Review Paper ■

The Impact of Electronic Health Records on Time Efficiency of Physicians and Nurses: A Systematic Review

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Abstract A systematic review of the literature was performed to examine the impact of electronic health records (EHRs) on documentation time of physicians and nurses and to identify factors that may explain efficiency differences across studies. In total, 23 papers met our inclusion criteria; five were randomized controlled trials, six were posttest control studies, and 12 were one-group pretest-posttest designs. Most studies (58%) collected data using a time and motion methodology in comparison to work sampling (33%) and self-report/survey methods (8%). A weighted average approach was used to combine results from the studies. The use of bedside terminals and central station desktops saved nurses, respectively, 24.5% and 23.5% of their overall time spent documenting during a shift. Using bedside or point-of-care systems increased documentation time of physicians by 17.5%. In comparison, the use of central station desktops for computerized provider order entry (CPOE) was found to be inefficient, increasing the work time from 98.1% to 328.6% of physician's time per working shift (weighted average of CPOE-oriented studies, 238.4%). Studies that conducted their evaluation process relatively soon after implementation of the EHR tended to demonstrate a reduction in documentation time in comparison to the increases observed with those that had a longer time period between implementation and the evaluation process. This review highlighted that a goal of decreased documentation time in an EHR project is not likely to be realized. It also identified how the selection of bedside or central station desktop EHRs may influence documentation time for the two main user groups, physicians and nurses.

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The electronic health record (EHR) is increasingly being deployed within health care organizations to improve the safety and quality of care.[1] However, to achieve these goals, the EHR must be used by clinicians, and this remains a major challenge. Various factors appear to be associated with EHR use. Maximization of the technical characteristics supporting the system such as speed and value-added functionalities such as order entry systems or automated reports[2–5] have been documented with higher rates of EHR use. User-related characteristics[3,4,6,7] as well as training[5] are also believed to be important. The integration of the EHR into clinical workflow must be taken into consideration in the early phases of planning in order to optimize the integration of the system into routine clinical use. Indeed, the need for a good fit between the EHR and routine clinical practice is recognized as essential,[3,8–12] and time efficiency is one of several factors that is used to assess the quality of this integration.

Clinicians spend the majority of their time providing direct care to patients[13–17] and hope that an EHR could increase this patient-interaction time and consequently the quality of care delivered.[18] On the other hand, provision of care requires the documentation of clinical information as an intrinsic aspect of routine clinical activity and is essential from both professional and legal standpoints. Thus, clinicians will consider a system to be efficient if the system reduces their documentation time,[19] even if the time savings do not translate into better patient care.[20] For this reason, in evaluating the impact of EHR on clinician activities, some studies use documentation time as a primary outcome and direct patient care time as a secondary outcome. The importance of evaluating time efficiency in documentation is also related to the observation that increased time for documentation is one of the most commonly stated barriers to successful implementation of an EHR.[3,10,11,18,21–23]

Electronic health record implementation requires considerable investment with most projects averaging several million dollars (U.S.).[24,25] For the EHR to be successful, it is essential that managers are able to identify and manage elements of EHR implementation that are critical to enhance time efficiency of documentation by physicians and nurses. Clinical information systems and user populations vary in their characteristics, and for this reason, individual studies are unable to identify common trends that would predict EHR implementation success. This paper presents the results of a systematic

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review conducted to estimate the extent to which an EHR affects clinicians' documentation time and to identify factors that may explain efficiency differences observed across studies. In the context of this review, documentation comprises all notes, orders, and referrals that are part of the care plan of a patient and documented in a patient's medical chart.

Methods

Search Strategy

An extensive search of the literature from 1966 to January 2004 was performed using MEDLINE, CINAHL, HEALTHSTAR, and Current Health databases. Search strategies were specific to the database and included the Medical Subject Headings (MeSH) associated with key words that reflected EHRs and workflow. The MEDLINE search strategy included the following terms: *health informatics*, *electronic records*, *medical records systems*, *medical informatics*, *information systems*, *computerized patient records*, *workflow*, *time and motion*, *task performance and analysis*, *work redesign*. When searching the CINAHL and HealthSTAR databases, the key words *efficiency*, *organizational*, *hospital information systems*, and *workload* were added to the search strategy used for the MEDLINE database. Only French or English full-text papers published in peer-reviewed journals and proceedings were selected for further review. Editorials, letters, and conceptual papers were excluded. While systematic reviews often limit their selection of papers to randomized, controlled trials (RCTs) as the highest level of evidence,[26] RCTs are not always feasible[27] or the method of choice[28] for the evaluation of the time efficiency of EHRs. Therefore, all papers that addressed the research question were retrieved, regardless of their study design. Abstracts of all papers identified from the search strategy were read and assessed by one of the authors. Abstracts that were rated as relevant to the research question were kept and full-text papers were retrieved for further review. In the absence of an abstract, full-text papers were retrieved and reviewed. Reference lists of selected papers were examined to identify other relevant articles. Finally, publications of key authors, selected based on their expertise and quality of publications in the area of workflow and EHRs, were looked at using the Web of Science Citation Index.

The quality of selected papers was assessed independently by two reviewers using a standardized evaluation process. For papers to be selected for final review, the following criteria had to be met: (1) the study design included a comparison group, (2) documentation or charting time was one of the outcomes, (3) quantitative estimates of time differences were documented, (4) subjects were health professionals, and (5) the working environment was either a home, hospital, or community clinic. Papers that assessed the impact of time efficiency only through direct patient care time measurement were excluded even if the authors assumed that the time difference in patient care could be attributed to increased or decreased time efficiency in chart documentation, as there was no evidence to support this assumption. Documentation was defined broadly to capture all patient-specific notes written in the chart by nurses or physicians, including order entries. Therefore, regardless of whether the term charting, writing notes, ordering, or documentation was used, if the authors made it clear that these clinical activities were for patient care, the study was included in the review. Evaluation disagreements between the two reviewers were resolved by a third reviewer.

Evaluation Process

Previous systematic reviews have used scoring systems to assess the validity of studies selected for review.[29–31] Existing scoring systems did not provide criteria that could be used in evaluating the scope of study designs and divergent methodologies used in the area of workflow assessment. Therefore, papers were rated qualitatively based on the two critical aspects that could influence the validity of the study: study design and methods used for data collection. Using the Campbell and Stanley[32] hierarchy for the internal validity of research designs, studies designed as RCTs were ranked first followed by posttest-only control group designs and one-group pretest-posttest designs in which the main source of internal bias would be related to the effects of temporal trends in care delivery. The method of measurement was ranked according to the precision of the data collection. Data collected by time and motion observer methodology ranked first, followed by video recordings as both provided direct and objective measurement of time. Work sampling techniques and self-reporting surveys were ranked third and fourth respectively, as they provide estimates of time efficiencies but the accuracy is influenced by the overall number of observations made,[33] interevent variability, and self-report biases.[34]

Studies that used time and motion or video-recording techniques measured time as a continuous variable and differences were reported as means (standard deviations) and units were minutes or seconds. Work sampling techniques estimate time using counts of the occurrences of an activity within a specified time period and were thus reported as proportions. To facilitate comparisons across studies and accommodate for the different sampling units, such as patient-physician encounters versus total working shifts, a relative time difference was calculated. The relative time difference was determined for each study as the time (mean or proportion) to document with computer minus the time to document on paper divided by the time to document on paper, producing a negative value when the EHR was time efficient. We calculated 95% confidence intervals for differences in means and proportions to assess the significance of reported differences. When there was insufficient information to compute 95% confidence intervals, the authors were contacted and the data needed to construct the confidence interval were requested. To account for the variability in sample sizes across studies, weighted averages were calculated for both types of sampling units (patients and working shifts). Weighted averages were calculated using the following formula:

$$\text{Weighted average} = \frac{\sum_{i=1}^{n} [SW(i) * RTD(i)]}{\sum_{i=1}^{n} SW(i)}$$

in which sampling weight (SW) = $(n_{group1} + n_{group2})$ and relative time difference (RTD) = (documentation time $_{group2}$ − documentation time $_{group1}$)/documentation time $_{group1}$.

Results

A total of 628 abstracts were read and of these, 63 papers were retrieved and assessed against the selection criteria. Forty papers failed to meet minimum requirements for review, the most common reason being unavailable or limited information on methodology. For example, 14 papers were excluded because the method for data collection or study design was not identified. Eleven papers did not report sufficient information on time efficiency, nine did not have paper charting comparisons, three did not report on documentation time, two papers did not address the issue of workflow/time efficiency, and one paper was a simulation study. In total, 23 papers met the final criteria and were included in this review. Major technology improvements occurred over the years, making systems developed 20 years ago incomparable with those developed more recently. We chose to present the results of all studies but excluded those published before 1990 from our data analysis. Table 1 summarizes the study designs and methodologies of the reviewed papers. Five were RCTs, six were posttest-control studies, and 12 were one-group pretest-posttest designs. A majority of studies (58%) collected data using a time and motion methodology in comparison to work sampling (33%) and self-report/survey methods (8%). Of all reviewed papers, subjects were either nurses or physicians, providing the opportunity to examine results and conduct separate analyses for each of the population groups being observed.

Impact on Time Efficiency

Nurses

Eleven studies examined the impact of EHRs on time efficiencies of nurses and the main characteristics of these studies are summarized in Table 2. The study by Bosman et al.[35] appears twice in Table 2 due to the report of time efficiencies using two different sampling units. Similarly, Pierpont and Thilgen[36] reported two sets of data but used the same sampling units. Among all studies, six[15,16,35–39] reported a reduction in documentation time when using a computer. Among those, the relative time differences ranged from −2.1% to −45.1% and each of these studies assessed the time efficiency of bedside terminals or computerized systems that were accessible through either bedside terminals or central station desktops. Two studies[13,35] found that bedside terminals increased documentation time (relative time difference of 7.7% and 32.9%, respectively). One study[35] reported different results depending on the specific content of the information being documented. Documenting the admission information was time efficient for nurses, while registration information required more time when entered on the computer rather than on paper. The largest time inefficiency reported is attributed to the use of a handheld device (personal digital assistant [PDA]) that required 128.4% more time than usual paper charting.[40] This study was the only one conducted in a home setting. The PDA was used to enter data on an activity of daily living (ADL) assessment tool and was used as an independent device with no data exchange at the time of data entry.

Two studies[13,16] were not taken into account in the calculations of weighted averages, one because of lack of reported sample size and the other because the study was conducted before 1990. Among the 11 studies (two studies reported two sets of data each), only three[35,40,41] assessed the impact of EHR on nurses' time efficiency using the patient as the sampling unit (Fig. 1). Regardless of whether documentation was performed on bedside terminals, central stations, or a PDA, the impact on time spent documenting per patient was unfavorable, with increases of time ranging from 7.7% to 128.4%. Conversely, studies[15,35–39,42] that reported the impact of EHR use on the total working shift are on average favorable. Weighted averages of the relative time differences are presented in Figure 2. When the weighting algorithm was applied to the individual studies, we determined that, on average, using bedside terminals saved nurses 24.5% of their overall time spent documenting during a shift, which compared advantageously with the use of central station desktops (23.5%). Despite similar weighted averages between bedside terminals and central station desktops, the five studies that assessed bedside terminals were consistent and showed a time reduction, while the two studies looking at central station desktops had opposite results.

Regardless of the system (bedside or central station desktops) being evaluated, most differences between paper and computer documentation systems were statistically significant (Table 2). Only two studies[15,37] had nonsignificant results. Three studies[16,36,42] lacked sufficient information to either

Table 1 ■ Study Designs and Data Collection Methodologies of Selected Papers ($n = 23$)

	Data Collection Methodology		
Study Design	Time and Motion Observed/Video Recording	Work Sampling	Survey/Self-report
RCT	Bosman et al.[35] (2003) Overhage et al.[46] (2001) Weinger et al.[48] (1997) Tierney et al.[22] (1993)	Bosman et al.[35] (2003)	Ammenwerth et al.[41] (2001)
Posttest-control	Apkon & Singhvaron[49] (2001) Makoul et al.[43] (2001) Hammer et al.[50] (1995) Minda & Bundage[38] (1994) Pringle et al.[53] (1985)	Marasovic et al.[37] (1997)	—
One-group pretest-posttest	Wong et al.[39] (2003) VanDenKerkhof et al.[32] (2003) Menke et al.[15] (2001) Warshawsky et al.[47] (1994) Herzmark et al.[52] (1984)	Pabst et al.[16] (1996) Hinson et al.[42] (1993) Bradshaw et al.[13] (1989) Pierpont & Thilgen[36] (1995) Shu et al.[45] (2001) Bates et al.[44] (1994)	Kovner et al.[40] (1997)

RCT = Randomized, Controlled Trial.

Table 2 ■ Characteristics of Papers Examining the Impact of Computers on Time Efficiency of Nurses

Authors	Study Design	Method	Sampling Unit Paper (No.)/Computer (No.)	Time Period From Implementation to Evaluation
Bosman et al.[35] (2003)	RCT crossover	Time & motion	Patients (55)/(59)	7 mo
Ammenwerth et al.[41] (2001)	RCT	Self-report	Patients (19)/(19)	7 wk
Kovner et al.[40] (1997)	Pre-post	Self-report	Patients (198)/(230)	≈1 yr
Wong et al.[39] (2003)	Pre-post	Time & motion	Working shift (10)/(10)	6 mo
Menke et al.[15] (2001)	Pre-post	Time & motion	Working shifts (12)/(12)	NA
Marasovic et al.[37] (1997)	Cross-sectional with controls	Work sampling	Working shifts (5)/(6) Obs (2,098)/(1,562)	NA
Pabst et al.[16] (1996)	Pre-post	Work sampling	Working shifts NA/NA	6 mo
Pierpont & Thilgen[36] (1995)	Pre-post	Work sampling	Working shifts (49)/(52)	3 mo
Minda & Bundage[38] (1994)	Cross-sectional	Time & motion	Working shifts total = 40	≈1 mo
Hinson et al.[42] (1993)	Pre-post	Work sampling	Working shifts (20)/(20)	6 mo
Bosman et al.[35] (2003)	RCT crossover	Work sampling	Working shifts (28)/(27)	7 mo
Bradshaw et al.[13] (1989)**	Pre-post	Work sampling	Working shifts (21)/(21) Obs (7,775)/(8,050)	6 mo

NA = Not Available; RCT = Randomized, Controlled Trial.
*Admission procedure.
†Estimated as task occurrence × mean duration.
‡Unable to calculate the 95% CI due to lack of SD reporting.
§Unable to calculate the 95% CI due to nonreporting of number of observations.

compute the 95% confidence interval or identify, from available information in the paper, whether or not the results were significant.

Physicians

Ten studies examined the impact of EHR on time efficiencies of physicians (Table 3). The study from Makoul et al.[43] reported two sets of time estimates that we reported separately. Studies[22,44,45] specifically identified as computerized provider order entry (CPOE) systems were analyzed separately from other studies that examined clinical information systems even if these had CPOE functionalities. Additionally, CPOE studies reported time efficiency estimates in relation to working shifts, contrary to the other physician studies that used patients or patient encounters as the sampling unit. Among studies that were not CPOE focused, four reported an increase in documentation time[43,46–48] with unweighted relative time differences ranging from 11.2% to 40.6%. In three studies,[49–51] the use of the EHR was time efficient with unweighted relative time reductions per patient or patient encounters of −12.6% to −45.5%. Weighted average relative time differences were estimated in relation to the system used. Our results (Fig. 1) show that using bedside or point-of-care computer systems increases documentation time of physicians by 17.5%. In comparison, the use of central station desktops to document clinical notes is slightly less time-consuming, with a weighted average of 8.2%. The use of central station desktops for CPOE was time inefficient in all three studies, consuming from 98.1% to 328.6% more time per working shift. The weighted average relative time difference across these CPOE-oriented studies was an increase in documentation time of 238.4% (Fig. 3).

Contrary to the study with nurses, the single physician study comparing the use of a PDA to paper[51] showed favorable results, with a 22.2% reduction in time. Although over 90 patient encounters were assessed, this was a single-physician study and thus the results may not be generalizable.

Table 2 (Continued) ■

Description of Computerized System	No. of Nurses Observed	Time Spent Documenting		Relative Time Difference Computer vs Paper	95% Confidence Interval for Time Difference
		Paper	Computer		
Bedside complete integrated charting system	NA	16.8 min	18.1 min	+ 7.7%*	0.04; 2.7
Central computerized nursing documentation system	12	4.7 min	6.6 min	+40.4%	0.09; 3.7
Point of care: pen-based handheld ADL score	12	4.5min	10.3 min	+128.4%	4.4; 7.2
Bedside: quantitative sentinel system, automated physiologic measures, menu list, clicking entry mode	10	24.5 min/h	15.3 min/h	−37.5%†	Not enough information available‡
Bedside terminals: ECLIPSYS: point-and-click data entry, charting by exception, free text	12	22.4 min/h	21.9 min/h	−2.1%	−3.3; 2.3
Bedside: EMTEK, automated charts, labs, pharmacy interfaces, automated capture of monitors, pumps, etc.	45	13.2%	12.04%	−8.5%	−1.0; 3.3
Bedside and central terminals: automated vital signs and intake/output modules, automated care	NA	13.7%	9,1%	−33.5%	Not enough information available§
Central station and bedside terminals: Care Vue CIS, online monitoring, manual data entry	58	40.1% 6.1%	22.0% 4.4%	−45.1%¶ −27.9%‖	Not enough information available§
Bedside terminals: default charting data entry using menu or free text	40	11.8 min	9.3 min	−21.0%	−4.2; −0.8
Bedside (very little use) and central terminals HELP-NIS: charting and assessment modules	10	27.4%	35.9%	+30.9%	Not enough information available§
Bedside complete integrated charting system	NA	20.5%	14.4%	−29.7%#	−8.1; −4.0
Bedside: charting and nursing care plans	16	18.2%	24.2%	+32.9%	4.6; 7.4

¶Charting time using the central station.
‖Charting time using the bedside terminals.
#Registration procedure.
**This paper was selected for the review paper but was not included in the analyses because it was an older paper.

Six of the ten studies[22,43–45,48,51] reported significant results. In the study conducted by Makoul et al.,[43] the use of a point-of-care system had a significant unfavorable impact on initial visit time (time increase of 40.6%), but the time increase (13.1%) per encounter regardless of the type of visit did not reach statistical significance. Only one study[50,52] lacked sufficient information to either compute the 95% confidence interval or identify from the information presented in the paper whether the results were significant. In the remaining three studies, there were no significant differences between computer and paper documentation time.

Study Characteristics

Of the 23 studies, only two[40,41] used self-reported time and both reported an increase in documentation time with computer-based documentation. Among all reviewed papers, one third conducted their evaluation process within three months of the implementation of the computerized system.[15,36,38,41,46,51] Overall, these studies tend to demonstrate favorable results with a reduction in documentation time with computer-based documentation (weighted average, −34.0%/working shifts) but a slight increase at the patient level (weighted average, 5.7%). In comparison, studies[13,16,35,39,40,42,43,47–49,52] that were conducted more than three months after system's implementation had an impact on time efficiency that was clearly unfavorable in relation to patients (weighted average, 66.1%) but favorable at the working shifts level (weighted average, −10.0%). Although three of the earliest studies[13,52,53] conducted in the 1980s show an increase in documentation time following computer use, no trend toward increased or diminished efficiency could be identified among the more recent studies with nurses (Fig. 4) or physicians (Fig. 5).

Discussion

To our knowledge, this is the first systematic review to document in a quantified way the time differences between

Table 3 ■ Characteristics of Papers Examining the Impact of Computers on Time Efficiency of Physicians

Authors	Study Design	Method	Sampling Unit Paper (No.)/ Computer (No.)	Time Period From Implementation to Evaluation
VanDenKerkhof et al.[51] (2003)	Pre-post	Time & motion	Patient encounters (100/94)	7 d
Overhage et al.[46] (2001)	RCT	Time & motion	Patient encounters (total = 744)	≈ 3 mo
Apkon & Singhaviron[49] (2001)	Cross-sectional with controls	Time and motion	Patient encounters (55)/(51)	1 yr
Makoul et al.[43] (2001)	Cross-sectional with controls	Video recordings	Patients (102)/(102) Patients (14)/(39)	18 mo
Weinger et al.[48] (1997)	RCT crossover	Time & motion	Patients (10)/(10)	Several months
Hammer et al.[50] (1995)	Cross-sectional with controls	Time and motion	Patients (15)/(18)	NA
Warshawsky et al.[47] (1994)	Pre-post	Video recordings	Patients (77)/(55)	2 yr
Herzmark et al.[52] (1984)¶	Pre-post	Video recordings	Patient encounters (75)/(137)	≈ 6 mo
Pringle et al.[53] (1985)¶	Cross-sectional with controls	Video recordings	Patient encounters (60)/(39)	NA
Bates et al.[44] (1994)	Pre-post	Work sampling	Working shifts (22)/(28) Working shifts (7)/(5)	NA
Tierney et al.[22] (1993)	RCT	Time & motion	Working shifts (48)/(48)	NA
Shu et al.[45] (2001)	Pre-post	Work sampling	Working shifts (119)/(87)	6 mo

NA = Not Available; PDA = Personal Digital Assistant; POE = Provider Order Entry; RCT = Randomized, Controlled Trial; DST = Decision Support Tools; CPOE = Computerized Provider Order Entry.
*Unable to calculate the 95% CI due to lack of SD reporting.
†Total encounter time of all visits.

computer- and paper-based documentation among studies that assessed the documentation activities of nurses and physicians. Time efficiency is only one possible outcome for which the success of EHR integration can be assessed, and studies in this review also reported on direct patient care time,[13,15,16,37,42,47,48,50] user satisfaction,[15,22,42,46] accuracy of the information,[13,15,40] completeness of data entered,[15,38,41,43,49,50] and the overall impact on workflow.[16,22,44,45] However, time efficiency is recognized as an important facilitator or barrier of EHR implementation,[3,10,11,18,21–23] and consequently needs to be assessed with rigorous methodologies. Only 23 studies (36% of total retrieved) involved a quantitative examination of the integration of EHR into clinical workflow. One possible explanation of the paucity of research may be the limitations associated with the methods available to accurately document the impact of EHR on time. Continuous observation of work processes as captured by time and motion or video-recording methods are seen as the most accurate data collection techniques to monitor clinical activities[33] as they provide precise estimates of time spent in each activity. Fifty-eight percent of the reviewed studies used these methods despite the higher costs of one-to-one direct observations. Under the work-sampling technique, data are collected at predefined intervals of time, which allows the observation of multiple individuals by a single observer, which is seen as a major advantage over the time and motion technique. Activities are captured as "snapshots" of professional processes. Single counts of categorized activities do not provide any information on the real time spent performing the activity.[54] The overall proportion of time must be estimated using the number of snapshots in one category over the total number of snapshots that were recorded during the work-sampling time period. Recognized as a valid approach to evaluate work patterns,[54,55] a major disadvantage of the work-sampling technique lies in its need for very large sample sizes for the time estimates to have an acceptable level of precision, a criterion not often met.[33] This limitation of work sampling methods is not likely to influence the conclusions of our review since the errors in estimating time related to the chart documentation would occur in both the computer- and paper-based groups.

Table 3 (Continued) ■

Description of Computerized System	No. of Physicians Observed	Time Spent Documenting		Relative Time Difference Computer vs Paper	95% Confidence Interval for Time Difference
		Paper	Computer		
Point of care: PDA, acute pain management system: tick off boxes or items from drop-down menu	1	5.3 min	4.0 min	−22.2%	−1.7; −0.1
Central system: GOPHER, POE, clinical documentation, review of diagnosis results	14	6.2 min	6.9 min	+11.2%	Not enough information available*
Central system: CLINFOSYS, structured and unstructured data entry	5	10.3 min	9.0 min	−12.6%	−0.3; 2.9
Point of care: EpicCare, record, display results, prescription and order entry, DST, reminders	3	23.6 min† 25.6 min‡	26.7 min 35.2 min	+13.1% +40.6%	−0.7; 6.9 0.8; 19.7
Point of care: ARKIVE or computer-touch screen, preconfigured templates, continuous recording & display of vital signs	9	14.7 min	17.2 min	+17.0%	1.2; 3.8
Point of care: MICRO-CARES, pen entry notebook and keyboard, look-up lists	NA	22 min	12 min	−45.5%	Not enough information available*
Point of care: CLINIC, structured data entry, reminders, algorithm-based menus	3	42.9%	56.16%	+30.9%	−3.8; 30.3
Point of care: free-text notes, menu-driven prescription refills	5	5.5 min	6.4 min	+16.4%	Not enough information available*
Point of care: preventive medicine information, demographics; reminders, little data entry	3	6.7 min	7.5 min	+11.9%	0.14; 1.44
Central system: CPOE	22/28 7/5	5.3% 6.4%	10.5% 15.5%	+98.1% +142.2%	Not enough information available§
Central system: CPOE, problem-specific menus, menu-driven or free-text orders	12	25.5 min/shift	58.5 min/shift	+130.9%	Not enough information available*
Central system: CPOE, coded form data entry	29	2.1%	9.0%	+328.6%	Not enough information available§

‡Total encounter time of initial visits.
§Unable to calculate the 95% CI due to nonreporting of number of observations.
¶These papers were selected for the review papers but were not included in the analyses because they were older papers.

Only a few study results[44,48] reported in our review had large confidence intervals (Tables 2 and 3), and although sample size may influence the width of confidence intervals, only one had a fairly small sample size (pre/post, 14/39 patients).[48] Population characteristics also play an important role in the variability of the data, and, hence, on the width of confidence intervals. For example, the two studies[44,48] were conducted in environments (general internal medicine and community clinics) where care delivery is highly variable because of the population's heterogeneity. In comparison, studies conducted in highly specialized settings such as the one by Weinger et al.[48] are more likely to have uniform care delivery patterns, less variability across patients and physicians, and therefore narrower confidence intervals, despite a smaller sample size.

Results of this review suggest that nurses are more likely than physicians to gain time efficiencies by using a computer system to document patient information. Several reasons may explain the difference between nurses and physicians. First, nurses and physicians document different types of information. Nurses often document using standardized forms or care plans,[56] while physicians rarely use standardized templates to write their clinical notes.

Retrieval or viewing of information is part of the work processes of both nurses and physicians. However, it is much more intricately related to the documentation process of physicians. This may have played an important role in time efficiencies of CPOE systems that combine retrieval, viewing of information, data entry, and, in many cases, responses to alerts and reminders. These additional factors are difficult to capture by time and motion or work-sampling methods as both have limited capacity in capturing simultaneous activities,[57] and these may have accounted for the extra time that physicians take to document or enter orders on a computer. Several studies have shown that computers increase the completeness of information being documented.[15,38,41,43,49,50,58] This additional information available to physicians will influence the time required to retrieve information,[59] and their motivation

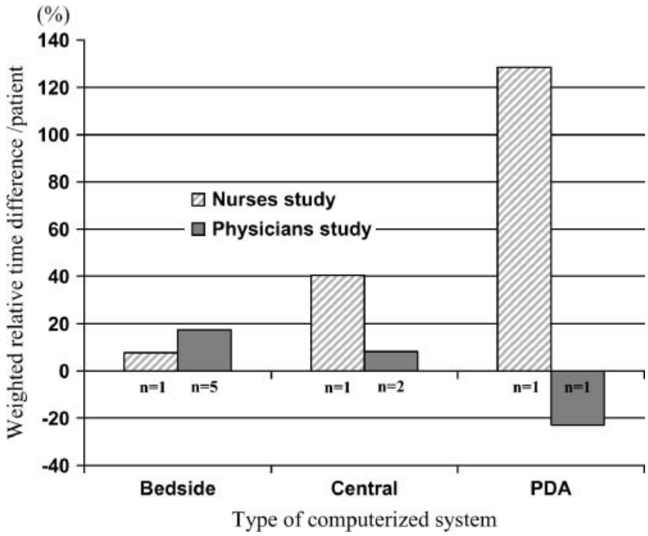

Figure 1. Weighted relative time difference per patient attributed to the use of computers or personal digital assistant (PDA) among nurses and physicians studies.

to use EHRs if part of that information is perceived as unnecessary to their clinical activities.[60,61]

While both nurses and physicians see the added value of integrating EHR into their daily practice,[17,59,62] physicians and nurses differ in their incentives to use the EHR[56] and in their speed of adoption.[63] These can be influenced by the fact that nurses tend to work in a single location and will therefore be more frequently exposed to the EHR in contrast to physicians who tend to work in several locations, both inside and outside the hospital. The degree of exposure to a newly implemented EHR may influence the learning curve and ability to become an efficient user more rapidly. As employees of a health care organization, nurses may be more likely to receive support from clinical leaders and paid training sessions, both of which have been identified as essential requirements for EHR adoption.[64] The autonomy and accountability of nurses and physicians are different and may influence their performance.[65] Those may explain why nurses tend to be more time efficient than physicians. Both groups also differ in their work processes. For example, nurses are part of a care team and need to verbally transmit information to their colleagues at the end of their working shifts. The use of computers has

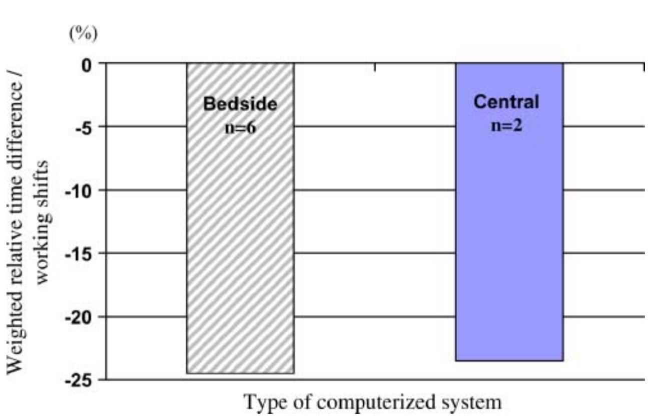

Figure 2. Weighted relative time difference per working shifts attributed to the use of computers among nurse studies.

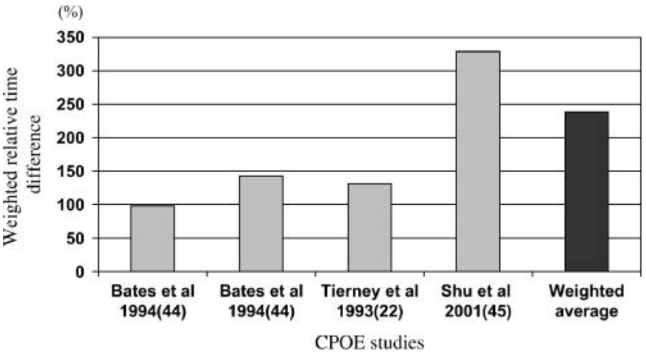

Figure 3. Reported relative time differences of the impact of computerized provider order entry (CPOE) use and weighted average of relative time differences across studies on CPOE.

been shown to reduce the time devoted to the end-of-shift report,[13] and this change in workflow may have been a strong incentive for nurses to become efficient users of the system. Our results support this assumption, with all studies examining the impact of EHR over working shift periods, reporting favorable time efficiencies compared to those with patients or patient encounters as the sampling units. In our review, all studies on physicians, except for CPOE studies, used patients as their unit of analysis and most reported an unfavorable impact of the EHR. Time gains, at the patient level, may be difficult to achieve and examining the impact of EHR time on the overall clinic or hospital day may have yielded different results for physicians.

It was surprising to see that studies that observed clinicians relatively soon after implementation time (three months or less) showed a slight reduction in documentation time, while those that waited longer tended to show increases. It is possible that once clinicians become familiar with the system, they begin to take advantage of its other functionalities and thus may appear to be less efficient. Another reason may be that most projects have intensive support in the early implementation phase and that support may decrease over time. The optimal time period for assessment of time efficiencies post-implementation of EHRs remains a challenge and will require further research.

To understand the role that system use may play in time efficiencies, standardized audit trail information needs to be collected that would allow assessment of the extent to which individual components of a system are used. This review clearly highlighted the absence of any consistency or agreement on a standard time period after which a system should be tested. In fact, 25% of the studies in our review neglected to mention the time period in which the evaluation was performed despite the importance of this time period on adoption, use, and efficiency rates.[15,16,46]

We attempted to characterize the different EHR systems reviewed in this paper in a systematic way and reported for each system the location (bedside or central station), data entry format (structured, free text, keyboard, touch screen), and the main functionalities (POE, complete clinical notes). Obviously, other characteristics such as the number of available fields in the EHR that one must navigate to enter data and the speed of the computer were not systematically reported and would likely play a major role in the clinician's time

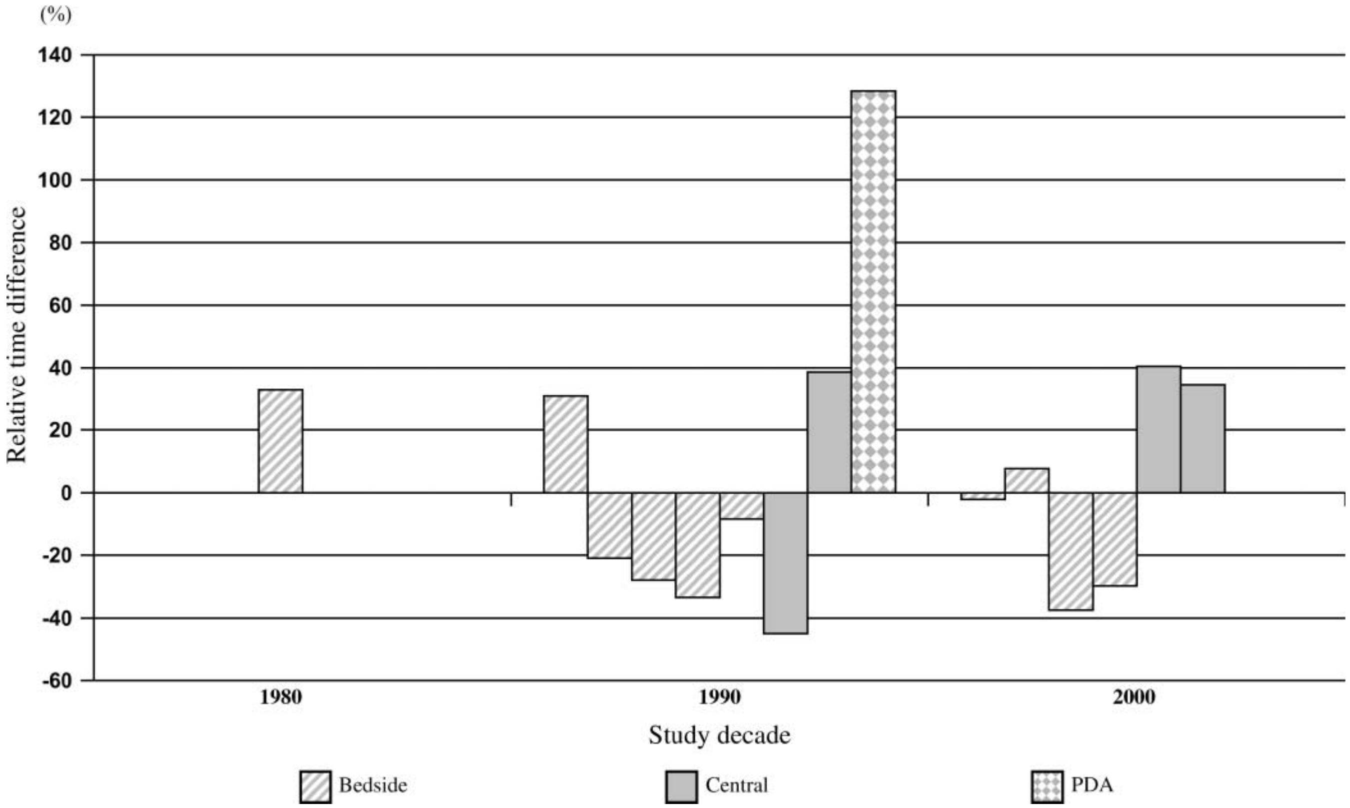

Figure 4. Comparison of unweighted relative time differences among nurses by study decade. PDA = personal digital assistant.

efficiency. For informed and valid comparisons of time efficiency within and across studies, timed standardized tasks would be helpful in establishing baseline expected efficiencies as some EHRs may not have the capacity to be time efficient in comparison to paper charting, regardless of the user or the environment. Knowing this information prior to EHR implementation will influence the deployment and training strategies. The focus on time efficiency should then be oriented toward

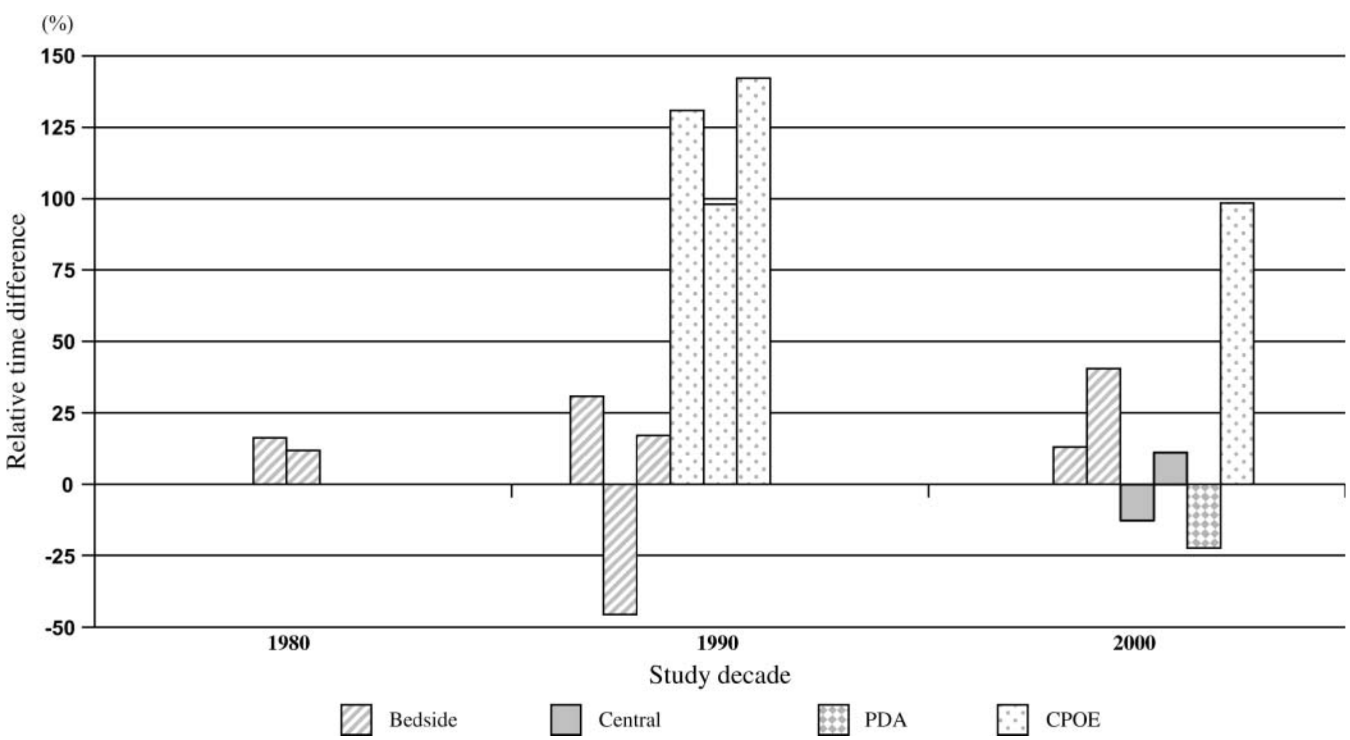

Figure 5. Comparison of unweighted relative time differences among physicians by study decade. CPOE = computerized provider order entry; PDA = personal digital assistant.

the overall processes of care delivery rather than toward the potential time gains in performing specific activities, like documenting or ordering tests.

Limitations of the Study

Only 23 papers met our selection criteria despite the fact that we examined all papers published since 1966 and did not limit our search to RCTs. The concept of time efficiency is reported in the health informatics literature through quantitative or qualitative results or anecdotal evidence, but our focus was on quantitative results only. The inclusion of the numerous qualitative or anecdotal evidence studies may have provided valuable information to this area of knowledge but would have prevented summarizing the results in a quantitative way, which we thought was highly informative. A wide range of EHR systems were covered in this review (from POE to full clinical notes system). We grouped time differences on the basis of users, systems, and sampling unit as we could not assume that, for example, a 10% increase in time efficiency per patient would be the equivalent of a 10% increase for the total working shift. Different grouping approaches may yield different time averages, but the overall direction of results, time efficiency versus time inefficiency, should remain the same.

We recognize that papers included in this review cover a ten-year time period during which technology was rapidly evolving. Combining results of studies conducted in the 1990s with studies from the early 2000s may be debatable. However, our results did not identify a clear trend toward enhanced time efficiency despite the increased speed of computers, the availability of customized software, and the large array of user interfaces and input devices. The role of factors that are external to the information systems in contributing to the time efficiency of clinicians needs to be better understood. The methods used in the selection and review of these papers did not allow us to examine the impact of these factors. Further studies are required to examine the role of clinicians, professional practice, and organizational environment in facilitating or not the efficient use of EHRs.

Conclusion

Time efficiency is one of many benefits targeted by EHR implementers, but, conversely, time inefficiency is also recognized as a major barrier to successful EHR implementation. Our initial search of the literature in the area of workflow and time efficiency allowed us to identify that the benefits of the EHR are still widely assessed from a user's perspective, looking at single processes (e.g., documentation) rather than on its impact on the set of processes involved in care delivery. We learned that expectations of EHR implementation projects that documentation time will be decreased are unlikely to be fulfilled, especially with physicians. However, EHR and CPOE systems can generate time savings in other activities, such as accessing a patient chart[44] or maintaining patients' report forms.[22] Consequently, assessing the impact of EHR on an ensemble of work processes and outputs such as the effectiveness of communications across care providers as measured by patient outcomes (e.g., reduction in medication errors, lower readmission rates) could potentially generate favorable results that would then act as incentives to physicians. This suggests that a shift from the user's efficiency to the organization's or even the system's efficiency is needed.[66] Such a shift will require that the EHR be seen as a tool that can transform work processes and support innovation in care delivery.[67,68] Future research is required to examine whether the capacity of the EHR to improve the overall care delivery process of patients will likely outweigh the barrier associated with the additional time required to use the system. New methods to measure the impact of the EHR on time efficiency from an organization's or a system's perspective will have to be developed. Further research is needed to examine the impact of EHR on system efficiency and how this will influence adoption rates by all users, particularly physicians.

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