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Decreased in-hospital mortality rate following implementation of a comprehensive electronic medical record system.

Abstract

Objectives: To evaluate changes in in-hospital mortality rate following implementation of a comprehensive Electronic Medical Record (EMR) system

Design: Before and after study

Setting: Paediatric teaching hospital

Participants: 355,709 hospital discharges over an 8-year period.

Intervention: “Big-bang” implementation of a comprehensive EMR system.

Major outcome measures: Crude number of in-hospital deaths, deaths per 1000 discharges, and standardised mortality ratio.

Results: Primary analysis of data from 2 years before and 2 years after EMR go-live showed a reduction in absolute mortality of 33 deaths, a reduction in mortality rate of 0.48 per 1000 discharges (95% CI 0.09, 0.88 per 1000): and a relative 22% decrease (95% CI: 4%, 36%, P=0.02) in deaths per 1000 discharges from 2.20 to 1.72.

There was also a reduction in standardised mortality ratio of 47% (95% CI: 18%, 66%, P=0.004).

Post-hoc analysis of mortality rates for an additional 2-year pre-intervention period indicated that these changes in mortality rate were not part of a pre-existing downward trend. Further analysis of an additional 20-month post-intervention period suggests that the reduced mortality rate has been sustained.

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Conclusion: We documented evidence of a clinically important decrease in in-hospital mortality rate following implementation of a modern comprehensive EMR system in an Australian paediatric teaching hospital. The study does not prove a causal relationship, and it is possible that other factors explain some, or all, of this difference, but no changes in the hospital population or other major interventions were identified as alternative explanations for this observed change.

The known: EMR implementations are expensive and can be disruptive. Previous evaluations of the hoped-for benefits of EMRs (including reduced mortality) have reported mixed results. Recent evaluations are limited in number, and little has been published on this topic in paediatric hospitals nor from Australasia in general.

The new: Implementation of a modern comprehensive EMR system at a paediatric teaching hospital was temporally associated with an estimated 22% reduction in in-hospital mortality.

The implications: This evidence is supportive of ongoing investment in EMR systems. Further study should help define the factors that might lead to improved outcomes and identify opportunities for further improvement in system design and human interface factors.

Key words

Child Health

Paediatric Medicine

Medical Records

Health Services Administration

Mortality

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Introduction

Over the last decade, electronic medical record (EMR) systems have been increasingly deployed into hospitals worldwide. They are common in the United States, where, since 2009, governments and hospitals have invested billions of dollars to promote their use (1). Australasia has been slower to adopt EMR systems in hospitals, but their use here has also been accelerating in the last 5 years. These systems have been introduced with the expectation that they will improve healthcare outcomes while simultaneously lowering costs.

Attempts to evaluate the clinical benefits of EMR systems have demonstrated mixed results. While there are many potential measures for evaluating these benefits, patient mortality is relevant as it is a concrete binary outcome and because proponents of EMR systems claim that their introduction will "save lives".

EMRs have evolved significantly in the last decade following substantial research and development investments from the major system vendors. Hence, it is important to continually re-evaluate the impact of EMRs as historical assessments may not be relevant today. There has also been little published about the clinical benefits of EMRs in paediatric patients nor in an Australasian context.

The Royal Children's Hospital is a large paediatric teaching hospital offering a full range of emergency, secondary, tertiary, and quaternary clinical services.

In April 2016, The Royal Children's Hospital implemented a comprehensive commercial EMR from Epic Systems Corporation (Verona, WI, USA). The Royal Children's Hospital was the first to implement this system in Australasia and the system went live after an 18-month project using a "Big-Bang" methodology (2). This involved transferring every department of the hospital, including Inpatient Wards; Emergency Department; Outpatient Clinics; Operating Theatres; Intensive Care Units; Oncology; Hospital in the Home; Mental Health Services and all Outreach Clinics, from predominantly paper-based medical records to the EMR on a single day. The system functionality that was implemented included electronic documentation; ordering; medications management (with closed-loop barcode scanning); blood management; scheduling; referrals; My Health Record integration; a patient/family portal; external provider portal; extensive bedside device integration; fully integrated

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anaesthesia and operating theatre clinical tools; remote clinician access; a range of mobile apps for clinicians and patients; plus research and reporting functionality.

The implementation was monitored through a pre-defined EMR benefit metrics program, which included outcomes for clinical quality and safety; operational effectiveness; financial return on investment; research utility; plus clinician and patient/family satisfaction. Here we report in-hospital mortality as one of the clinical outcomes that were monitored.

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Methods

We conducted a before and after study of the absolute number of in-hospital deaths and number of deaths per 1,000 discharges, using data aggregated by months, to determine the effect of the EMR implementation. The data were supplied by the hospital's business reporting unit.

The pre-intervention period included deaths and discharges during the two years from 1 April 2014 to 31st March 2016, and the post-intervention period 1 July 2016 to 30 June 2018. The three months from 1 April 2016 to 30 June 2016 were captured but excluded from analysis as a transition period, to account for patients who would have received inpatient care that bridged the pre-intervention and post-intervention phases.

We also used independent data from the Health Roundtable (HRT) (3) who provide risk-adjusted Hospital Diagnosis Standardised Mortality Ratio (HDxSMR) figures for hospitals that participate in their program. HDxSMR is the ratio of the number of observed deaths to the number of expected deaths. The numbers of expected deaths for each period were calculated by the HRT from demographic and case-mix data (age, sex, urgency status, acute transfer and a detailed analysis of all diagnoses present on admission) submitted from our hospital, using a statistical model developed from data contributed over a three-year reference period from over 200 Australian and New Zealand hospitals. The SMR was calculated as the ratio of observed to expected deaths.

No patient-level or identifiable data were accessed for these analyses.

A period of two years either side of the EMR implementation was selected as a reasonable time frame for the primary analysis that would allow any effect of the EMR implementation to be identified, without potential confounding by any longer-term changes in the complexity or case-mix of admitted patients or other changes to hospital programs and interventions .

Following the primary analysis, additional periods of data were included for a post-hoc analysis of mortality rates over a broader time-frame from 1 April 2012 to 29 February 2020 (i.e., an additional two years prior to 1 April 2014 and a further 20 months after 30 June 2018). The plan had been to extend this additional post-intervention period to two additional years, but the COVID-19 pandemic resulted in sudden and major changes to hospitalisation rates from March 2020, with cancellation of most elective surgery and a reduction in lower acuity admissions. We felt that data from March 2020 onwards was not suitable for inclusion in any comparison.

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Statistical analysis

The data are first presented as the crude numbers of deaths and crude mortality rates, i.e. the number of deaths per 1000 discharges, in the two years before and after the implementation of the EMR. Simple comparison of mortality risk between the two periods was performed by estimating the risk ratio with 95% confidence interval (CI), along with two-tailed chi-squared test.

Interrupted time-series (ITS) models were then employed to further examine the effect of the implementation of the EMR on crude mortality rate and standardised mortality rate, allowing for potential underlying trends over time before and after the implementation. (4).

Analysis was performed in Stata. The authors had full access to all data in the study (including statistical reports and tables).

Results

There were 202 deaths in the two years prior to the implementation of the EMR and 169 deaths in the two years after the implementation; an absolute decrease of 33. In the two years prior to the implementation of the EMR, the mortality rate was 2.20 deaths per 1000 discharges (95% CI: 1.91, 2.53), and in the two years after the implementation, the mortality rate was 1.72 deaths per 1000 discharges (95% CI: 1.47, 2.00). This represents a reduction in mortality rate of 0.48 per 1000 discharges (95% CI 0.09 to 0.88 per 1000), and a relative 22% decrease (95% CI: 4%, 36%, P=0.02). Table 1 shows data for the primary and extended analysis periods and figure 1 shows deaths per 1000 discharges.

The time-series analysis of mortality rate over the 4 years of the primary analysis showed no evidence of a trend over time, with the result that the estimated effect of the EMR implementation was the same as from the crude analysis (reduction of 21.8%; 95% CI: 4.1, 36.3, P=0.018). The post-hoc analysis on the additional data, which included the extended time-frames, showed a very similar but more precisely estimated post-implementation reduction in mortality rate of 22.1% (95% CI: 9.6, 32.9, P=0.001). (Figure 2)

Time-series analysis of the SMR showed an even greater post-implementation reduction of 47.4% (95% CI: 18.5, 66.1, P=0.004), in the context of some evidence for a (log-linear) background increase over time in the underlying SMR. The supplementary material provides additional details on model specification and selection and results.

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Table 1: Descriptive statistics

	Period 1	Period 2	Period 3	Period 4
Date range	1st April 2012 – 31st March 2014	1st April 2014 – 31st March 2016	1st July 2016 to 30th June 2018	1st July 2018 to 29th Feb 2020
Duration (months)	24	24	24	20
Discharges (n)	77,308	91,709	98,169	88,523
Deaths (n)	170	202	169	151
Deaths per 1000 discharges (95% CI)	2.20 (1.89, 2.55)	2.20 (1.91, 2.53)	1.72 (1.47, 2.00)	1.71 (1.45, 2.00)

Note: Periods 2 and 3 were used for the primary analysis. EMR was implemented between Period 2 and Period 3 in April 2016. Periods 1 and 4 were included for the post-hoc analysis of a further 2 years prior and 20 months post implementation respectively.

See separate file for figure 1

Figure 1: Mortality rates pre-EMR (Period 1 and 2) and post-EMR (Period 3 and 4), with 95% confidence intervals

See separate file for figure 2

Figure 2: Interrupted time series analysis of mortality rate over the four time periods

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Discussion

In the 2 years following implementation of a comprehensive EMR system there were fewer annual deaths, and a reduction in both crude and standardised mortality rates, when compared with the 2 years prior. The change corresponds to one less death every 2-3 weeks in our hospital

Further analyses of an extended period suggest these changes were not part of a pre-existing downward trend and that the reduced mortality rate has been sustained at least for a further 20 months.

The significant limitation of this study is the before and after nature of the comparison. This is the best applicable methodology for EMR implementations as it is not possible to do a randomised study in a single hospital where some patients are randomised to care supported by an EMR while others have care using existing paper-based records.

ITS analysis was used as a robust method for evaluating the effect of population-level health interventions that were implemented at a specific point in time, accounting for underlying time trends. ITS analysis accounts for underlying time-trends and is valuable in situations where conducting a large-scale randomised controlled trial is either infeasible or unethical (4).

It should be noted that there were more discharges after the EMR implementation. This reflects a year-upon-year trend for over the last 20 years at our hospital. There was no step change in this trend following implementation and were very careful to not include any types of discharges that we didn't previously count.

We are unaware of any significant changes in the nature or medical complexity of patients admitted to our hospital between these 2 time periods. The analysis of standardised mortality ratio should in any case allow for this possibility and admitting a greater number of "less seriously ill" children wouldn't account for the drop in total numbers of deaths.

Three of the authors are clinicians working within the hospital and we are not aware of the introduction of any other significant interventions or practice changes during this time, but it is possible that other factor/s explain some, or all, of this observed difference. We

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conclude that the mortality reduction is temporally associated with the use of the EMR, but we are guarded about conclusions regarding causality.

There have been prior publications on the impacts of EMR systems on clinical outcomes, including mortality, but these have been relatively few in number. Many of the publications are quite dated given the fact that EMRs have evolved significantly in the last decade as the major system vendors have improved their functionality and the human-system interface. Therefore, historical evaluations of impact may be less relevant now. Not all EMR systems are the same. There can be quite different functions and utility of use between different systems. Studies with one commercial system do not necessarily apply to others. There has also been very little published on the Australasian experience of the clinical outcomes impact of local EMR implementations. Most prior publication comes from the US where the healthcare systems and clinical documentation requirements are very different.

The most recently published systematic review and meta-analysis of changes in mortality associated with the use of EMRs was in 2015 (5) and concluded that EMR interventions were not shown to have a substantial effect on mortality. Of the 33 studies included, some went back to 1998 and none were more recent than 2012. Many included only partial EMR solutions such as order-entry systems or decision support tools. None studied a comprehensive EMR with the modern feature sets currently available, nor systems implemented using a comprehensive “Big-bang” methodology. The included studies varied substantially in terms of patient numbers and study quality. None were from Australasia.

A study of collated nationwide hospital data examined the hospital 30-day mortality rates for adult patients with heart failure, pneumonia, and acute myocardial infarction for the years 2008–2015 (6). They compared hospitals with and without an EMR. Despite finding improvements in process measures (such as timely medical interventions) they found no substantial differences in mortality rates.

Although now 10 years old, a study from the Lucille Packard Children’s Hospital at Stanford Medical Centre (7) is interesting to compare with our findings. It is a tertiary children’s hospital, similar to our own, and the study methodology was similar, albeit with a different commercial system and limited functionality compared with our current EMR. They demonstrated a similar reduction (20%) in mortality rate. It is noteworthy that this study

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and ours were conducted in paediatric patients and both have positive findings which is different to most other studies that have focussed on adult patients.

There are many reasons why implementation of an EMR system might be associated with improvements in quality of care and reductions in mortality. A major factor is the use of a single clinical system rather than a combination of mostly paper-based records with some fragmented electronic databases. System advantages include: improved availability, findability and legibility of clinical documentation; improved prescribing with extensive decision support; improved drug administration with nurse task management tools and closed-loop barcode medication scanning; easy real-time remote and mobile app access to the system; integrated ordering and viewing of investigation results and images; inbuilt physiological monitoring systems with alerts for clinical review or calling the Medical Emergency Team (MET); and improved consistency in clinical care driven by system design. We are unable to dissect which, if any, of these factors may have contributed to the changes we have observed but we have documented reduced rates of medication prescribing and administration errors, and increased rates of seeking clinical review and MET calls in deteriorating patients. Staff surveys have shown high levels of satisfaction with the EMR and 65% of our staff rated their ability to provide high quality clinical care as “Better” or “Much Better” since its introduction.

Conclusion

This study demonstrates a reduction in absolute number of deaths and relative risk of mortality at a large paediatric teaching hospital that was temporally associated with the introduction of a modern comprehensive EMR. Further evaluation suggests that this reduction was not part of a pre-existing trend of reduced mortality and that the change has been sustained for a further period beyond that initially studied. We have not identified changes in our patient population or other interventions that might explain this change but some factor/s other than the EMR implementation remain possible contributors to this observed change. Identifying the hoped-for improvements in clinical outcomes is important as the implementation of these EMR systems is expensive and disruptive. Further study should delve into the factors which may have led to these improved outcomes to identify opportunities for further improvement in system design and human interface factors.

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Ethical approval

The study was approved as a Quality Assurance & Negligible Risk Research Application by our Human Research Ethics Committee.

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Conflict of interest

None. No external funding was received for this study. The authors have no association with the EMR vendor beyond being staff at one of its hospital customers.

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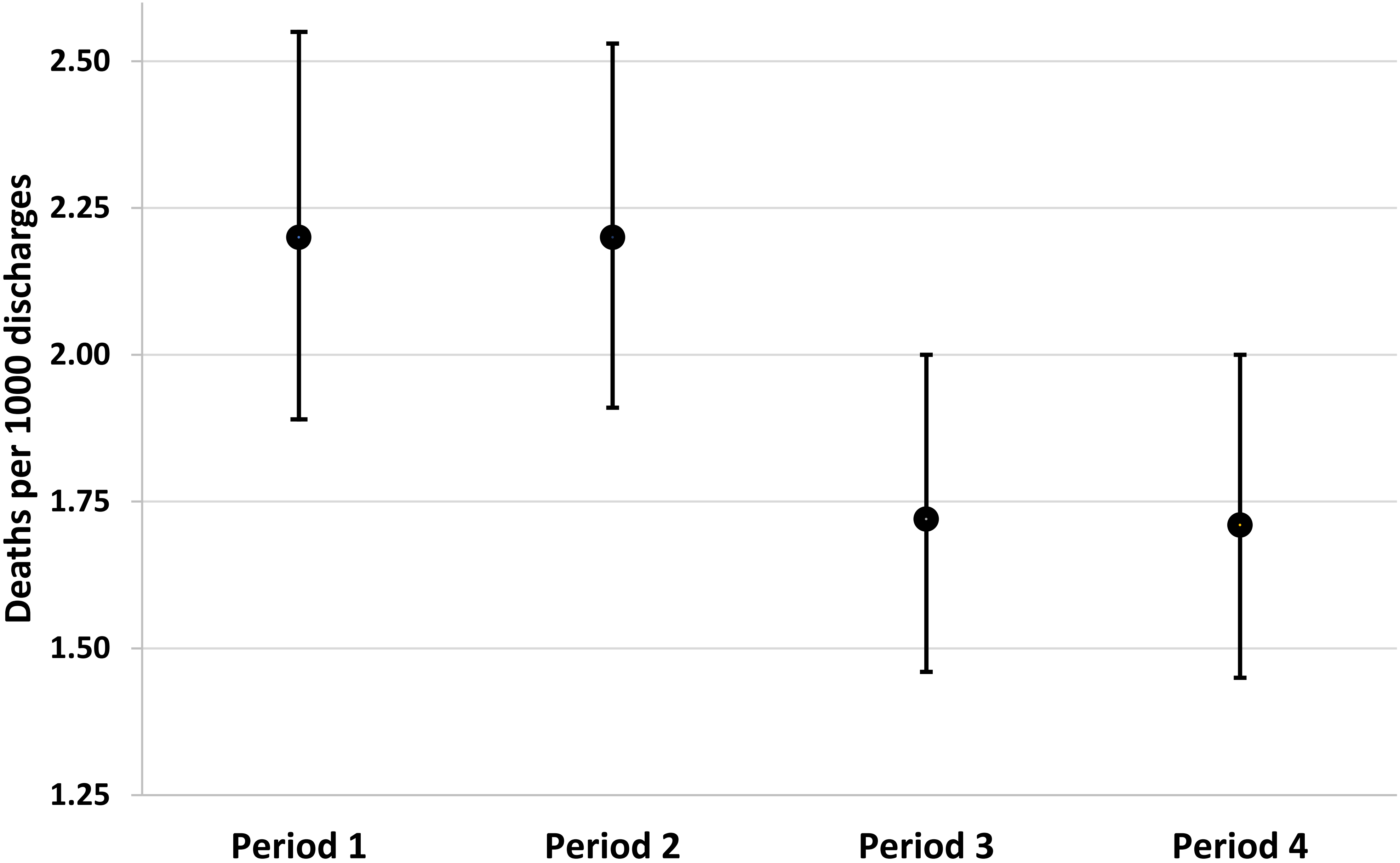

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