the evaluation. This is important in its own right and likely to affect clinicians' acceptance of EPR systems, their command of their work, and consequently the attainment of 'downstream' effects on patient outcomes.

Keywords: electronic patient records, mental workload, team conferences, nursing handovers, healthcare IT, real-world evaluation

1.1 Introduction

While electronic patient record (EPR) systems are currently being developed and deployed at substantial costs in hospitals across Europe and North America, researchers are debating whether such electronic records provide benefits over conventional paper records. Researchers seem to agree that electronic records hold considerable potential but only some studies find that this potential is being attained [1, 2]. Others find, for example, that electronic records have neither enhanced clinical practice nor patient care, nor have they improved patient outcomes [3], that electronic records redistribute rather than improve healthcare work and risks [4], that electronic records seem to foster errors rather than reduce their likelihood [5], that the introduction of electronic records concurred with an increase in patient mortality [6], and that the same EPR system yielded different results when introduced in different organizations [7]. This suggests that many efforts to develop and deploy EPR systems may under-recognize the complexity of healthcare work and the extent to which clinicians'

command of their work hinges on an understanding they hold in their head as well as on information in patient records.

In this article we report from an evaluation in which a fully integrated clinical-process module of an EPR system was in trial use at a stroke unit. The EPR system was evaluated with respect to its effects on clinicians' mental workload, overview, and need for exchanging information in relation to three clinical activities: team conferences, medical ward rounds, and nursing handovers. Thus, the evaluation focused on effects of the EPR system on the clinicians and their assessment of their command of their work. This focus is important because clinicians' work conditions are themselves of great consequence and because the effects of an EPR system on clinicians' command of their work are central to the attainment of 'downstream' effects on patient outcomes. Furthermore, the effects were selected in collaboration with clinicians from the stroke unit and concern issues they considered important to evaluate.

The evaluation was conducted as part of the activities involved in the project tender and bid for a large EPR contract of strategic importance to both customer and vendor. The customer, Region Zealand (one of five healthcare regions in Denmark), provided access to the stroke unit at Roskilde Hospital and agreed to let the EPR system replace all paper records in this unit for the duration of a five-day trial period. The vendor, CSC Scandihealth, made their highly configurable EPR platform available for the evaluation and spent considerable resources iteratively configuring it to the requirements of the stroke unit. The resulting EPR system supported the clinical documentation and decision making of physicians as well as nurses, comprised all their continual documentation of their observations, treatment, and care of patients, and provided integration with systems concerning patients' medication, results of lab tests, and other information acquired from departments outside the stroke unit. This EPR system was evaluated by comparing measurements of its use during treatment of real patients with similar measurements of the use of paper records, obtained prior to the trial period.

The next section describes the background and methodology of the EPR evaluation, including a description of the EPR system. Section 3 gives the results of the evaluation in terms of the effects of the EPR system on team conferences, ward rounds, and nursing handovers. Section 4 discusses the EPR evaluation and possible reasons for the positive effects of the EPR system.

2 The EPR evaluation

2.1 The stroke unit

The stroke unit is part of the neurological ward of Roskilde Hospital, a medium-sized Danish hospital. Stroke is a leading cause of death and chronic disability in most industrialized countries [8, 9]. The stroke unit is an in-patient clinic with nine beds and treats approximately 650 acute-stroke patients a year, plus approximately 200 patients that turn out not to have suffered a stroke. The clinical staff comprises physicians, nurses, and therapists. On any shift one physician is in charge of the medical treatment of the patients and one nurse is the leader of a team of 2-4 nurses and auxiliary nurses. During day shifts the group of therapists includes occupational therapists, physiotherapists, speech therapists, and neuropsychologists.

Two central aspects of the work at the stroke unit are the clinicians' continual creation and recreation of an overview of the status of the individual patients and the coordination among the clinicians, within as well as across staff groups. Overview and coordination are particularly prominent in relation to three clinical activities:

Team conferences. Every morning on weekdays physicians, nurses, and therapists meet for about 15 minutes to walk through the admitted patients. The team conference provides an overview of the patients' status, informed by all three staff groups, and serves as a forum for cross-group coordination. In addition to a status, given by the nurse team leader, an overview of current plans is available on a whiteboard or, during the trial use of electronic records, a screen projected on the wall. The terse format makes the team conferences predominantly oral and largely precludes information seeking.

Ward rounds. After the team conference the chief physician starts his or her ward round, which consists of medically assessing each patient and adjusting the treatment and care accordingly. In doing this the physician consults the patient records, sees the patient, and often seeks additional information from nurses and therapists. As there usually is no time for a nurse to escort the physician during the ward round, information exchange and coordination is obtained through the patient record and by ad hoc communication. Due to frequent interruptions the ward round stretches over a period of 3-6 hours.

Nursing handovers. At the start of every nursing shift the nurses and auxiliary nurses meet for about 45 minutes to walk through the admitted patients and coordinate activities. The walkthrough is led by the nurse team leader and based entirely on reading the patient records; no nurses from the previous shift are present. The nurse team leader gives an oral overview of each patient based on the patient records; the other nurses listen and, during the trial use of electronic records, view the projected screen. In the following we focus on the nursing handover that takes place in the morning and marks the start of the day shift.

2.2 The EPR system

The EPR system was made in the clinical framework tool CSC Clinical Suite, which is based on Oracle's Healthcare Transaction Base. In this tool, screens are specified as XML templates. The EPR system comprised a total of 243 screens and included real-time integration with the hospital's patient-administrative system, its medication system, and several of its laboratory systems. Data about the hospital's patients during the previous five years (in total more than 26 million records from 330000 patients) were migrated to the system prior to the trial period to have access to past information about patients and to obtain a realistic data load.

Physicians and nurses used the EPR system for all their continual documentation of their observations, treatment, and care of patients. In addition, the system contained standard plans, results from lab tests, and other information supporting clinical documentation and decision making. Three central system facilities were the screens developed for team conferences, ward rounds, and nursing handovers. These screens collected various pieces of patient information and presented an overview tailored to the specific clinical activity. For example, the screen for team conferences consisted of panels with information about current diagnoses, nursing and therapeutic observations, planned interventions, electrocardiograms (ECG), next-of-kin meetings, and patient and treatment status.

During the trial period the EPR system was available on the computers in the stroke unit, including the portable computers physicians bring to the patients' bedside during ward rounds. Further, the system was projected on the wall in the conference room where team conferences and nursing handovers took place. Finally, measurements of patients' temperature, blood pressure, and the like were recorded at their bedside on handheld devices integrated with the EPR system.

In order to simulate a fully integrated EPR system, a back office was established and staffed 24 hours a day. Patient-record entries that involved paper transactions with other wards were initiated in the system by the clinicians. The back office continuously monitored the system, identified such entries, mailed them in the conventional fashion, waited for the results to arrive, and immediately typed them into the EPR system. Thus, the clinicians experienced the EPR system as if all transactions were fully IT supported. This way the EPR system simulated a fully integrated system two or more years before such systems are expected to be in operational use in Denmark.

2.3 Measurements

The measurements were specified in close collaboration with the clinicians from the stroke unit and focused on overview of patient status, coordination among clinicians, and decision making with regard to patient care and treatment. The EPR evaluation comprised measurements of mental workload during all three clinical activities and additional measurements directed specifically at the team conferences and nursing handovers.

Mental workload was measured by the NASA task load index (TLX [10]). TLX consists of six subscales (mental demand, physical demand, temporal demand, effort, performance, and frustration), each of which is rated on a scale from 'low' (0) to 'high' (100) in increments of five, except for

performance where the anchors are ‘good’ (0) and ‘bad’ (100). For team conferences the clinicians rated their mental workload at the end of the conference and the rating covered the entire team-conference task. For ward rounds and nursing handovers the clinicians rated their mental workload after each patient and it covered the work concerning that patient. TLX ratings were made individually by all clinicians participating in the activities.

For the team conferences three additional measures were obtained. The chief physician in charge of stroke patients on that shift rated the clarity about the importance assigned to work tasks and about who was responsible for work tasks. Both these measures were rated on a scale from ‘clear’ (0) to ‘unclear’ (100) in increments of five. Further, the participants at the team conferences collectively indicated when they lacked a piece of information. The number of missing pieces of information was recorded by adding marks on a paper sheet visible to all. When a clinician found that information was missing he or she would suggest adding a mark, and the other clinicians would either agree or a brief discussion would ensue to reach consensus.

For the nursing handovers four additional measures were obtained. The participants at the nursing handovers individually rated their perception of the status of the plan for the nursing of the patient and the status of the physicians’ plan for the medical treatment of the patient. Both these measures were rated on a scale from ‘clear’ (0) to ‘unclear’ (100) in increments of five. Further, the participants at the nursing handovers collectively indicated when they lacked a piece of information and when they encountered a need to pass on a message to another clinician after the nursing handover. The numbers of missing pieces of information and messages to pass on were recorded by adding marks on a paper sheet visible to all; that is, similarly to how missing pieces of information were recorded at the team conferences.

In addition to the measurements above, we observed the team conferences, nursing handovers, part of the ward rounds, and work at the stroke unit in general. We also made nine interviews with clinicians. The observations and interviews provided a background understanding of the clinicians’ activities and opportunities for exploring how the clinicians approached and embraced the EPR system.

2.4 Procedure

The evaluation involved three sets of activities: preparations, measurements of the use of paper records, and measurements of the use of electronic records. In total, more than 20 clinicians took part in the measurements.

Preparations. Through five full-day workshops CSC Scandihealth, Region Zealand, clinicians from the stroke unit, and the authors analysed clinical needs and specified an EPR system. Main parts of the system were configured through up to four iterative events progressing from mock-ups on flip-over charts, through non-interactive prototypes in PowerPoint to running prototypes. In parallel, the effects to be measured during the evaluation were identified. After the last workshop, CSC Scandihealth undertook the technical configuration, integration, and implementation of the EPR system. Finally, the clinicians at the stroke unit received an introduction to the evaluation and about half a day of training in the use of the EPR system and in working according to some revised, EPR-supported patient trajectories.

Measurements of the use of paper records. The established practice of using paper records formed the baseline for measuring the effects of the EPR system. We conducted measurements of the use of paper records about a month before the period during which the clinicians used the EPR system. Initially, measurements from one team conference, ward round, and nursing handover were performed as training to acquaint the clinicians with the measuring instruments. Then, measurements were obtained from 6 team conferences, 4 ward rounds, and 5 nursing handovers.

Measurements of the use of electronic records. In the final part of the evaluation, the EPR system replaced paper records for all patients for a period of five days. All clinicians on all shifts used the EPR system during this period. To safeguard against misunderstandings that might have entailed risk to patient health the clinicians could request support from ‘shadows’ who knew the system well and were present 24 hours a day. Measurements were performed in the same way as during the

measurements of the use of paper records. The use of electronic records was measured during 5 team conferences, 3 ward rounds, and 5 nursing handovers.

Approval for the evaluation was obtained from the hospital's management board, which subsumes the hospital's Institutional Review Board (IRB) committee.

2.5 Data analysis

Initially, we analysed learning effects in relation to the use of electronic records. The independent variable in these analyses had a level for each of the five days of the trial period. Subsequently, we analysed the data using analyses of variance with record type (electronic, paper) as the main independent variable. For the team conferences, staff group (physician, nurse, therapist) constituted a second independent variable. For the nursing handovers, nursing group (nurse team leader, other nurses) constituted a second independent variable. Statistical significance was set at the level of .05.

3 Results

3.1 Control variables

In comparing paper and electronic records other variables have to be controlled for. We have tested whether the number of patients, duration of activities, and nursing-workload ratings differ between the measurements of the use of paper records and those of the use of electronic records, see Table I.

For number of patients, we found no significant differences between paper and electronic records for team conferences and ward rounds but a significant difference for nursing handovers. On average, the nursing handovers involved fewer patients during the use of electronic records than during the use of paper records.

For duration, we found no significant differences between paper and electronic records for team conferences and nursing handovers. The duration of ward rounds was not measured because they are frequently interrupted by other activities and stretch over most of the chief physician's shift.

On every shift the nurses rate each patient on a 4-point scale according to the number of daily hours of work required to nurse the patient. These nursing-workload ratings are part of the nurses' clinical work and thus not introduced by the EPR evaluation. For the nursing-workload ratings we found no significant difference between the patients in the nursing handovers performed with paper records and those in the nursing handovers performed with electronic records.

Thus, apart from fewer patients during the nursing handovers the control variables revealed no differences between the measurements of the use of paper and electronic records.

Table I. Control variables.

Measure	**Paper records**		**Electronic records**		**Statistical test**	
	M	*SD*	*M*	*SD*	*Test and N value*	*Significance*
Number of patients						
Team conferences	7.17	2.23	4.60	1.52	$F(1, 9) = 4.75$, $N = 11$	$p = .06$
Ward rounds	4.50	1.29	4.67	2.31	$F(1, 5) = .02$, $N = 7$	$p = .9$
Nursing handovers	9.40	1.95	4.60	1.52	$F(1, 8) = 18.89$, $N = 10$	$p = .002$
Duration (minutes)						
Team conferences	14.83	2.86	12.60	4.22	$F(1, 9) = 1.09$, $N = 11$	$p = .3$
Nursing handovers	56.40	11.93	57.80	19.72	$F(1, 8) = .02$, $N = 10$	$p = .9$
Nursing-workload rating	2.32	.94	2.64	.67	Mann-Whitney, $N = 58$	$p = .2$

M = mean, *SD* = standard deviation

3.2 Team conferences

For the team conferences, the measurements of mental workload included 71 TLX ratings, each covering a clinician's rating of the mental workload of an entire team conference. We initially analysed whether mental workload dropped over the five team conferences performed with electronic records. Using Helmert contrasts, we found no such effect of increased experience, $F(24, 91.91) = .68$, $p = .9$.

An overall multivariate analysis of the six TLX subscales showed a tentative but not significant difference between paper and electronic records, $F(6, 60) = 1.70$, $p = .1$. Individual analyses of variance for the TLX subscales showed significant differences between paper and electronic records for five of the six subscales, see Table II. In all five cases the clinicians experienced lower workload with electronic records. The sixth subscale, physical demand, may be difficult to relate to the activities of a team conference. The overall multivariate analysis of the six TLX subscales showed a significant interaction between record type and staff group, $F(12, 120) = 2.06$, $p = .02$. Whereas the physicians experienced significantly lower mental workload with electronic records ($p = .04$), there was no significant change in mental workload for the nurses ($p = .1$) and therapists ($p = .8$).

Table II. Mental workload for team conferences, $N = 71$ TLX ratings.

TLX subscale	**Paper records**		**Electronic records**		**Statistical test**	
	M	*SD*	*M*	*SD*	*ANOVA*	*Significance*
Mental demand	34.57	21.91	29.31	20.15	$F(1, 65) = 4.04$	$p = .048$
Physical demand	18.86	14.61	18.89	18.64	$F(1, 65) = .11$	$p = .7$
Temporal demand	40.00	23.42	33.06	20.88	$F(1, 65) = 4.34$	$p = .04$
Effort	29.09	17.12	24.03	19.52	$F(1, 65) = 4.46$	$p = .04$
Performance	34.71	22.26	26.67	21.88	$F(1, 65) = 7.85$	$p = .007$
Frustration	32.86	26.63	21.81	19.86	$F(1, 65) = 7.38$	$p = .008$

M = mean, *SD* = standard deviation

In addition to the TLX ratings, three measures were obtained for each of the 11 team conferences, see Table III. For number of missing pieces of information per patient, we found no significant difference between paper and electronic records. For clarity about the importance assigned to work tasks, the chief physician (in charge of the patients on that shift) experienced a significant difference between paper and electronic records. The size of the effect was substantial in that clarity improved from a mean of 49.17 with paper records to a mean of 6.00 with electronic records. For clarity about who was responsible for work tasks, the chief physician also experienced a significant difference between paper and electronic records. Again, the size of the effect was large and in favour of electronic records.

Table III. Measures specific to team conferences, $N = 11$ team conferences.

Measure	**Paper records**		**Electronic records**		**Statistical test**	
	M	*SD*	*M*	*SD*	*ANOVA*	*Significance*
Missing pieces of information	.75	.77	.04	.09	$F(1, 9) = 4.09$	$p = .07$
Importance assigned to tasks	49.17	29.73	6.00	8.94	$F(1, 9) = 9.65$	$p = .01$
Responsibility for tasks	27.50	12.15	5.00	5.00	$F(1, 9) = 14.84$	$p = .004$

M = mean, *SD* = standard deviation

3.3 Ward rounds

For the ward rounds, the measurements of mental workload included 31 TLX ratings, each covering the chief physician's rating of the mental workload involved in treating a single patient. An overall multivariate analysis of the six TLX subscales showed a significant difference between paper and electronic records, $F(6, 24) = 10.73$, $p = .00001$. Individual analyses of variance for the TLX

subscales showed significant differences between paper and electronic records for all six subscales, see Table IV. All six differences were in favour of electronic records, and the sizes of the effects were large.

Table IV. Mental workload for ward rounds, $N = 31$ TLX ratings.

TLX subscale	Paper records		Electronic records		Statistical test	
	M	*SD*	*M*	*SD*	*ANOVA*	*Significance*
Mental demand	40.28	15.86	8.85	7.40	$F(1,29) = 43.85$	$p = .00001$
Physical demand	28.89	18.44	6.54	7.74	$F(1,29) = 16.83$	$p = .0003$
Temporal demand	46.94	16.46	15.77	15.66	$F(1,29) = 28.18$	$p = .00001$
Effort	42.50	14.88	9.62	9.23	$F(1,29) = 49.47$	$p = .00001$
Performance	26.39	12.58	3.08	3.25	$F(1,29) = 42.23$	$p = .00001$
Frustration	27.78	17.08	3.08	3.25	$F(1,29) = 26.25$	$p = .00002$

M = mean, *SD* = standard deviation

3.4 Nursing handovers

An overall multivariate analysis of the TLX subscales showed a significant effect of day of week over the five nursing handovers performed with the aid of electronic records, $F(24, 241.92) = 3.11$, $p = .00001$. Using Helmert contrasts, we found that all six subscales of mental workload were rated significantly higher on the first day and the second day, compared to the average of later days (all ps $< .05$). For this reason we excluded the first two nursing handovers performed with electronic records and based our analysis on the three last nursing handovers, for which mental workload had stabilized. All five nursing handovers performed with paper records were included in the analysis. Thus, the measurements of mental workload for the nursing handovers included 169 TLX ratings, each covering a nurse's rating of the mental workload involved in the handover of a single patient.

An overall multivariate analysis of the six TLX subscales showed neither a significant difference between paper and electronic records, $F(6, 160) = .66$, $p = .7$, nor an interaction between record type and nursing group, $F(6, 160) = .64$, $p = .7$. Table V gives the means for the individual TLX subscales.

Table V. Mental workload for nursing handovers, $N = 169$ TLX ratings.

TLX subscale	Paper records		Electronic records		Statistical test	
	M	*SD*	*M*	*SD*	*ANOVA*	*Significance*
Mental demand	22.37	24.06	16.32	14.55	$F(1, 165) = .81$	$p = .4$
Physical demand	12.86	18.20	8.82	8.26	$F(1, 165) = .30$	$p = .6$
Temporal demand	22.18	22.44	18.82	13.68	$F(1, 165) = .07$	$p = .8$
Effort	18.17	22.03	14.47	11.20	$F(1, 165) = .10$	$p = .8$
Performance	16.37	17.06	14.21	10.81	$F(1, 165) = .04$	$p = .8$
Frustration	18.40	22.00	17.89	12.45	$F(1, 165) = .09$	$p = .8$

M = mean, *SD* = standard deviation

Two additional measures were obtained from each nurse for each patient, see Table VI. These measures display an effect of day of week similar to that of the TLX ratings and consequently the analysis includes the five nursing handovers performed with paper records and the three last nursing handovers performed with electronic records, a total of 169 ratings of each measure. For clarity about the status of the plan for the nursing of the patient, we found no significant difference between paper and electronic records, but a significant interaction between record type and nursing group, $F(1, 165) = 3.87$, $p = .05$. Whereas the nurse team leader experienced a reduction in clarity about the status of the nursing plan (electronic records 4.09 scale points less clear than paper records), the other nurses at the nursing handovers experienced increased clarity (electronic records 6.28 scale points clearer than paper records). For clarity about the status of the plan for the medical treatment of the patient, we found no significant difference between paper and electronic records, but a near-significant interaction

between record type and nursing group, $F(1, 163) = 3.54$, $p = .06$. As for the nursing plan, the nurse team leader tended to experience a reduction in clarity about the status of the plan for the medical treatment, whereas the other nurses tended to experience increased clarity.

Table VI. Measures specific to nursing handovers. The first two measures were obtained for each patient, $N = 169$ ratings, the last two for each nursing handover, $N = 10$ nursing handovers.

Measure	**Paper records**		**Electronic records**		**Statistical test**	
	M	*SD*	*M*	*SD*	*ANOVA*	*Significance*
Nursing plan	12.37	14.25	9.34	8.79	$F(1, 165) = .17$	$p = .7$
Medical-treatment plan	13.91	19.05	12.76	9.84	$F(1, 163) = .07$	$p = .8$
Missing pieces of information	.90	.64	.17	.24	$F(1, 8) = 5.71$	$p = .04$
Messages to pass on	.73	.12	.10	.15	$F(1, 8) = 54.41$	$p = .0001$

M = mean, *SD* = standard deviation

Finally, two measures were obtained for each of the ten nursing handovers, see Table VI. For number of missing pieces of information per patient, we found a significant difference between paper and electronic records. The mean number of missing pieces of information per patient was .90 with paper records and only .17 with electronic records. For number of messages to pass on per patient, we also found a significant difference between paper and electronic records. The size of the effect was again large and in favour of electronic records.

4 Discussion

4.1 Effects of electronic records

The EPR evaluation yielded positive effects of the use of electronic records for all three clinical activities involved in the measurements. This is especially encouraging given the mixed results of previous EPR research [2-7]. For the team conferences mental workload was lower on five of the six TLX subscales, and the physicians experienced an overall reduction in mental workload. The overall reduction for physicians, as opposed to nurses and therapists, probably reflects that the team conferences are mainly an activity intended to inform the physicians by providing them with multidisciplinary views on the patients. Further, the chief physician found that the importance assigned to work tasks and the responsibility for work tasks were clearer when electronic records were used during team conferences. For the ward rounds the chief physician's mental workload was reduced, corroborating the results for team conferences. For the nursing handovers the number of missing pieces of information and the number of messages to pass on were lower with electronic records. Further, the status of the plans for the nursing of a patient was less clear for the nurse team leader when electronic records were used but more clear for the other nurses at the nursing handovers. A probable explanation of this is that the nurse team leader was preoccupied with the operation of the EPR system, which was new to her, to a larger extent than with the handling of the paper records, whereas the other nurses received additional information by listening to the team leader as well as reading from the shared display.

4.2 Changes in work practices

During the trial period we observed how several new work practices emerged among the clinicians in response to the changes introduced by the EPR system. Two of these work practices are briefly described below because they provide insights into how the clinicians embraced the system. Both examples concern the nurses who were particularly active in utilizing the opportunities provided by the EPR system. It should be noted that the new work practices did not become firmly established and that they are reported based on our observations and interviews rather than the quantitative measurements.

Conventionally, the nurse team leader scans a patient's paper record and reads key information out loud. The other nurses at the nursing handovers listen to this oral presentation and usually do not see

the written content of the paper record. In contrast, the electronic records were visible to everybody on the projected screen, and the nurses at the handovers engaged in a process of collective reading. The content of the electronic records was inspected by the group of nurses, who collectively participated in interpreting the status and condition of the patients, guided by the team leader. At the end of the trial period a new and more collaborative work practice was clearly in the making at the nursing handovers. This change was experienced as positive by the nurses, and it is contrary to how electronic records affected nursing handovers at another Danish hospital. At this other hospital, electronic records tended to replace oral reporting and work practices became more individualized [4].

At the team conferences, the nurses experienced how the information on the team-conference screen formed the agenda for these conferences. Halfway through the trial period the nurses initiated a change to the team-conference screen, which was extended with a panel specifying their observations of relevance to the team conference. This way, the nurses could select observations for presentation at the team conferences and these selected observations became more salient to the group of clinicians in their process of forming an overview of the status of the patients. While the change of the EPR system was small, it relieved the nurses of actively and repeatedly calling attention to their observations and it improved collaboration across staff groups.

4.3 Possible reasons for the positive effects

Contrary to a number of previous studies [3-6, 11], the EPR system evaluated in this article yielded positive effects. Six factors appear particularly important to the success of the EPR system.

First, the stroke unit had well-described workflows. Standard procedures and paper forms existed for most tasks, providing a good starting point for the development of the EPR system. Further, the clinicians were interested in developing their work practices further and saw the EPR system as an opportunity for doing this (see Section 4.2).

Second, the evaluation focused on three clinical activities during which information already in the patient records is utilized, and a data-presentation screen was tailored to each of the three clinical activities. A focus on data presentation disregards problems specific to data entry, which is generally less rewarding than utilizing previously entered information. Specifically, it often causes problems to rely on physicians to enter data into EPR systems [12]. Further, we consider it an advantage to have a data-presentation screen for each of the targeted clinical activities, rather than a single, generic data-presentation form as in a previous EPR system for stroke units [13].

Third, nursing handovers and, in particular, team conferences are clinical activities during which quick access to information is a precondition for looking into an issue. Otherwise, the issue must be postponed and someone has to remember to obtain the information at a later point in time. This reiterates the need for screens tailored to the individual clinical activities, and electronic records are well-suited to satisfy this need because multiple views can be provided on the same data. During clinical activities with looser time constraints quick access may be less important relative to, for example, the way in which data are presented [14].

Fourth, the EPR system supported cross-disciplinary communication and coordination in two simultaneous ways: (a) through the EPR system and (b) face-to-face at team conferences. That is, the EPR system enhanced rather than replaced previous ways of working. This avoids problems of misrepresenting communication as information transfer, leading for example to loss of feedback [5].

Fifth, the EPR system was not restricted to stationary computers away from the patients but was also available on laptops, which were brought to patients' bedside, and as a shared display in the conference room where team conferences and nursing handovers took place. Previous studies of electronic records have noted the advantages of bedside access with regard to the use and accuracy of patient records (e.g. [15]). The shared display in the conference room was central to the EPR system, and its positive contribution accords with a previous study, which found that a shared electronic whiteboard improved communication and reduced mental workload at an emergency department [16].

Sixth, the EPR system was developed through a participatory design process, ensuring a focus on clinicians' needs and concerns. This was partly made possible by the flexibility of the development

tools and concurs with previous work arguing that active and direct involvement of clinicians in EPR projects is a prerequisite for success [17].

4.4 Limitations

Three limitations should be remembered in interpreting the results of this study. First, the duration of the trial period was limited to five days. In future work longer trial periods will be required, but we consider it promising that significant effects of the use of electronic records were obtained in five days. Second, the EPR system cannot be dissociated from the work practices involved in using it. This is a consequence of evaluating the system in a real work setting as opposed to a controlled, laboratory environment. We consider a real work setting highly preferable and emphasize that the obtained effects are effects of the use of electronic records, not of electronic records as such. Third, the measurements included in the evaluation concerned the clinicians and their assessment of their command of their work. This focus is important in its own right and it is, in turn, likely to have an impact on patient outcomes but it does not allow conclusions about effects on patient outcomes.

5 Conclusion

Many, if not most, IT projects do not produce the effects customers are aiming to achieve. It is therefore encouraging that the clinicians at the stroke unit in this study experienced several significant improvements of using the EPR system, compared to the use of paper records. The evaluation demonstrates positive effects of electronic records for all three clinical activities involved in the measurements. Most notably, the physicians experienced reduced workload during team conferences and ward rounds, and the nurses experienced fewer missing pieces of information during nursing handovers and fewer messages to pass on after the handovers. Furthermore, interesting changes in work practices were observed during the trial period, particularly a shift from oral presentation to collective reading and interpretation of patient records during team conferences and nursing handovers. The trial period was, however, too short for new work practices to stabilize. Finally, the participatory design process, the back office that simulated some system facilities, and the shadows who provided protection against risks to patient health made it possible to evaluate fully electronic records in a real work setting well in advance of when fully electronic records will be in operational use at Danish hospitals.

Authors' contributions

The first author made the statistical analysis of the data and wrote most of the paper. The second author critically revised several drafts of the paper. The authors contributed equally to the design of the study and the execution of the empirical work.

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Statement on conflicts of interest

The authors are not financially related with the customer, vendor, stroke unit or any other party involved in this study. Further, the authors are not personally or otherwise related with parties involved in the study, apart from the professional relations that evolved with the vendor, customer, and stroke unit in the course of the study.

Summary table.

What was known about the topic before this study	What this study has added to our knowledge
• Electronic records are gradually replacing paper records at more and more hospitals but studies of the effects of electronic records yield mixed results	• With electronic records physicians' mental workload was lower during team conferences and ward rounds
• Only few studies have evaluated fully functional and completely integrated EPR systems	• With electronic records fewer pieces of information were missing during nursing handovers and fewer messages had to be passed on after the handovers
• Team conferences, ward rounds, and nursing handovers are central clinical activities at stroke units	• With electronic records work practices appeared to change from oral presentation to collective reading and interpretation during team conferences and nursing handovers

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