Observational Study

Medicine®

OPEN

Association between Electronic Medical Records and Healthcare Quality

Hong-Ling Lin, MS[a], Ding-Chung Wu, MS[a,b], Shu-Meng Cheng, PhD[c], Cheng-Jueng Chen, PhD[d], Mei-Chuen Wang, PhD[a], Chun-An Cheng, PhD[e,*]

Abstract

The implementation of electronic medical records (EMRs) has generally been thought to improve medical efficiency and safety, but consistent evidence of improved healthcare quality due to EMRs in population-based studies is lacking. We assessed the relationship between the degree of EMR adoption and patient outcomes.

We performed an observational study using discharge data from Tri-service General Hospital from 2013 to 2018. The levels of EMR utilization were divided into no EMRs, partial EMRs and full EMRs. The primary healthcare quality indicators were inpatient mortality, readmission within 14 days, and 48-hour postoperative mortality. We performed a Cox proportional hazards regression analysis to evaluate the relationship between the EMR utilization level and healthcare quality.

In total, 262,569 patients were included in this study. Compared with no EMRs, full EMR implementation led to lower inpatient mortality [adjusted hazard ratio (HR) 0.947, 95% confidence interval (CI): 0.897–0.999, $P = ..049$] and a lower risk of readmission within 14 days (adjusted HR 0.627, 95% CI: 0.577–0.681, $P < .001$). Full EMR implementation was associated was a lower risk of 48-hour postoperative mortality (adjusted HR 0.372, 95% CI: 0.208–0.665, $P = .001$) than no EMRs. Partial EMR implementation was associated with a higher risk of readmission within 14 days than no EMRs (HR 1.387, 95% CI: 1.298–1.485, $P < .001$).

Full EMR adoption improves healthcare quality in medical institutions treating severely ill patients. A prospective study is needed to confirm this finding.

Abbreviations: CI = confidence interval, DRGs = diagnostic related groups, EMRs = electronic medical records, HR = hazard ratio.

Keywords: electronic medical records, healthcare quality

1. Introduction

The health information technology practices promoted by electronic medical records (EMRs) improve healthcare efficiency and promote patient safety.[1] According to a meta-analysis, the adoption of EMRs leads to better adherence to clinical guidelines, fewer medication errors and fewer adverse drug reactions but has no significant effect on mortality.[2] The full implementation of EMRs improves healthcare quality,[3] but a recent population-based study showed conflicting results and the lack of associations between the adoption of EMRs and improvement in inpatient mortality, readmissions, and patient safety indicators after adjusting for patient and hospital factors.[4]

The widespread implementation of EMRs is likely to have a significant impact on the quality of medical records in surgical settings.[5] Those involved in public health should combine their efforts in interoperability projects to ensure that EMRs are both fully adopted and fully interoperable, which could greatly increase the availability, accuracy, and comprehensiveness of data across the country and enhance benchmarking and disease surveillance/prevention capabilities.[6] EMRs can improve healthcare productivity and efficiency, leading to better public health outcomes. High-quality EMR applications in health care are used as decision-support tools to minimize medical errors.[7] EMRs with Health Information Technology have the potential to reduce medical costs.[8,9]

Although EMRs are superior to paper-based health records in terms of process and structure, in terms of quantity and content quality, paper-based records have been shown to be superior to EMRs in the nursing setting.[10] A lack of improvement in pediatric healthcare quality, more medical errors, a lack of adherence to guidelines related to chronic illnesses, and decreased communication with other providers were observed after the implementation of EMRs (2016 compared with 2012) in a recent study.[11] Minimal or no improvement was observed after implementing EMRs for preventive health and chronic illness in

Editor: Vineet Gupta.

The authors have no funding and conflicts of interest to disclose.

The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

[a] Medical Records Department, Tri-Service General Hospital, [b] Department of Public Health, National Defense General Hospital, [c] Department of Cardiology, [d] Department of Surgery, [e] Department of Neurology, Tri-Service General Hospital, National Defense Medical Center, Taipei, Taiwan.

[*] Correspondence: Chun-An Cheng, Department of Neurology, Tri-Service General Hospital, National Defense Medical Center, No. 325, Section 2, Cheng-Kung Road, Neihu District, Taipei City 11490, Taiwan (e-mail: cca@ndmctsgh.edu.tw).

How to cite this article: Lin H-L, Wu D-C, Cheng S-M, Chen C-J, Wang M-C, Cheng C-A. Association between electronic medical records and healthcare quality. Medicine 2020;99:31(e21182).

Received: 23 January 2020 / Received in final form: 7 May 2020 / Accepted: 4 June 2020

http://dx.doi.org/10.1097/MD.0000000000021182

family medicine.[12] No independent associations between patient pain perception scores and documented pain assessments or nutritional disorder screening results were reported.[13]

The government began planning the National Health Informatics Project in Taiwan in 2004. The government plays a leading role in the development of the national health information system and promotion of the implementation of important infrastructure needed for EMRs. With the development of EMRs, the medical operating environment has changed, especially in the fields of data integration and information dissemination, and EMRs have been widely applied to promote medical team communication, physician-patient communication and the prevention of medical errors.[12,14–18]

Tri-Service General Hospital is a medical center in northern Taiwan that cooperated with the government to promote the establishment of EMRs. Since 2009, EMRs have been implemented in 4 stages.

The first stage occurred from 2009 to 2014 and focused on commonly used medical imaging examination reports and outpatient medical records, while inpatient EMRs were limited to discharge and nursing records, and the remaining inpatient medical records were still recorded on paper due to issues related to EMR stability and incomplete privacy protection measures. Overall, paperless records were not implemented during the first phase. The second phase occurred from 2015 to 2016 and mainly added laboratory inspection reports and emergency medical records to the EMRs. Inpatient medical records recorded electronically were related to admission, progress and discharge and were mainly based on single sheets used by doctors while caring for patients; partial EMRs were gradually implemented with paperless work records and signatures.

During the third phase, which occurred from 2017 to 2018, specific disposal, specialist inspection forms and team-based care integration forms were developed. More than 80% of the medical records were integrated into the system, and most paperwork was reduced.

The fourth phase is nearly completed and involved the inclusion of various types of equipment inspection reports, limitation of access to the EMR system, the conversion of consent letters, certificates, medical consultation plans and medical forms into paperless format, and the implementation of a completely paperless medical work environment that supports big data management and the use of artificial intelligence in medical research.

The process of implementing EMRs is slow and complicated and requires consideration of the process necessary for personnel to learn and master the complete information system. Meanwhile, healthcare quality is the result of a combination of structures, processes and outcomes, and the characteristics of physicians and patients directly affect the outcomes. Past research concerning the quality of healthcare has largely ignored the facts that EMRs comprise hundreds of individual medical records and that different sequences of EMR implementation have different effects on the behaviors of various medical personnel, the timing of the recording of the data, and the speed and complexity of the import process.[19] Furthermore, there are still inconsistent results regarding the association between the implementation of EMRs and improvements in healthcare quality, including at various hospital levels. No significant correlations have been found between the degree of EMR implementation and the rates of mortality, readmission, and complications.[4] In patients with illnesses of average severity, the implementation of EMRs did not lead to reduced mortality; however, there was a decrease in mortality of 1 in 100 patients with severe illnesses.[20]

Therefore, this study explored the history of EMRs in a single medical center and investigated the impacts on the risk of inpatient mortality, readmission within 14 days, and 48-hour postoperative mortality. We assessed the association between the implementation of EMRs and healthcare quality.

2. Methods

2.1. Data source and study population

The medical records of inpatients discharged from Tri-Service General Hospital were collected from 2013 to 2018. To reduce differences in the level of familiarity of physicians with EMRs, physicians who continually practiced in hospitals between 2013 and 2018 were included.

The 14-day readmission data were obtained from a discharge dataset of patients with the same diagnosis based on comparing the discharged date of the index admission with the admission date of the following admission within a 14-day period. The death within 48 hours after operation data was assessed from a discharge dataset to compare the mortality date and operation date within a 2-day period.

Patients with repeat admissions who were serviced by discontinued service physicians were excluded. The variables assessed in this study included the basic demographic data of the patients (sex and age), their hospitalization characteristics (department, physician, and length of stay), and adverse events (mortality, discharge against medical advice, readmission for the same disease within 14 days, and death within 48 hours after an operation). The inpatient mortality, 14-day readmission for the same disease, and 48-hour postoperative mortality data were assessed as indicators of healthcare quality in this study. The study was approved by TSGH IRB 1-108-05-179.

2.2. Statistical analysis

A descriptive statistical analysis was performed; the categorical variables, including the patients' sex, medical department, and discharge status, are presented as counts and percentages, while the continuous data, including age and length of stay, are presented as the mean and standard deviation. The data were stratified by the EMR utilization stage. The differences in each variable by stage were determined by a X^2 test and 1-way ANOVA. Statistical significance was defined as $P < .05$.

Univariate analyses were performed to analyze inpatient mortality, 14-day readmission and 48-hour postoperative mortality according to EMR utilization. To adjust for the effects of sex, age, and physician on the medical outcomes, we performed a multivariate Cox proportional hazards regression analysis to assess the risk of patient outcomes in all medical and surgical settings. The statistical software used in this study was IBM SPSS Statistics Version 22 (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp., released 2013).

3. Results

There were 262,569 hospitalizations, including 79,252 patients during the period of no EMRs, 90,386 patients during the partial EMR period and 92,931 patients during the full EMR period. A flow chart is presented in Figure 1.

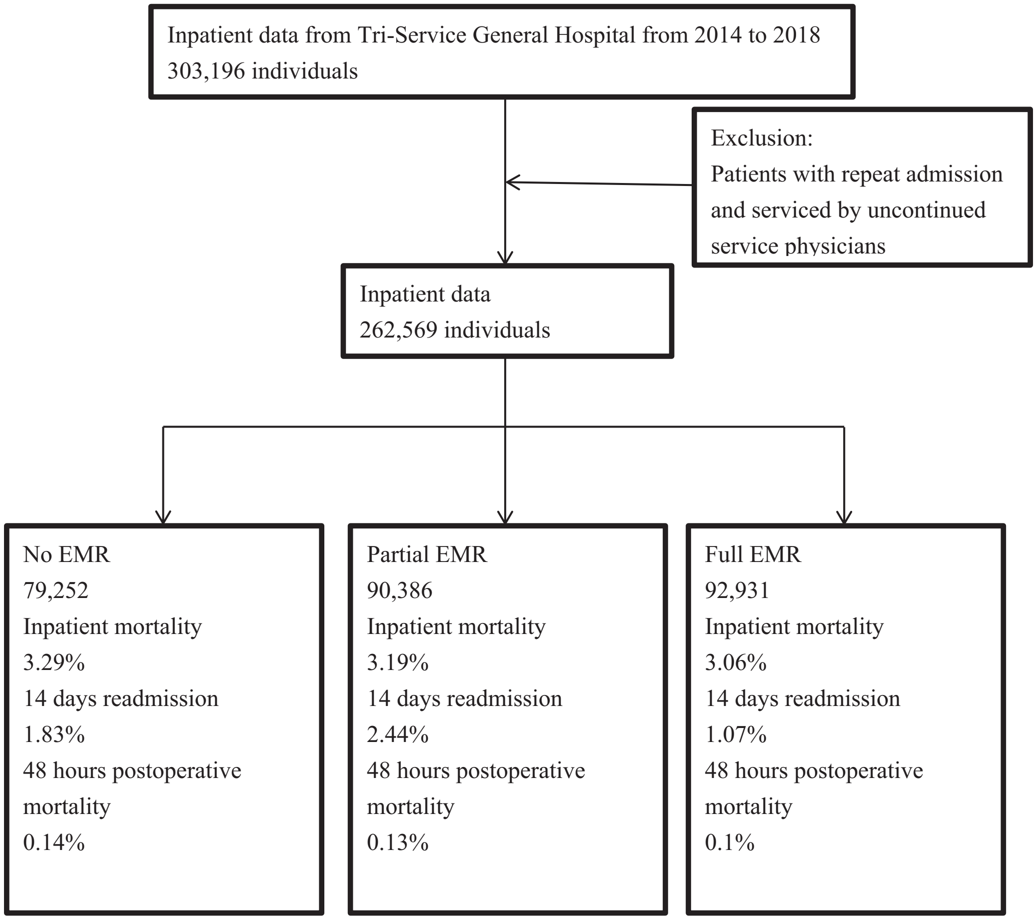

Figure 1. The flowchart of this study.

Of the total patient population, 49.32% were admitted to medical departments, 33.99% were admitted to surgical departments, 7.35% were admitted to the gynecology and obstetrics department, 2.5% were admitted to the pediatric department, and 6.84% were admitted to other departments. The average length of stay was 6.7 days. The inpatient mortality rate was 3.17%, the rate of readmission within 14 days was 1.72%, and the mortality rate within 48 hours after an operation was 0.051%.

Compared with the stage of no EMR, during the full EMR stage, there was a higher proportion of older patients, higher proportions of surgical and pediatric admissions, lower proportions of medical and obstetrics and gynecology admissions, shorter lengths of stay, and a lower mortality rate. Compared with the stage of no EMR, the partial EMR phase had a higher 14-day readmission rate. Compared with the stage of no EMR, both the full and partial EMR stages had more female patients (Table 1).

We only investigated the medical and surgical admissions because there were fewer events in the other departments. Compared with the stage of no EMR, the partial EMR stage had a higher risk of readmission within 14 days for the same disease (adjusted HR 1.387, 95% confidence interval [C.I.]: 1.298–1.485, $P<.001$, 1.266 (95% C.I.: 1.171–1.370, $P<.001$ in the medical setting and 1.878, 95% C.I.: 1.581–2.231, $P<.001$ in the surgical setting). Compared with the stage of no EMR, the full EMR stage had a significantly lower risk of inpatient mortality (adjusted HR 0.947, 95% C.I.: 0.897–0.999, $P=.049$) and a significantly lower risk of readmission for the same disease within 14 days (adjusted HR 0.627, 95% C.I.: 0.577–0.681, $P<.001$). There was a lower risk of readmission (adjusted HR 0.590, 95% C.I.: 0.537–0.649, $P<.001$) in the medical setting and a lower risk of 48-hour postoperative mortality (adjusted HR 0.372, 95% C.I.: 0.208–0.665, $P=.001$) in the surgical setting (Table 2).

The hierarchical analysis is shown in Table 3. Most patients and older patients were admitted to the medical setting. There were more males in the medical and surgical settings. The 14-day readmission rate increased in the medical, surgical and gynecology and obstetrics settings during the partial EMR stage. The length of stay was reduced in the medical setting but increased in the surgical and gynecology and obstetrics settings during the full EMR stage.

4. Discussion

Our study found that the inpatient mortality rate and 14-day readmission rate during the full EMR stage were reduced compared with those during the no EMR stage. The postoperative 48-hour mortality rate of the surgical patients decreased during the full EMR stage. The risk of 14-day readmission during the partial EMR period was higher than that during the no EMR period. The development and application of EMRs resulted in

Table 1

Demographic and clinical characteristics in this study.

	All	No EMR	Partial EMR	Full EMR	*P*
N	262,569	79,252	90,386	92,931	
Age (yr) (SD)	56.1 (20.55)	55.8 (20.42)	55.4 (20.91)	57.0 (20.27)	<.001*
Gender (%)					
Male	129,710 (49.40)	39,378 (49.69)	44,355 (49.07)	45,977 (49.47)	.049*
Female	147,039 (50.60)	39,874 (50.31)	46,031 (50.93)	46,954 (50.53)	
Departments (%)					
Medical	129,495 (49.32)	40,529 (51.14)	44,292 (49.00)	44,674 (48.07)	<.001*
Surgical	89,242 (33.99)	26,295 (33.18)	30,425 (33.66)	32,522 (35.00)	
GYN and OBS	19,311 (7.35)	6334 (7.99)	6927 (7.66)	6050 (6.51)	
Pediatric	6561 (2.50)	1403 (1.77)	2618 (2.90)	2540 (2.73)	
Others	17,960 (6.84)	4691 (5.92)	6124 (6.78)	7145 (7.69)	
Length of stay (d) (SD)	6.7 (7.92)	6.8 (8.00)	6.6 (7.88)	6.7 (7.89)	.003*
Inpatient mortality (%)	8331 (3.17)	2610 (3.29)	2881 (3.19)	2840 (3.06)	.019*
14 d readmission (%)	4504 (1.77)	1405 (1.83)	2134 (2.44)	965 (1.07)	<.001*
Denominators	254,238	76,642	87,505	90,091	
48 h postoperative mortality (%)	135 (0.12)	48 (0.14)	48 (0.13)	39 (0.1)	.16
Denominators	112,594	33,511	38,230	40,853	

EMR = electronic medical records, GYN and OBS = gynecology and obstetrics, SD = standard deviation.
Fourteen-day readmission (%), patients readmitted within 14 days/the survival discharged patients (all discharged patients minus inpatient mortality patients)
48 hours postoperative mortality (%), patients died within 2 days after operation/operation patients

Table 2

Relationship of patient's outcomes according different adopted stage of electronic medical records status compared with no electronic medical records stage.

Group	Outcome	Univariate. hazard ratio (95%CI)	Multivariate adjusted hazard ratio (95%CI)
All	Inpatient mortality		
	No EMR	Reference	
	Partial EMR	0.991 (0.940–1.045)	
	Full EMR	0.942 (0.893–0.993)*	0.947 (0.897–0.999)*
	14 d readmission		
	No EMR	Reference	
	Partial EMR	1.358 (1.270–1.453)***	1.387 (1.298–1.485)***
	Full EMR	0.592 (0.546–0.643)***	0.627 (0.577–0.681)***
	48 h post operation death		
	No EMR	Reference	
	Partial EMR	0.887 (0.595–1.324)	
	Full EMR	0.697 (0.457–1.063)	
Medical	Inpatient death		
	No EMR	Reference	
	Partial EMR	1.020 (0.961–1.0820	
	Full EMR	0.999 (0.942–1.061)	
	14 d readmission		
	No EMR	Reference	
	Partial EMR	1.272 (1.178–1.374)***	1.266 (1.171–1.370)***
	Full EMR	0.589 (0.536–0.647)***	0.590 (0.537–0.649)***
	48 h post operation death		
	No EMR	Reference	
	Partial EMR	0.931 (0.465–1.861)	
	Full EMR	0.973 (0.491–1.925)	
Surgical	Inpatient death		
	No EMR	Reference	
	Partial EMR	1.022 (0.900–1.160)	
	Full EMR	0.908 (0.799–1.031)	
	14 d readmission		
	No EMR	Reference	
	Partial EMR	1.811 (1.531–2.143)***	1.878 (1.581–2.231)***
	Full EMR	0.730 (0.598–0.892)**	0.864 (0.705–1.060)
	48 h post operation death		
	No EMR	Reference	
	Partial EMR	0.850 (0.516–1.398)	
	Full EMR	0.555 (0.321–0.959)*	0.372 (0.208–0.665)**

EMR = electronic medical records
* $P<.05$
** $P<.01$
*** $P<.001$

Table 3

Demographic and clinical characteristics stratified by different departments.

	All	No EMR	Partial EMR	Full EMR	P
Numbers	262,569	79,252	90,386	92,931	
Medical	129,495 (49.32)	40,529 (51.14)	44,292 (49.00)	44,674 (48.07)	<.001*
Surgical	89,242 (33.99)	26,295 (33.18)	30,425 (33.66)	32,522 (35.00)	
GYN and OBS	19,311 (7.35)	6334 (7.99)	6927 (7.66)	6050 (6.51)	
Pediatrics	6561 (2.50)	1403 (1.77)	2618 (2.90)	2540 (2.73)	
Others	17960 (6.84)	4691 (5.92)	6124 (6.78)	7145 (7.69)	
Age (yr) mean±SD					
Medical	61.6 (18.12)	61.2 (18.45)	61.1 (18.31)	62.3 (17.60)	<.001*
Surgical	55.7 (19.16)	54.4 (19.56)	55.3 (19.34)	57.1 (18.57)	<.001*
GYN and OBS	44.6 (14.68)	43.3 (14.49)	44.1 (14.66)	46.5 (14.72)	<.001*
Pediatrics	4.9 (5.40)	5.1 (5.33)	4.3 (5.31)	5.4 (5.46)	<.001*
Others	49.3 (19.35)	48.5 (19.24)	49.1 (19.42)	49.9 (19.35)	.001*
Sex n (%)					
Medical					
Male	67,566 (52.18)	21,377 (52.74)	22,830 (51.54)	23,359 (52.29)	.003*
Surgical					
Male	48,813 (54.70)	14,561 (55.38)	16,896 (55.53)	17,356 (53.37)	<.001*
GYN and OBS					
Female	19,311 (100.00)	6334 (100.00)	6927 (100.00)	6050 (100.00)	–
Pediatrics					
Female	4143 (63.15)	858 (61.15)	1712 (65.39)	1573 (61.93)	.006*
Others					
Female	6849 (38.13)	1752 (37.35)	2339 (38.19)	2758 (38.60)	.333
Length of stay (d) mean±SD					
Medical	8.0 (8.96)	8.1 (9.12)	7.9 (8.94)	7.9 (8.83)	.005*
Surgical	6.1 (7.18)	6.0 (6.97)	6.1 (7.16)	6.2 (7.35)	<.001*
GYN and OBS	3.7 (3.59)	3.7 (3.57)	3.6 (3.42)	3.8 (3.79)	.002*
Pediatrics	3.6 (5.00)	3.0 (3.48)	4.0 (5.55)	3.5 (5.08)	<.001*
Others	4.5 (5.24)	4.8 (5.35)	4.4 (5.12)	4.4 (5.25)	<.001*
Inpatient mortality (%)					
Medical	6653 (5.14)	2107 (5.20)	2283 (5.15)	2263 (5.07)	.666
Surgical	1490 (1.67)	434 (1.65)	534 (1.76)	522 (1.61)	.326
GYN and OBS	124 (0.64)	51 (0.81)	37 (0.53)	36 (0.60)	.128
Pediatrics	30 (0.46)	4 (0.29)	13 (0.50)	13 (0.51)	.558
Others	34 (0.19)	14 (0.30)	14 (0.23)	6 (0.08)	.022*
14 d readmission (%)					
Medical	3359 (2.73)	1120 (2.92)	1522 (3.62)	717 (1.69)	<.001*
Surgical	810 (0.92)	199 (0.77)	425 (1.42)	186 (0.58)	<.001*
GYN and OBS	249 (1.30)	60 (0.96)	143 (2.08)	46 (0.76)	<.001*
Pediatrics	30 (0.46)	8 (0.57)	15 (0.58)	7 (0.28)	.223
Others	56 (0.31)	18 (0.38)	29 (0.47)	9 (0.13)	.001*
48 h postoperative mortality (%)					
Medical	49 (0.452)	16 (0.48)	16 (0.455)	17 (0.426)	.943
Surgical	84 (0.099)	31 (0.124)	31 (0.107)	22 (0.071)	.122
GYN and OBS	1 (0.012)	0 (0.000)	1 (0.035)	0 (0.000)	–
Pediatrics	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	–
Others	1 (0.011)	1 (0.04)	0 (0.000)	0 (0.000)	–

* $P<.05$.

EMR = electronic medical records, GYN and OBS = gynecology and obstetrics, SD = standard deviation.

Fourteen-day readmission (%), patients readmitted within 14 days/the survival discharged patients (all discharged patients minus inpatient mortality patients). The denominators of 14 day readmission according to all, no EMR, partial EMR, full EMR were 122,842; 38,422; 42,009; 42,411 in medical department, 87,752; 25,861; 29,891; 32,000 in surgery department, 19,187; 6,283; 6,890; 6,014 in gynecology and obstetrics department, 6531; 1399; 2605; 2527 in pediatrics department and 17,926; 4677; 6110; 7139 in other departments.

Forty-eight hours postoperative mortality (%), patients died within 2 days after operation/ operation patients. The denominators of 48 hours postoperative mortality according to all, no EMR, partial EMR, full EMR were 10,832; 3,331; 3,514; 3,987 in medical department, 84,780; 24,980; 28,904; 30,896 in surgery department, 8279; 2681; 2842; 2756 in gynecology and obstetrics department and 8703; 2519; 2970; 3214 in other departments.

significant benefits in terms of healthcare quality in our study. The full EMR completion stage displayed positive effects.

The mechanisms by which EMRs improve healthcare quality include reduction in medication errors due to the use of a clinical decision system, improved clinical communication, improved information management leading to better treatment decisions and shared data, leading to reduced information fragmentation.[21]

This study investigated the impact of the degree of EMR utilization on healthcare quality. The first stage of EMR implementation involved outpatient and nurse records. The inpatient records were still kept on paper. Information transmission and communication among medical professionals were still based on paper records. The first stage had a minimal impact on medical record keeping by doctors. In a past study, there was no improvement in the quality of the nurse and outpatient family medicine records with the implementation of EMRs.[10,12] This study showed a similar result.

The second phase mainly involved the integration of paperless work records and signatures; during this stage, doctors were required to be familiar with the use of EMRs and the storage of records in the information system. As before, all paper medical records were collected and recorded. The transmission of information was scattered and incomplete. It was difficult for the medical staff to find patient information in the different interfaces. It was difficult to integrate the data across media, resulting in confusion. Therefore, the healthcare quality was reduced during this transitional period. During this stage, the physicians were required to instantly record the patients' conditions and adopt new medical rules with additional complexity in the clinical setting. Converting to EMRs was time consuming and interfered with patient care.[22] EMR implementation may actually increase the duration of clinical pediatric visits.[23] A past study found a weekend decline in the intensity of care by using EMR interactions as a global measure of intensity. This finding was associated with the length of stay but not in-hospital mortality.[24] In previous studies, the weekend effects of EMR adoption were found to be related to the performance of general surgery procedures in emergency departments with fewer residents and higher workloads.[25] The 14-day readmission rate increased due to changes in the behavior of doctors and the burden imposed by the transition to EMRs. The transition to EMRs needs to be facilitated by adequate education and training to reduce the gap in healthcare quality.

A past survey of medical providers found that the adoption of EMRs led to improvements in healthcare.[3] During the full EMR stage, the medical records are integrated into the system, making it easier to query medical records and deliver information. The transfer of information in team-based care is more immediate, and most paperwork is reduced. During this stage, the rates of inpatient mortality and 14-day readmission were significantly reduced. In addition, the development of EMRs for surgery and anesthesia were completed during this period, and the corresponding results showed that the risk of postoperative mortality was also significantly reduced.

The 14-day readmission rate and length of stay were reduced in the medical setting. However, the 14-day readmission rate was reduced, but the length of stay was increased in the surgical and gynecology and obstetrics settings. A potential reason is that patients receiving surgery stay longer to confirm their full recovery and avoid readmission.

There was no improvement in the pediatric healthcare quality according to a survey of pediatricians inquiring about EMRs; in a recent study, pediatricians reported that they spent more time documenting care in EMRs, resulting in a delay in the implementation of direct messaging during care transitions.[11] Our study yielded similar results with a crude odds ratio of 1.80 (95% C.I.: 0.59–5.52, $P=.305$) for inpatient mortality and 0.48 (95% C.I.: 0.17–1.33, $P=.16$) for the 14-day readmission rate. A potential reason is that the conditions of pediatric patients are more variable and complicated.

There were inconclusive effects on healthcare quality after the introduction of EMRs.[2,4] A past study found that EMRs led to reduced mortality in patients with severe illnesses.[20] Readmission was reduced after the implementation of EMRs.[26] Appropriate training on EMR use may help healthcare professionals cope with the increased level of complexity. The standards for interoperability need to continue to progress. This study found significantly reduced mortality and 14-day readmission rates after the full implementation of EMRs. Our study reviewed inpatient data from a single medical center with more severe patient conditions and a higher than average mixed case index (approximately 1.25) in Taiwan, and the physicians closely followed the treatment guidelines. The patients' care facility did not change in the following periods. These findings could encourage hospitals to adopt EMRs to improve patient care.

5. Limitations

There were some limitations in our study. First, this study is a 6-year observational study in a single medical institution; the results may be influenced by health policies, hospital management strategies, and emerging medical technologies during the study periods. Diagnostic related groups (DRGs) began in 2010, and phase 2 was expected to start in 2014 with the adoption of the package payment by the Health Insurance Agency. DRG payments have a long-term impact on the medical resource management and healthcare quality management of medical institutions. There was a 10% decrease in the length of stay but no significant change in health outcomes after implementing DRGs.[27] According to the survey data of the Health Insurance Department, there was an increased 14-day readmission rate during the initial implementation period. Determining the extent to which EMRs affected the rate of readmission is challenging. The DRG proportion was one-half of all admissions (50%), which may have led to an underestimation of the EMR benefits in this study.

Second, the healthcare quality was only assessed based on inpatient mortality, readmission, and postoperative mortality rates in this study. This study also provided limited information regarding patient treatment courses and readmission to other hospitals with underestimation. Other parameters of healthcare need to be considered in the future.

Third, this study surveyed a single Taiwanese medical institution. Past studies included multiple institutions, different treatment courses, and different levels of hospitals; the facility level and patient severity affect patient outcomes. A previous study found a higher ischemic stroke risk following sepsis in local hospitals than medical centers.[28] We designed a study in a single medical center to achieve a fixed effect. Physicians must be aware of the domains and function of EMRs to improve healthcare quality. A prospective study with multiple levels of medical units is needed in the future.

Fourth, healthcare quality may be impacted by physicians' experiences; future studies should survey the relationship between physician experiences and healthcare outcomes. One study surveyed the accuracy of the diagnosis of neoplastic colon polyps by senior and junior attending physicians of more than 5 years of experience and showed no significant difference (90.5% vs 87%, $P=.18$) in our hospital.[29] However, the medical care in our medical center closely followed medical guidelines, and EMR adoption was a new experience for all physicians during the study periods. This study suggests that a potential association exists between EMR use and healthcare outcomes.

6. Conclusion

This study found a potential association between the levels of EMR use and the risk of several outcomes in hospitalized patients in 1 large hospital. Healthcare quality is affected by diverse and complex characteristics. During the process of EMR implementation, appropriate training is needed to decrease the burden on physicians and nurses and preserve efficiency. Therefore, we believe that different levels of EMR adoption contribute to the quality of healthcare. It is necessary to conduct in-depth studies to explore the effectiveness of EMRs.

Author contributions

Conceptualization: Ding-Chung Wu.
Data curation: Hong-Ling Lin.
Formal analysis: Ding-Chung Wu.
Investigation: Ding-Chung Wu, Chun-An Cheng.
Methodology: Mei-Chuen Wang.
Resources: Mei-Chuen Wang.
Software: Ding-Chung Wu.
Supervision: Chun-An Cheng.
Validation: Shu-Meng Cheng, Cheng-Jueng Chen.
Visualization: Cheng-Jueng Chen.
Writing – original draft: Hong-Ling Lin.
Writing – review & editing: Chun-An Cheng.

References

[1] Buntin MB, Burke MF, Hoaglin MC, et al. The benefits of health information technology: a review of the recent literature shows predominantly positive results. Health Affairs 2011;30:464–71.
[2] Campanella P, Lovato E, Marone C, et al. The impact of electronic health records on healthcare quality: a systematic review and meta-analysis. Eur J Public Health 2015;26:60–4.
[3] Ayaad O, Alloubani A, ALhajaa EA, et al. The role of electronic medical records in improving the quality of health care services: Comparative study. Int J Med Inform 2019;127:63–7.
[4] Yanamadala S, Morrison D, Curtin C, et al. Electronic health records and quality of care: an observational study modeling impact on mortality, readmissions, and complications. Medicine 2016;95:e3332.
[5] Chalikonda L, Phelan N, O'Byrne J. An assessment of the quality of clinical records in elective orthopaedics using the STAR score. Ir J Med Sci 2019;188:849–53.
[6] Kruse CS, Stein A, Thomas H, et al. The use of electronic health records to support population health: a systematic review of the literature. J Med Syst 2018;42:214.
[7] Adane K, Gizachew M, Kendie S. The role of medical data in efficient patient care delivery: a review. Risk Manag Healthc Policy 2019;12:67–73.
[8] Yoshida Y, Imai T, Ohe K. The trends in EMR and CPOE adoption in Japan under the national strategy. Int J Med Inform 2013;82:1004–11.
[9] Paré G, Raymond L, de Guinea AO, et al. Barriers to organizational adoption of EMR systems in family physician practices: a mixed-methods study in Canada. Int J Med Inform 2014;83:548–58.
[10] Akhu-Zaheya L, Al-Maaitah R, Bany Hani S. Quality of nursing documentation: paper-based health records versus electronic-based health records. J Clin Nurs 2018;27:e578–89.
[11] Temple MW, Sisk B, Krams LA, et al. Trends in use of electronic health records in pediatric office settings. J Pediatr 2019;206:164–71.
[12] Crosson JC, Stroebel C, Scott JG, et al. Implementing an electronic medical record in a family medicine practice: communication, decision making, and conflict. Ann Fam Med 2005;3:307–11.
[13] Mô Dang V, Francois P, Batailler P, et al. Medical record-keeping and patient perception of hospital care quality. Int J Health Care Qual Assur 2014;27:531–43.
[14] DesRoches CM, Campbell EG, Rao SR, et al. Electronic health records in ambulatory care–a national survey of physicians. N Engl J Med 2008;359:50–60.
[15] Cebul RD, Love TE, Jain AK, et al. Electronic health records and quality of diabetes care. N Engl J Med 2011;365:825–33.
[16] Kazmi Z. Effects of exam room EHR use on doctor-patient communication: a systematic literature review. Jo Innov Health Inform 2014;21:30–9.
[17] Miller DD, Brown EW. Artificial intelligence in medical practice: the question to the answer? Am J Med 2018;131:129–33.
[18] Evans R. Electronic health records: then, now, and in the future. Yearb Med Inform 2016;25(Suppl 1):S48–61.
[19] Gans D, Kralewski J, Hammons T, et al. Medical groups' adoption of electronic health records and information systems. Health Aff 2005;24:1323–33.
[20] McCullough JS, Parente ST, Town R. Health information technology and patient outcomes: the role of information and labor coordination. Rand J Econ 2016;47:207–36.
[21] Atasoy H, Greenwood BN, McCullough JS. The digitization of patient care: a review of the effects of electronic health records on health care quality and utilization. Annu Rev Public Health 2019;40:487–500.
[22] Jones SS, Adams JL, Schneider EC, et al. Electronic health record adoption and quality improvement in US hospitals. Am J Manag Care 2010;16(Suppl 12):S64–71.
[23] Samaan ZM, Klein MD, Mansour ME, et al. The impact of the electronic health record on an academic pediatric primary care center. J Ambul Care Manag 2009;32:180–7.
[24] Blecker S, Goldfeld K, Park N, et al. Electronic health record use, intensity of hospital care, and patient outcomes. Am J Med 2014;127:216–21.
[25] Kothari AN, Zapf MA, Blackwell RH, et al. Components of hospital perioperative infrastructure can overcome the weekend effect in urgent general surgery procedures. Ann Surg 2015;262:683–91.
[26] Frisse ME, Johnson KB, Nian H, et al. Focus on health information technology, electronic health records and their financial impact: the financial impact of health information exchange on emergency department care. J Am Med Inform Assoc 2012;19:328–33.
[27] Cheng S-H, Chen C-C, Tsai S-L. The impacts of DRG-based payments on health care provider behaviors under a universal coverage system: a population-based study. Health Policy 2012;107:202–8.
[28] Cheng C-A, Cheng C-G, Lin H-C, et al. New-onset atrial fibrillation-related ischemic stroke occurring after hospital discharge in septicemia survivors. QJM 2017;110:453–7.
[29] Chen P-J, Lin M-C, Lai M-J, et al. Accurate classification of diminutive colorectal polyps using computer-aided analysis. Gastroenterology 2018;154:568–75.