Association of Pediatric Medical Emergency Teams With Hospital Mortality

Editorial, see p 47

Shelby Kutty, MD, PhD, MHCM
Philip G. Jones, MS
Quentin Karels, MBA
Navya Joseph, MD
John A. Spertus, MD, MPH
Paul S. Chan, MD, MSc

BACKGROUND: Implementation of medical emergency teams has been identified as a potential strategy to reduce hospital deaths, because these teams respond to patients with acute physiological decline in an effort to prevent in-hospital cardiac arrest. However, prior studies of the association between medical emergency teams and hospital mortality have been limited and typically have not accounted for preimplementation mortality trends.

METHODS: Within the Pediatric Health Information System for freestanding pediatric hospitals, annual risk-adjusted mortality rates were calculated for sites between 2000 and 2015. A random slopes interrupted time series analysis then examined whether implementation of a medical emergency team was associated with lower-than-expected mortality rates based on preimplementation trends.

RESULTS: Across 38 pediatric hospitals, mean annual hospital admission volume was 15 854 (range, 6684–33 024), and there were a total of 1 659 059 hospitalizations preimplementation and 4 392 392 hospitalizations postimplementation. Before medical emergency team implementation, hospital mortality decreased by 6.0% annually (odds ratio [OR], 0.94; 95% confidence interval [CI], 0.92–0.96) across all hospitals. After medical emergency team implementation, hospital mortality continued to decrease by 6% annually (OR, 0.94; 95% CI, 0.93–0.95), with no deepening of the mortality slope (ie, not lower OR) in comparison with the preimplementation trend, for the overall cohort (P=0.98) or when analyzed separately within each of the 38 study hospitals. Five years after medical emergency team implementation across study sites, there was no difference between predicted (hospital mean of 6.18 deaths per 1000 admissions based on preimplementation trends) and actual mortality rates (hospital mean of 6.48 deaths per 1000 admissions; P=0.57).

CONCLUSIONS: Implementation of medical emergency teams in a large sample of pediatric hospitals in the United States was not associated with a reduction in hospital mortality beyond existing preimplementation trends.

Correspondence to: Paul S. Chan, MD, MSc, Saint Luke's Mid America Heart Institute, 4401 Wornall Rd, Kansas City, MO 64111. E-mail pchan@saint-lukes.org

Sources of Funding, see page 45

Key Words: emergency medicine ■ heart arrest ■ hospital mortality ■ hospital rapid response team ■ hospitals, pediatric

Clinical Perspective

What Is New?

- Although most US hospitals have implemented medical emergency teams to reduce hospital mortality in response to the Institute for Healthcare Improvement's Five Million Lives Campaign, whether these teams have resulted in a reduction in hospital mortality beyond temporal trends is unclear.
- We found that routine implementation of a medical emergency team in 38 freestanding pediatric hospitals was not associated with lower hospital mortality than what would have been expected based on preimplementation trends, both overall and within each hospital.
- Our study is the largest to date to examine the association of medical emergency team implementation on hospital mortality.

What Are the Clinical Implications?

- Although the theoretical foundation for medical emergency teams has merit, prior studies have found that medical emergency teams are not always deployed to patients with acute physiological decline who may benefit from them.
- Our study's null findings on hospital mortality suggest that medical emergency teams either have no effect on hospital mortality or are poorly implemented in the real world. Further study is required to establish the effectiveness of medical emergency teams in reducing hospital mortality and whether there are specific team designs (composition, activation, and therapeutic interventions) that are effective.

Medical emergency teams, also known as rapid response teams, have been implemented throughout hospitals in the United States as part of the Institute for Healthcare Improvement's Five Million Lives Campaign to reduce hospital morbidity and mortality.[1] By promptly evaluating, triaging, and treating patients with signs of acute clinical deterioration, a medical emergency team, in theory, can reduce medical complications and prevent in-hospital cardiac arrest. Because fewer than 1 in 4 patients with an in-hospital cardiac arrest survives to hospital discharge,[2] many have proposed that medical emergency teams can reduce hospital mortality by reducing the incidence of in-hospital cardiac arrest.[3] However, whether routine implementation of medical emergency teams in pediatric hospitals has resulted in a reduction in hospital mortality, beyond temporal trends, is unclear. Addressing this gap in knowledge is important to understand to justify the costs, training, and staffing of medical emergency teams.

Prior studies examining the association of medical emergency teams with hospital mortality have been limited, especially in pediatric hospitals. One single-center study found that the implementation of a medical emergency team in a pediatric hospital was associated with a 35% reduction in hospital mortality,[4] whereas another study reported 18% lower hospital mortality postimplementation.[5] A recent meta-analysis, however, identified only 7 single-center studies that have evaluated the effect of medical emergency team implementation on mortality in pediatric hospitals.[6] Although this meta-analysis found that medical emergency team implementation was associated with a 21% lower hospital mortality rate, only 1 study adjusted for preintervention hospital mortality trends, whereas the other studies simply compared aggregated rates of hospital mortality before and after medical emergency team implementation. If rates of hospital mortality were already decreasing before medical emergency team implementation because of overall improvements in cardiac resuscitation,[2,7] sepsis,[8,9] and intensive care,[10] the findings from this meta-analysis, which was not able to adjust for preimplementation mortality trends, may have been attributable to existing temporal trends and not to medical emergency team implementation.

Accordingly, the goal of the present investigation was to more accurately characterize the association between medical emergency team implementation and hospital mortality across a wide range of unselected pediatric institutions. Leveraging annual hospital mortality data from the Pediatric Health Information System (PHIS), the effect of medical emergency team implementation on hospital mortality was evaluated across 38 hospitals after accounting for preimplementation mortality trends at each hospital.

METHODS

Data Sources

PHIS is an inpatient database created by the Children's Hospital Association to support clinical effectiveness research and quality improvement projects among 47 not-for-profit freestanding children's hospitals.[11] Data are electronically and automatically collected and include patients' demographics and diagnoses, and annual mortality rates for each participating hospital, as well. Quality and validity checks are performed on collected data, and standard proprietary methodology was used for data definitions to ensure consistency across hospitals. For this study, patient-level data from PHIS was used to calculate hospital case-mix for all admitted patients at each site for each year, which were, in turn, used to risk-adjust a hospital's annual mortality rate.

Study Population

The study cohort included 47 pediatric hospitals that participated in PHIS between January 1, 2000, and December 31,

2015. For each hospital, we obtained information on the calendar year in which a medical emergency team was implemented from a member of its medical emergency or acute resuscitation (Code Blue) team. Nine hospitals were excluded because their medical emergency team was implemented before participation in PHIS and therefore had no preimplementation mortality data available for analysis. Thus, the primary analysis of the association between medical emergency team implementation and hospital mortality included 38 hospitals.

Study Outcomes

The primary outcome was risk-adjusted hospital mortality after medical emergency team implementation. Hospital mortality was defined as deaths per 1000 admissions and calculated for each calendar year, adjusted by the case-mix of patients admitted to the hospital that calendar year (see Statistical Analysis).

Statistical Analysis

Summary statistics were used to describe baseline characteristics of hospitals in the study sample. Within each PHIS hospital, annual mortality rates were determined for each site and included all patients, regardless of do-not-resuscitate status. Next, risk-adjusted annual mortality rates for each calendar year at each site were calculated. This was accomplished by multiplying the observed mortality rate during a given year at a hospital by that hospital's observed to expected mortality rate. The expected mortality rate was determined by applying previously developed mortality weights based on illness severity and 1 of 322 All Patients Refined Diagnosis Related Groups to each admitted patient during a calendar year.[12,13]

Because most prior studies have simply performed aggregate preimplementation and postimplementation comparisons, secular hospital trends in cardiac resuscitation quality improvement, sepsis and intensive care management, and other factors unrelated to medical emergency team implementation, which could have had an impact on overall hospital mortality rates, were not accounted for. We therefore conducted an interrupted time series analysis, within a hierarchical logistic regression framework, to compare mortality trends before and after medical emergency team implementation. In this analysis, trend lines (slope and intercept) were estimated for each hospital before and after medical emergency team implementation, with the year of implementation designated as the reference year (time zero). Nonlinearity was assessed using restricted cubic splines but was nonsignificant (P=0.39), so straight-line trends were fitted. The slopes and intercepts were treated as correlated random effects within the hierarchical model using an unstructured covariance matrix. The resultant average slope and intercept from the model represented the overall population trend, and a joint statistical test was performed to assess whether the average mortality intercept or slope differed after medical emergency team implementation in comparison with preimplementation trends. Specifically, a more negative slope would indicate a decrease in hospital mortality after medical emergency team implementation beyond what would be expected based on preimplementation hospital mortality trends). To facilitate interpretability, we compared mortality rates for hospitals 5 years after medical emergency team implementation with projected estimates based on preimplementation trends alone. Moreover, interactions between implementation of a medical emergency team and small and large hospital size (<250 beds versus ≥250 beds) and US Census region were examined to assess whether the effect of medical emergency teams on hospital mortality differed by these characteristics. As a sensitivity analysis, within each calendar year, we compared aggregated risk-adjusted mortality rates for hospitals that had already implemented a medical emergency team in comparison with hospitals that had not yet implemented their team.

In addition, comparisons were performed within each hospital, using the estimated effects from the hierarchical model, to determine whether medical emergency team implementation was associated with a lower mortality rate for any individual hospital. F-tests for each hospital assessed for a difference in slopes or intercepts after medical emergency team implementation. The P values from these tests were assessed for significance after accounting for multiple testing, using a step-up approach constraining the false discovery rate to be ≤5% (ie, adjusted P<0.05).[14]

Finally, we conducted simulations to determine the minimum effect (change in slope of risk-adjusted mortality postimplementation) that we would have been able to detect with 80% power in our sample population. Data were simulated using the existing observed preimplementation mortality rates and randomly generating postimplementation rates for each hospital based on parameter estimates from the primary analysis model augmented with a constant acceleration term to simulate the effect of implementation on the mortality slope.

For each analysis, we evaluated the null hypothesis at a 2-sided significance level of 0.05 and calculated 95% confidence intervals (CIs) using robust standard errors. All analyses were performed using SAS version 9.4 (SAS Institute) and R version 3.3.1 (R Foundation for Statistical Computing).[15] The institutional review board of Saint Luke's Hospital approved the study and waived the requirement for informed consent because the analyses involved use of deidentified data.

RESULTS

Of 38 pediatric hospitals, 37 (97.4%) were academic hospitals, and the majority (29 [76.3%]) had ≥250 beds. The hospitals were distributed across the United States, with 5 (13.2%) from the Northeast, 10 (26.3%) from the Midwest, 14 (36.8%) from the South, and 9 (23.7%) from the West (Table 1).

During the study period, the mean number of admissions at each site was 15 854 (range, 6684–33 024), and medical emergency team implementation at sites occurred between 2005 and 2013. The mean duration of the preimplementation and postimplementation periods was 3.0 years (range, 0.9–4.7) comprising 1 659 059 hospitalizations and 7.4 years (range, 2.1–9.8) comprising 4 392 392 hospitalizations.

Table 1. Summary Characteristics of Study Hospitals

Hospital Characteristic	Total N=38
Academic, n (%)	37 (97.4)
Staffed beds, n (%)	
126–249	9 (23.7)
250–592	29 (76.3)
Census region, n (%)	
Northeast	5 (13.2)
Midwest	10 (26.3)
South	14 (36.8)
West	9 (23.7)

Effect of Medical Emergency Teams on Hospital Mortality

Unadjusted and adjusted hospital mortality rates by when each hospital implemented its medical emergency team are displayed in Figure 1. The mean (95% CI) unadjusted hospital mortality rate was 8.5 (7.6–9.5) deaths per 1000 admissions 2 years before medical emergency team implementation, 8.0 (7.2–8.9) deaths per 1000 admissions during the year of hospitals' implementation of their medical emergency team, and 6.2 (5.7–6.7) deaths per 1000 admissions 5 years after medical emergency team implementation (Table 2). After adjustment for case-mix severity of all hospital admissions, the mean risk-adjusted hospital mortality rate was 9.5 (9.0–10.1), 8.8 (8.3–9.3), and 6.5 (6.2–6.8) deaths per 1000 admissions at 2 years before, during, and 5 years after medical emergency team implementation, respectively.

A comparison of pooled risk-adjusted hospital mortality rates found no difference in model intercepts or slopes after medical emergency team implementation (Table 3). Model intercepts for hospital mortality (time zero denotes year of medical emergency team implementation) before and after medical emergency team implementation were 8.4 (95% CI, 7.8–9.0) and 8.8 (95% CI, 8.3–9.3) deaths per 1000 admissions (*P* for difference between the 2 periods of 0.11), and model slopes for hospital mortality (odds ratio [OR] per calendar year) before and after medical emergency team implementation were 0.94 (95% CI, 0.92–0.96) and 0.94 (95% CI, 0.93–0.95) (*P* for difference between the 2 periods of 0.98). This comparison of model slopes suggests that the hospital mortality rate across all 38 hospitals before medical emergency team implementation was decreasing at 6.0% per year before medical emergency team implementation and continued to decrease at 6.0% per year after medical emergency team implementation. At 5 years after medical emergency team implementation, the mean risk-adjusted hospital mortality rate was predicted to be 6.18 (95% CI, 5.23–7.29) deaths per 1000 admissions based on preimplementation risk-adjusted mortality trends alone, which was similar (*P*=0.57) to the actual mean risk-adjusted hospital mortality rate of 6.48 (95% CI, 6.19–6.79) deaths per 1000 admissions after medical emergency team implementation (Table 2). Simulation analyses revealed that our study had 80% power to detect a postimplementation slope of 0.913 versus the observed preimplementation slope of 0.940, which suggests our study had 80% power to detect an absolute decrease of approximately 2 deaths per 10 000 admissions annually (based on a baseline risk-adjusted mortality rate of 8.8 deaths per 1000 admissions dur-

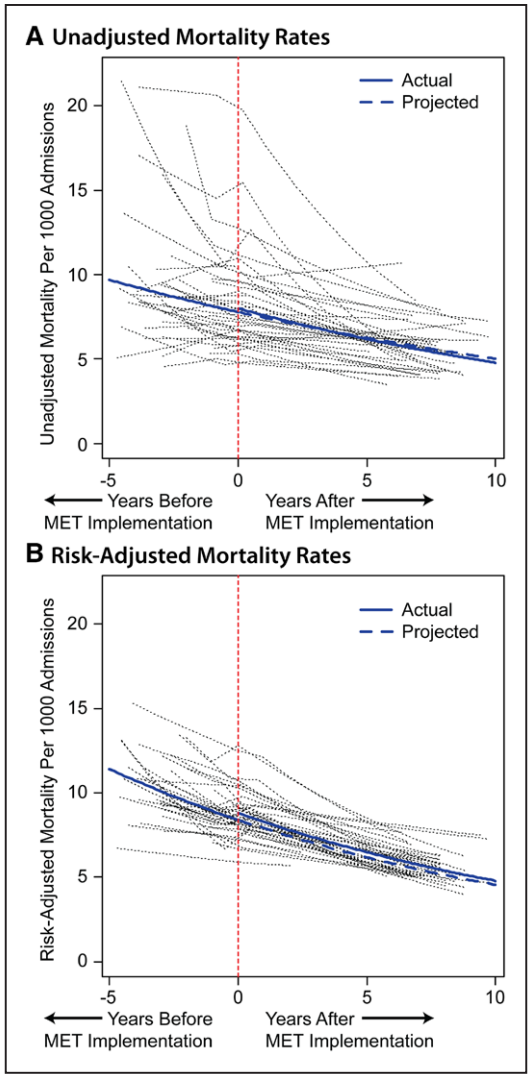

Figure 1. Unadjusted and risk-adjusted annual mortality rates for each hospital.
Unadjusted (**A**) and risk-adjusted (**B**) annual mortality data are presented by years before, the year of (red vertical dashed line), and years after medical emergency team implementation at each site. The dashed and solid trend lines represent the mean projected and actual mortality rates, respectively, for the study hospitals after medical emergency team implementation. MET indicates medical emergency team.

Table 2. Hospital Mortality Rates Before and After Medical Emergency Team Implementation

Deaths per 1000 Admissions	Mean Hospital Mortality Rates	
	Unadjusted (95% CI)	Adjusted (95% CI)
2 y preinitiation	8.5 (7.6–9.5)	9.5 (9.0–10.1)
Year of initiation (intercept)	8.0 (7.2–8.9)	8.8 (8.3–9.3)
5 y postinitiation	6.2 (5.7–6.7)	6.5 (6.2–6.8)

The mean unadjusted and risk-adjusted hospital mortality rates 2 years before, the year of, and 5 years after implementation of medical emergency teams in study hospitals are summarized. CI indicates confidence interval.

ing the year of implementation and a 2.7% relative annual decrease in mortality attributable to implementation of a medical emergency team).

To further clarify that our findings were not confounded by secular mortality trends, the adjusted mortality rates for each hospital by calendar year are displayed in Figure 2, and a comparison of aggregated risk-adjusted mortality for hospitals that had and had not yet implemented a medical emergency team for each calendar year are summarized in Table 4. Within each calendar year, there was no difference in aggregated risk-adjusted mortality between hospitals that had implemented a medical emergency team in comparison with those that had not yet already done so. When these individual calendar year comparisons were pooled, implementation of a medical emergency team was not associated with a reduction in hospital mortality (pooled OR, 1.04; 95% CI, 0.96–1.12; P=0.31), and the nonsignificantly higher OR for hospital mortality after medical emergency team implementation mirrored the 5-year postimplementation predicted versus observed mortality analyses (see Results above).

Moreover, within each of the 38 hospitals, a comparison of risk-adjusted mortality trends before and after medical emergency team implementation found that individual hospital mortality intercepts and slopes did not differ significantly for 36 (94.7%) of the hospitals (Table I in the online-only Data Supplement). Two hospitals demonstrated significant differences pre- versus postimplementation, but in the opposite direction (a less negative slope over time leading to

Table 3. Impact of Medical Emergency Team on Risk-Adjusted Hospital Mortality

Study Cohort	Mortality Trend Before MET Intervention	Mortality Trend After MET Intervention	*P* Value
Entire cohort			
Intercept (deaths per 1000 admissions)*	8.4 (7.8–9.0)	8.8 (8.3–9.3)	0.11
Slope (odds ratios per year)	0.94 (0.92–0.96)	0.94 (0.93–0.95)	0.98
Interaction analyses			
By bed size			0.69†
Intercept (deaths per 1000 admissions)*			
<250 Hospital beds	7.6 (6.4–9.0)	8.1 (7.2–9.1)	
≥250 Hospital beds	8.6 (8.0–9.3)	9.0 (8.4–9.6)	
Slope (odds ratios per year)			
<250 Hospital beds	0.91 (0.86–0.97)	0.96 (0.93–0.98)	
≥250 Hospital beds	0.94 (0.92–0.97)	0.94 (0.93–0.95)	
By US census region			0.85†
Intercept (deaths per 1000 admissions)*			
Northeast	7.3 (5.3–10.2)	8.1 (6.7–9.9)	
Midwest	8.4 (7.3–9.6)	8.6 (7.8–9.6)	
South	8.6 (7.8–9.6)	9.4 (8.4–10.4)	
West	8.8 (7.8–9.9)	8.6 (7.8–9.5)	
Slope (odds ratios/y)			
Northeast	0.96 (0.85–1.07)	0.95 (0.93–0.97)	
Midwest	0.94 (0.89–0.99)	0.94 (0.93–0.96)	
South	0.94 (0.91–0.97)	0.94 (0.91–0.96)	
West	0.96 (0.92–0.99)	0.93 (0.91–0.95)	

Mortality trends before and after implementation of a MET in study hospitals are compared. A significantly lower intercept or a more negative slope (lower odds ratio) after implementation would indicate that METs reduced hospital mortality. Results are presented for the entire cohort and by hospital subgroups. MET indicates medical emergency team.

*Deaths per 1000 admissions at time of MET implementation.

†Overall *P* value for interaction between hospital characteristic and MET implementation.

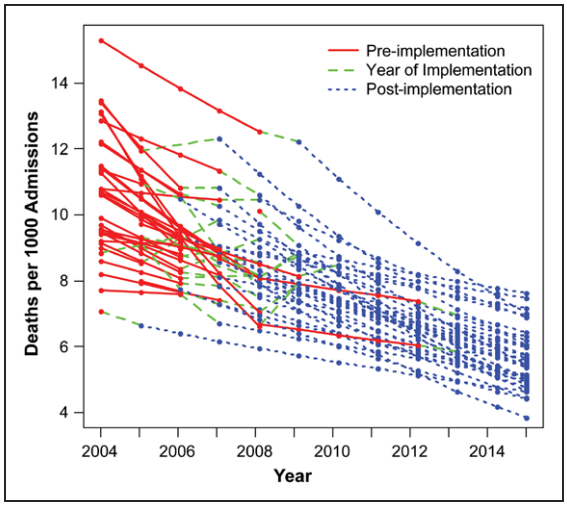

Figure 2. Risk-adjusted annual mortality rates for each hospital by calendar year.
Each hospital's risk-adjusted mortality by calendar year is displayed, with red denoting the period before a hospital's implementation of a MET team, green for the year of MET implementation, and blue for the period after MET implementation. MET indicates medical emergency team.

higher-than-expected mortality after medical emergency team implementation; Figure I in the online-only Data Supplement). This suggests that implementation of a medical emergency team was not associated with a decrease in hospital mortality in any individual hospital beyond what would have been expected based on preimplementation trends. Finally, we found no difference in the effect of implementation of a medical emergency team by hospital size or geographic region (interaction *P* values of 0.69 and 0.85, respectively; see Table 3).

DISCUSSION

To reduce morbidity and improve hospital survival by proactively intervening in patients with clinical deterioration, many hospitals have implemented medical emergency teams. Whether the costs and efforts in training and staffing such teams have led to lower hospital mortality has not been clear, despite initial findings from single-center studies. We found that implementation of a medical emergency team in 38 pediatric hospitals was not associated with lower hospital mortality than what would have been expected based on preimplementation trends. This was the case overall, for each individual hospital, and regardless of hospital size or geography. Collectively, our results do not support the notion that medical emergency teams reduce hospital mortality.

Prior studies on the impact of medical emergency teams on mortality in pediatric hospitals have been limited. The few studies that exist have been single-center studies[4,5,16,17] (thus lacking generalizability) and may have been individually underpowered for an outcome such as hospital mortality, although a few of these studies did report significantly lower hospital mortality postimplementation. In addition, most prior studies have simply compared aggregate preimplementation versus postimplementation hospital mortality rates. This

Table 4. Yearly Comparisons of Risk-Adjusted Hospital Mortality Between Hospitals Before and After Medical Emergency Team Implementation

Year	Number of Hospitals			Aggregated Risk-Adjusted Mortality		
	MET Not Yet in Place	MET Begun This Year	MET in Place	MET Not Yet in Place	MET in Place	Odds Ratio for MET Implementation (95% CI)
2004	38	0	0	10.6	NA	NA
2005	35	3	0	9.8	NA	NA
2006	29	6	3	9.1	9.3	1.03 (0.87–1.21)
2007	16	13	9	8.8	9.0	1.02 (0.91–1.14)
2008	6	10	22	7.3	8.3	1.14 (1.00–1.29)
2009	3	3	32	7.6	8.1	1.06 (0.91–1.24)
2010	2	1	35	6.9	7.5	1.09 (0.88–1.34)
2011	2	0	36	7.5	6.9	0.93 (0.76–1.14)
2012	1	1	36	4.4	6.7	1.55 (1.00–2.38)
2013	0	1	37	NA	6.3	NA
2014	0	0	38	NA	6.0	NA
2015	0	0	38	NA	5.1	NA

When the individual calendar year comparisons were pooled, implementation of a MET was not associated with a reduction in hospital mortality (pooled odds ratio, 1.04; 95% CI, 0.96–1.12; *P*=0.31). CI indicates confidence interval; MET, medical emergency team; and NA, for calendar years without at least 1 hospital with preimplementation and postimplementation mortality data, odds ratios were not calculated.

approach ignores mortality trends before medical emergency team implementation and could lead to incorrect inferences regarding the effect of these teams on hospital mortality. This is particularly important to consider because efforts for earlier detection and treatment of sepsis and improved intensive unit care over the past decade have resulted in lower hospital mortality. Our study extends the findings of prior studies by examining the effect of medical emergency teams across 38 hospitals, thus increasing generalizability and statistical power. By controlling for preimplementation hospital mortality trends (which were decreasing by a mean of 6.0% annually in our study sample), we found that hospital mortality rates were nearly identical to what would have been expected had a medical emergency team not been put into place. Moreover, by leveraging data involving >6 million hospitalizations, we determined that our study had 80% power to detect even a small decrease of 2 deaths per 10 000 admissions annually with medical emergency team implementation.

The Institute of Healthcare Improvement has proposed implementation of medical emergency teams as 1 of 6 strategies to avoid preventable hospital deaths.[1] Ideally, medical emergency teams are deployed to treat patients with acute physiological decline to prevent in-hospital cardiac arrest, which has a low survival rate of 20% to 25%.[2] Reducing the morbidity and mortality of in-hospital cardiac arrest has been a focus of the American Heart Association and the Institute of Medicine, with the latter issuing a call to action in 2016 given the high prevalence and mortality associated with cardiac arrest events.[18] In theory, by reducing the occurrence and morbidity associated with in-hospital cardiac arrest, medical emergency teams can also reduce hospital mortality and improve patient safety and outcomes.

Whether a hospital activates a medical emergency team in a consistent manner to respond to patients with acute physiological decline to realize these gains, however, is less clear. A recent study of 21 913 adult patients with in-hospital cardiac arrest from 274 hospitals found that only 1 in 6 patients had a medical emergency team evaluation before cardiac arrest, and of those without an evaluation, 40% had evidence of severe vital sign derangement at least 1 hour before cardiac arrest that could have prompted evaluation by a medical emergency team but did not.[19] Thus, the lack of significant benefit from medical emergency teams observed in this study may be attributable to their suboptimal implementation in routine practice, and it is possible that these teams could reduce hospital mortality if better protocols and implementation were developed. Given that our study is, to date, the largest to evaluate the effect of medical emergency team implementation on hospital mortality and exceeds the number of hospitals in the pediatric medical emergency team literature, it will be critical that future studies test specific designs of medical emergency team implementation, activation, and staff response to determine how best to realize the potential benefits of these teams.

Although studies have reported a decrease in cardiac arrest rates after implementation of a medical emergency team,[5,16,17] the discordance between a reduction in cardiac arrest rates in prior studies and hospital mortality in this study may be attributable to 4 reasons. First, most prior studies evaluating the effect of medical emergency teams on rates of in-hospital cardiac arrest have not accounted for preimplementation trends, thus overestimating the benefit of these teams on lowering cardiac arrest rates. Second, because medical emergency teams transfer patients with acute physiological decline to the intensive care unit, and because most prior studies have reported only rates of non–intensive care unit cardiac arrests (rather than hospital-wide rates), findings from these studies are subject to high levels of reporting bias, because a patient transferred to the intensive care unit by the medical emergency team with a subsequent in-hospital cardiac arrest would not have been counted in these studies' results.[20] Third, because one of the potential actions of medical emergency teams is to establish do-not-resuscitate orders in appropriate patients, higher rates of do-not-resuscitate orders after medical emergency team implementation could lead to lower rates of in-hospital cardiac arrest, but would not be expected to affect overall hospital mortality. Finally, even if a medical emergency team is successful in preventing an in-hospital cardiac arrest short-term, this may not be sufficient to alter overall mortality risk in critically ill patients throughout their hospitalization. These considerations highlight the importance for future studies to use rigorous methodology to adjust for preimplementation trends and demonstrate that medical emergency teams decrease rates of not only in-hospital cardiac arrest but also hospital mortality.

Our study should be interpreted in the context of the following limitations. The PHIS database does not collect information on in-hospital cardiac arrest, and only 3 of this study's 38 hospitals participate in the national Get With The Guidelines-Resuscitation registry for in-hospital cardiac arrest.[21] Therefore, we were unable to examine the effect of medical emergency teams on rates of in-hospital cardiac arrest across the study sample. Nonetheless, our study's mortality findings raise questions as to whether just showing lower cardiac arrest rates would be meaningful, because cardiac arrest is an intermediate outcome in comparison with hospital mortality. Second, the PHIS database does not contain information on cause of death; therefore, we were unable to assess the impact of medical emergency teams on rates of cardiovascular mortality. Third, our study assumed that preimplementation mortality trends would continue postimplementation. This assumption is less

problematic, however, because study hospitals did not implement their medical emergency teams during the same calendar year, and it is unlikely that an external confounder was present for different years for each hospital and coincidental only during each hospital's preimplementation period. This is also supported by the fact that, for each calendar year, we found that the mortality rate of hospitals that had implemented their medical emergency team was not lower than of hospitals that had not yet implemented their medical emergency team. Fourth, our study was unable to assess other outcomes, such as nursing satisfaction, establishment of do-not-resuscitate orders, and prevention of in-hospital complications. We acknowledge that there has been a significant change in hospital culture over the past decade, wherein resuscitation care is no longer perceived as futile. As such, medical emergency teams may provide important support and value for nursing staff even if they are not associated with lower hospital mortality. Fifth, we did not have detailed data on medical emergency team composition or implementation strategy at each hospital. Such information could have been used to identify medical emergency team characteristics associated with lower hospital mortality; however, because we did not detect evidence for improvement in hospital mortality in the overall study sample or in any individual hospital, this information would not have been useful in discriminating which medical emergency team designs are most effective. Sixth, all but one of the study hospitals were academic hospitals. Nonetheless, because nearly all children's hospitals in the United States are academic hospitals, our findings are likely representative of pediatric centers. Finally, our study examined the effect of medical emergency teams on pediatric hospital mortality; therefore, our findings may not be generalizable to adults.

Conclusions

Across a broad range of unselected pediatric hospitals in the United States, implementation of medical emergency teams was not associated with a reduction in hospital mortality beyond what would have been expected based on preimplementation mortality trends.

ACKNOWLEDGMENTS

Dr Chan authored the report and had full access to all of the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design were developed by Drs Kutty and Chan. Dr Kutty, Q. Karels, and Dr Joseph acquired the data. P. G. Jones and Q. Karels performed statistical analysis. Dr Kutty, P. G. Jones, Q. Karels, and Drs Joseph, Spertus, and Chan performed analysis and interpretation of data. Drs Kutty and Chan drafted the manuscript. Dr Kutty, P. G. Jones, Q. Karels, and Drs Joseph, Spertus, and Chan performed critical revision of the manuscript for important intellectual content. Dr Chan supervised the study.

SOURCES OF FUNDING

Dr Kutty is supported by funding (R41HD089823-01) from the National Institute of Child Health and Development. Dr Chan is supported by funding (R01HL123980) from the National Heart, Lung and Blood Institute.

DISCLOSURES

Dr Chan has served as a consultant for the American Heart Association and Optum Rx. The other authors report no conflicts.

AFFILIATIONS

Division of Cardiology, Department of Pediatrics, Children's Hospital and Medical Center, University of Nebraska Medical Center, and Creighton University (S.K.). Division of Cardiology, Department of Pediatrics, University of Nebraska Medical Center and Children's Hospital of Omaha (Q.K., N.J.). Mid America Heart Institute at Saint Luke's Hospital, Kansas City, MO (P.G.J., J.A.S., P.S.C.). Department of Internal Medicine, University of Missouri–Kansas City (J.A.S., P.S.C.).

FOOTNOTES

Received May 16, 2017; accepted September 15, 2017.

The online-only Data Supplement is available with this article at http://circ.ahajournals.org/lookup/suppl/doi:10.1161/CIRCULATIONAHA.117.029535/-/DC1.

Circulation is available at http://circ.ahajournals.org.

REFERENCES

1. Institute for Healthcare Improvement. Protecting 5 Million Lives From Harm. ttp://www.ihi.org/Engage/Initiatives/Completed/5MillionLivesCampaign/Pages/default.aspx. Accessed February 27, 2017.
2. Girotra S, Nallamothu BK, Spertus JA, Li Y, Krumholz HM, Chan PS; American Heart Association Get with the Guidelines–Resuscitation Investigators. Trends in survival after in-hospital cardiac arrest. *N Engl J Med*. 2012;367:1912–1920. doi: 10.1056/NEJMoa1109148.
3. Devita MA, Bellomo R, Hillman K, Kellum J, Rotondi A, Teres D, Auerbach A, Chen WJ, Duncan K, Kenward G, Bell M, Buist M, Chen J, Bion J, Kirby A, Lighthall G, Ovreveit J, Braithwaite RS, Gosbee J, Milbrandt E, Peberdy M, Savitz L, Young L, Harvey M, Galhotra S. Findings of the first consensus conference on medical emergency teams. *Crit Care Med*. 2006;34:2463–2478.
4. Tibballs J, Kinney S. Reduction of hospital mortality and of preventable cardiac arrest and death on introduction of a pediatric medical emergency team. *Pediatr Crit Care Med*. 2009;10:306–312. doi: 10.1097/PCC.0b013e318198b02c.
5. Sharek PJ, Parast LM, Leong K, Coombs J, Earnest K, Sullivan J, Frankel LR, Roth SJ. Effect of a rapid response team on hospital-wide mortality and code rates outside the ICU in a Children's Hospital. *JAMA*. 2007;298:2267–2274. doi: 10.1001/jama.298.19.2267.
6. Maharaj R, Raffaele I, Wendon J. Rapid response systems: a systematic review and meta-analysis. *Crit Care*. 2015;19:254. doi: 10.1186/s13054-015-0973-y.
7. Anderson ML, Nichol G, Dai D, Chan PS, Thomas L, Al-Khatib SM, Berg RA, Bradley SM, Peterson ED, American Heart Association's Get With

the Guidelines-Resuscitation Investigators. Association between hospital process composite performance and patient outcomes after in-hospital cardiac arrest care. *JAMA Cardiol*. 2016;1:37–45.
8. Angus DC, van der Poll T. Severe sepsis and septic shock. *N Engl J Med*. 2013;369:840–851. doi: 10.1056/NEJMra1208623.
9. Kumar G, Kumar N, Taneja A, Kaleekal T, Tarima S, McGinley E, Jimenez E, Mohan A, Khan RA, Whittle J, Jacobs E, Nanchal R, Milwaukee Initiative in Critical Care Outcomes Research (MICCOR) Group of Investigators. Nationwide trends of severe sepsis in the 21st century (2000–2007). *Chest*. 2011;140:1223–1231.
10. Zimmerman JE, Kramer AA, Knaus WA. Changes in hospital mortality for United States intensive care unit admissions from 1988 to 2012. *Crit Care*. 2013;17:R81.
11. Danford DA, Karels Q, Kulkarni A, Hussain A, Xiao Y, Kutty S. Mortality-related resource utilization in the inpatient care of hypoplastic left heart syndrome. *Orphanet J Rare Dis*. 2015;10:137. doi: 10.1186/s13023-015-0355-1.
12. Averill RF, McCullough, EC, Goldfield N, Hughes JS, Bonazelli J, Bentley L, Muldoon J, Turner L. *3M APR DRG Classification System*. 31st ed. Wallingford, CT: Agency for Healthcare Research and Quality; 2013. Report No.: GRP-041.
13. Parker MW, Shah SS, Hall M, Fieldston ES, Coley BD, Morse RB. Computed tomography and shifts to alternate imaging modalities in hospitalized children. *Pediatrics*. 2015;136:e573–e581. doi: 10.1542/peds.2015-0995.
14. Jones HE, Ohlssen DI, Spiegelhalter DJ. Use of the false discovery rate when comparing multiple health care providers. *J Clin Epidemiol*. 2008;61:232–240. doi: 10.1016/j.jclinepi.2007.04.017.
15. R Development Core Team. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing; 2008. ISBN 3-900051-07-0, http://www.R-project.org/..
16. Zenker P, Schlesinger A, Hauck M, Spencer S, Hellmich T, Finkelstein M, Thygeson MV, Billman G. Implementation and impact of a rapid response team in a children's hospital. *Jt Comm J Qual Patient Saf*. 2007;33:418–425.
17. Brilli RJ, Gibson R, Luria JW, Wheeler TA, Shaw J, Linam M, Kheir J, McLain P, Lingsch T, Hall-Haering A, McBride M. Implementation of a medical emergency team in a large pediatric teaching hospital prevents respiratory and cardiopulmonary arrests outside the intensive care unit. *Pediatr Crit Care Med*. 2007;8:236–246; quiz 247. doi: 10.1097/01.PCC.0000262947.72442.EA.
18. Committee on the Treatment of Cardiac Arrest: Current Status and Future Directions; Board on Health Sciences Policy; Institute of Medicine. *Strategies to Improve Cardiac Arrest Survival: A Time to Act*. In: Graham R, McCoy MA, Schultz AM, eds. Washington, DC: Institute of Medicine; 2015.
19. Chan ML, Spertus JA, Tang F, Jayaram N, Chan PS. Missed opportunities in use of medical emergency teams prior to in-hospital cardiac arrest. *Am Heart J*. 2016;177:87–95. doi: 10.1016/j.ahj.2016.04.014.
20. Chan PS, Jain R, Nallmothu BK, Berg RA, Sasson C. Rapid response teams: a systematic review and meta-analysis. *Arch Intern Med*. 2010;170:18–26. doi: 10.1001/archinternmed.2009.424.
21. Peberdy MA, Kaye W, Ornato JP, Larkin GL, Nadkarni V, Mancini ME, Berg RA, Nichol G, Lane-Trultt T. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation*. 2003;58:297–308.

Association of Pediatric Medical Emergency Teams With Hospital Mortality

Shelby Kutty, Philip G. Jones, Quentin Karels, Navya Joseph, John A. Spertus and Paul S. Chan

Circulation. 2018;137:38-46; originally published online October 4, 2017;
doi: 10.1161/CIRCULATIONAHA.117.029535
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539

SUPPLEMENTARY MATERIAL

eTable 1. Comparison of Mortality Trends Before and After Implementation of a Medical Emergency Team in Each Hospital. A significantly lower intercept or a more negative slope (lower odds ratio) *after* implementation would indicate that medical emergency teams reduce hospital mortality. This was not seen in any of the 38 study hospitals, although 2 hospitals (hospitals 1 and 2) had a less negative slope (i.e., higher mortality than projected based on pre-intervention trends) after team implementation.

Hospital	Total Admissions in Cohort	Total Years Represented	Intercept Before MET team	Intercept After MET team	Mortality Slope Before MET team	Mortality Slope After MET team	P-Value†
1	324952	12	6.5	8.1	0.86	0.94	0.002
2	178106	12	6.1	8.1	0.84	0.94	0.007
3	278347	12	8.0	9.3	0.92	0.90	0.151
4	184414	12	12.5	13.3	0.95	0.91	0.324
5	156331	12	10.6	12.8	0.89	0.92	0.412
6	161126	12	10.4	10.5	0.99	0.94	0.573
7	180186	12	11.0	10.8	0.96	0.91	0.657
8	116593	12	8.4	9.5	0.92	0.91	0.803
9	147985	12	8.7	9.9	0.93	0.94	0.873
10	85985	12	7.8	9.0	0.93	0.97	0.873
11	159642	11	8.3	9.2	0.91	0.91	0.873
12	158163	12	10.6	11.7	0.90	0.90	0.873
13	205832	12	7.8	8.8	0.93	0.95	0.873
14	164008	12	9.1	8.6	0.99	0.95	0.873
15	135322	12	8.2	9.4	0.94	0.97	0.873
16	159197	12	8.4	9.4	0.94	0.98	0.873
17	225563	12	10.6	10.5	0.96	0.93	0.873
18	193048	12	8.8	7.8	0.97	0.94	0.873
19	288031	11	8.0	8.6	0.96	0.96	0.873
20	216958	12	8.4	9.3	0.89	0.92	0.873
21	253018	12	8.2	9.0	0.94	0.95	0.884
22	204996	12	10.1	9.2	0.93	0.91	0.884
23	174977	12	7.5	6.8	0.99	0.96	0.884
24	77173	8	9.6	9.1	0.94	0.90	0.884
25	157030	12	8.3	8.6	0.94	0.92	0.884
26	181690	12	7.7	8.1	0.93	0.97	0.947
27	243506	8	7.3	7.2	0.98	0.96	0.975
28	179225	12	7.2	7.2	0.97	0.95	0.975
29	86899	12	8.6	8.1	0.94	0.94	0.975

Hospital	Total Admissions in Cohort	Total Years Represented	Intercept Before MET team	Intercept After MET team	Mortality Slope Before MET team	Mortality Slope After MET team	P-Value†
30	88980	12	10.0	10.3	0.93	0.93	0.975
31	327064	12	7.7	8.1	0.95	0.96	0.975
32	156650	12	6.7	6.7	0.95	0.96	0.975
33	136938	12	8.5	8.2	0.97	0.95	0.975
34	162233	12	8.3	8.4	0.96	0.95	0.975
35	49951	8	5.9	5.9	0.97	0.98	0.975
36	147092	12	8.1	7.9	0.95	0.94	0.975
37	119943	12	7.6	7.9	0.96	0.97	0.975
38	149004	11	7.7	7.6	0.96	0.96	0.975

† Global P-value for a difference in the intercept or slope after accounting for multiple comparisons across the 38 study hospitals.

eFigure 1. Risk-Adjusted Mortality Rates Before and After Medical Emergency Team Implementation in Two Hospitals With Higher Than Expected Mortality After Team Implementation. In panel A, this hospital's mortality rates leveled off after medical emergency team implementation. In Panel B, this hospital's mortality rates plummeted the year prior to medical emergency team implementation. When that year's data is excluded, the mortality slopes before and after medical emergency team implementation would no longer be significantly different.