ORIGINAL RESEARCH

Impact of Proactive Rounding by a Rapid Response Team on Patient Outcomes at an Academic Medical Center

Brad W. Butcher, MD[1]*, Eric Vittinghoff, PhD[2], Judith Maselli, MSPH[1], Andrew D. Auerbach, MD, MPH[1]

[1]Department of Medicine, Division of Hospital Medicine, University of California San Francisco, San Francisco, California; [2]Department of Epidemiology and Biostatistics, Division of Biostatistics, University of California San Francisco, San Francisco, California.

BACKGROUND: The impact of rapid response teams (RRT) on patient outcomes remains uncertain.

OBJECTIVE: To examine the effect of proactive rounding by an RRT on outcomes of hospitalized adults discharged from intensive care.

DESIGN: Retrospective, observational study.

SETTING: Academic medical center.

PATIENTS: All adult patients discharged alive from the intensive care unit (ICU) at the University of California San Francisco Medical Center between January 2006 and June 2009.

INTERVENTION: Introduction of proactive rounding by an RRT.

MEASUREMENTS: Outcomes included the ICU readmission rate, ICU average length of stay (LOS), and

in-hospital mortality of patients discharged from the ICU. Data were obtained from administrative billing databases and analyzed using an interrupted time series (ITS) model.

RESULTS: We analyzed 17 months of preintervention data and 25 months of postintervention data. Introduction of proactive rounding by the RRT did not change the ICU readmission rate (6.7% before vs 7.3% after; $P = 0.24$), the ICU LOS (5.1 days vs 4.9 days; $P = 0.24$), or the in-hospital mortality of patients discharged from the ICU (6.0% vs 5.5%; $P = 0.24$). ITS models testing the impact of proactive rounding on secular trends found no improvement in any of the 3 clinical outcomes relative to their preintervention trends.

CONCLUSIONS: Proactive rounding by an RRT did not improve patient outcomes, raising further questions about RRT benefits. *Journal of Hospital Medicine* 2013;8:7–12. © 2012 Society of Hospital Medicine

Rapid response teams (RRT) have been promoted by numerous patient safety organizations to reduce preventable in-hospital deaths.[1–4] Initial studies of RRTs were promising,[5–7] but recent literature,[8–11] including systematic reviews and meta-analyses, has called these findings into question. Nevertheless, RRTs remain popular in academic and community hospitals worldwide, and many have expanded their roles beyond solely responding to the deteriorating patient.[12]

Some RRTs, for example, proactively round on seriously ill ward patients and patients recently discharged from the intensive care unit (ICU) in an effort to prevent transitions to higher levels of care. Priestley and colleagues demonstrated that institution of such a team, referred to as a critical care outreach team (CCOT), decreased in-hospital mortality while possibly increasing hospital length of stay (LOS).[13] Three additional single-center studies from the United Kingdom, where CCOTs are common, specifically exam-

ined proactive rounding by CCOTs on the ICU readmission rate: 2 observed no improvement,[14,15] while the third, limited by a small sample size, demonstrated a modest reduction in ICU readmissions.[16]

We sought to determine the impact of proactive rounding by an RRT on patients discharged from intensive care on the ICU readmission rate, ICU LOS, and in-hospital mortality of patients discharged from the ICU. We hypothesized that proactive rounding by an RRT would decrease the ICU readmission rate, ICU LOS, and the in-hospital mortality of patients discharged from the ICU.

MATERIALS AND METHODS
Site and Subjects
We carried out a retrospective, observational study of adult patients discharged from the ICU at University of California San Francisco (UCSF) Medical Center between January 2006 and June 2009. UCSF is a 790-bed quaternary care academic hospital that admits approximately 17,000 patients annually and has 5 adult ICUs, with 62 beds and 3500 to 4000 ICU admissions annually. Our study was approved by the UCSF Medical Center Committee on Human Research; need for informed consent was waived.

Description of the RRT Before June 1, 2007
Throughout the study, the goal of the RRT was unchanged: to assess, triage, and institute early treatment in patients who experienced an acute decline in

their clinical status. From November 2005 to October 2006, the RRT was staffed by an attending hospitalist and medicine resident during daytime, and by a critical care fellow at nighttime and on weekends. The RRT could be activated by any concerned staff member in response to a set of predetermined vital sign abnormalities, decreased urine output, or altered mental status, or simply if the staff member was concerned about the patient's clinical status. Despite extensive educational efforts, utilization of the team was low (2.7 calls per 1000 admissions) and, accordingly, it was discontinued in October 2006. After this time, staff would contact the primary team caring for the patient, should concerns regarding the patient's condition arise.

Description of the RRT After June 1, 2007

In an effort to expand its scope and utility, the RRT was reinstated on June 1, 2007 with a new composition and increased responsibilities. After this date, physician roles were eliminated, and the team composition changed to a dedicated critical care nurse and respiratory therapist, available 24 hours a day. Criteria for calling the team remained unchanged. In addition to responding to acute deteriorations in patients' clinical courses, the RRT began to proactively assess all patients within 12 hours of discharge from the ICU and would continue to round on these patients daily until it was felt that they were clinically stable. During these rounds, the RRT would provide consultation expertise to the bedside nurse and contact the patient's clinicians if concern existed about a patient's clinical trajectory; decisions to transfer a patient back to the ICU ultimately rested with the patient's primary team. During this time period, the RRT received an average of 110.6 calls per 1000 admissions.

Data Sources

Data collected included: demographics, clinical information (all patient refined [APR] severity of illness, APR risk of mortality, and the presence of 29 comorbidities), whether there was a readmission to the ICU, the total ICU LOS, and the vital status at the time of hospital discharge.

Outcomes

Outcomes included: readmission to the ICU, defined as 2 noncontiguous ICU stays during a single hospitalization; ICU LOS, defined as the total number of ICU days accrued during hospitalization; and in-hospital mortality of patients discharged from the ICU.

Adjustment Variables

Patient age, gender, race, and ethnicity were available from administrative data. We used admission diagnosis code data to classify comorbidities using the method of Elixhauser et al.[17]

Statistical Analysis

For each of the 3 study outcomes, we assessed the effects of the intervention using multivariable models adjusting for patient- and service-level factors, including a gamma model for ICU LOS and logistic models for ICU readmission and in-hospital mortality of patients discharged from the ICU. We first compared unadjusted outcome levels before and after implementation. We then used an interrupted time series (ITS) framework to assess the effects of the intervention in terms of 5 measures: 1) the secular trend in the mean of the outcome *before* the intervention; 2) the change in the mean *at the start* of the implementation, or immediate effects; 3) the secular trend in the mean *after* implementation; 4) the *change* in secular trend, reflecting cumulative intervention effects; and 5) the *net* effect of the intervention, estimated as the adjusted difference between the fitted mean at the end of the postintervention period and the expected mean if the preintervention trend had continued without interruption or change.

Secondary Analyses

Given the heterogeneity of the RRT in the preintervention period, we assessed potential changes in trend at October 2006, the month in which the RRT was discontinued. We also examined changes in trend midway through the postimplementation period to evaluate for increased efficacy of the RRT with time.

Selection of Covariates

Age, race, and admitting service were included in both the pre–post and ITS models by default for face validity. Additional covariates were selected for each outcome using backwards deletion with a retention criterion of $P < 0.05$, based on models that allowed the outcome rate to vary freely month to month. Because these data were obtained from administrative billing datasets, and the presence of comorbidities could not be definitively linked with time points during hospitalization, only those comorbidities that were likely present prior at ICU discharge were included. For similar reasons, APR severity of illness and risk of mortality scores, which were calculated from billing diagnoses at the end of hospitalization, were excluded from the models.

RESULTS
Patient Characteristics

During the study period, 11,687 patients were admitted to the ICU; 10,288 were discharged from the ICU alive and included in the analysis. In the 17 months prior to the introduction of proactive rounding by the RRT, 4902 (41.9%) patients were admitted, and during the 25 months afterwards, 6785 (58.1%) patients. Patients admitted in the 2 time periods were similar, although there were clinically small but statistically significant differences in race, APR severity of illness,

TABLE 1. Patient Characteristics

	Pre-RRT (n = 4305) N (%)	Post-RRT (n = 5983) N (%)	P Value
Age, mean (y [SD])	57.7 [16.6]	57.9 [16.5]	0.50
Female gender	2,005 (46.6)	2,824 (47.2)	0.53
Race			0.0013
White	2,538 (59.0)	3,520 (58.8)	
Black	327 (7.6)	436 (7.3)	
Asian	642 (14.9)	842 (14.1)	
Other	719 (16.7)	1,121 (18.7)	
Unknown	79 (1.8)	64 (1.1)	
Ethnicity			0.87
Hispanic	480 (11.2)	677 (11.3%)	
Non-Hispanic	3,547 (82.4)	4,907 (82.0%)	
Unknown	278 (6.5)	399 (6.7)	
Insurance			0.50
Medicare	1,788 (41.5)	2,415 (40.4)	
Medicaid/Medi-Cal	699 (16.2)	968 (16.2)	
Private	1,642 (38.1)	2,329 (38.9)	
Other	176 (4.1)	271 (4.5)	
Admission source			0.41
ED	1,621 (37.7)	2,244 (37.5)	
Outside hospital	652 (15.2)	855 (14.3)	
Direct admit	2,032 (47.2)	2,884 (48.2)	
Major surgery			0.99
Yes	3,107 (72.2)	4,319 (72.2)	
APR severity of illness			0.0001
Mild	622 (14.5)	828 (13.8)	
Moderate	1,328 (30.9)	1,626 (27.2)	
Major	1,292 (30.0)	1,908 (31.9)	
Extreme	1,063 (24.7)	1,621 (27.1)	
APR risk of mortality			0.0109
Mild	1,422 (33.0)	1,821 (30.4)	
Moderate	1,074 (25.0)	1,467 (24.5)	
Major	947 (22.0)	1,437 (24.0)	
Extreme	862 (20.0)	1,258 (21.0)	
Admitting service			0.11
Adult general surgery	190 (4.4)	260 (4.4)	
Cardiology	347 (8.1)	424 (7.1)	
Cardiothoracic surgery	671 (15.6)	930 (15.5)	
Kidney transplant surgery	105 (2.4)	112 (1.9)	
Liver transplant surgery	298 (6.9)	379 (6.3)	
Medicine	683 (15.9)	958 (16.0)	
Neurology	420 (9.8)	609 (10.2)	
Neurosurgery	1,345 (31.2)	1,995 (33.3)	
Vascular surgery	246 (5.7)	316 (5.3)	
Comorbidities			
Hypertension	2,054 (47.7)	2,886 (48.2)	0.60
Fluid and electrolyte disorders	998 (23.2)	1,723 (28.8)	<0.0001
Diabetes	708 (16.5)	880 (14.7)	0.02
Chronic obstructive pulmonary disease	632 (14.7)	849 (14.2)	0.48
Iron deficiency anemia	582 (13.5)	929 (15.5)	0.005
Renal failure	541 (12.6)	744 (12.4)	0.84
Coagulopathy	418 (9.7)	712 (11.9)	0.0005
Liver disease	400 (9.3)	553 (9.2)	0.93
Hypothyroidism	330 (7.7)	500 (8.4)	0.20
Depression	306 (7.1)	508 (8.5)	0.01
Peripheral vascular disease	304 (7.1)	422 (7.1)	0.99
Congestive heart failure	263 (6.1)	360 (6.0)	0.85
Weight loss	236 (5.5)	425 (7.1)	0.0009
Paralysis	225 (5.2)	328 (5.5)	0.57
Neurological disorders	229 (5.3)	276 (4.6)	0.10
Valvular disease	210 (4.9)	329 (5.5)	0.16
Drug abuse	198 (4.6)	268 (4.5)	0.77
Metastatic cancer	198 (4.6)	296 (5.0)	0.42

(Continued)

TABLE 1. (*Continued*)

	Pre-RRT (n = 4305) N (%)	Post-RRT (n = 5983) N (%)	P Value
Obesity	201 (4.7)	306 (5.1)	0.30
Alcohol abuse	178 (4.1)	216 (3.6)	0.17
Diabetes with complications	175 (4.1)	218 (3.6)	0.27
Solid tumor without metastasis	146 (3.4)	245 (4.1)	0.07
Psychoses	115 (2.7)	183 (3.1)	0.25
Rheumatoid arthritis/collagen vascular disease	96 (2.2)	166 (2.8)	0.08
Pulmonary circulation disease	83 (1.9)	181 (3.0)	0.0005
Outcomes			
Readmission to ICU	288 (6.7)	433 (7.3)	0.24
ICU length of stay, mean [SD]	5.1 [9.7]	4.9 [8.3]	0.24
In-hospital mortality of patients discharged from the ICU	260 (6.0)	326 (5.5)	0.24

Abbreviations: APR, all patient refined; ED, emergency department; ICU, intensive care unit; RRT, rapid response teams; SD, standard deviation.

APR risk of mortality, and certain comorbidities between the 2 groups (Table 1).

ICU Readmission Rate

Introduction of proactive rounding by the RRT was not associated with unadjusted differences in the ICU readmission rate (6.7% preintervention vs 7.3% postintervention, $P = 0.24$; Table 1). In the adjusted ITS model, the intervention had no net effect on the odds of ICU readmission (adjusted odds ratio [AOR] for net intervention effect 0.98, 95% confidence interval [CI] 0.42, 2.28), with similar secular trends both preintervention (AOR 1.00 per year, 95% CI 0.97, 1.03), and afterwards (AOR 0.99 per year, 95% CI 0.98, 01.00), and a nonsignificant increase at implementation (Table 2). Figure 1 uses solid lines to show the fitted readmission rates, a hatched line to show the projection of the preintervention secular trend into the postintervention period, and circles to represent adjusted monthly means. The lack of a net intervention effect is indicated by the convergence of the solid and hatched lines 24 months postintervention.

ICU Average LOS

Introduction of proactive rounding by the RRT was not associated with unadjusted differences in ICU average LOS (5.1 days preintervention vs 4.9 days postintervention, $P = 0.24$; Table 1). Trends in ICU LOS may have changed in October 2006 ($P = 0.07$), decreasing in the first half of the study period (adjusted rate ratio [ARR] 0.98 per year, 95% CI 0.96–1.00), but did not change significantly thereafter. As with the ICU readmission rate, neither the change in estimated secular trend after implementation (ARR 0.98, 95% CI 0.96–1.01), nor the net effect of the intervention (ARR 0.62, 95% CI 0.32–1.22) was statistically significant (Table 2); these results are depicted graphically in Figure 2.

TABLE 2. Adjusted Impact of Proactive Rounding by an RRT on Clinical Outcomes

Outcome: Summary Effect Measure	Value (95% CI)	*P* Value
ICU readmission rate—adjusted odds ratio		
Pre-RRT trend	1.00 (0.97, 1.03)	0.98
Change at RRT implementation	1.24 (0.94, 1.63)	0.13
Post-RRT trend	0.98 (0.97, 1.00)	0.06
Change in trend	0.98 (0.96, 1.02)	0.39
Net intervention effect	0.92 (0.40, 2.12)	0.85
ICU average length of stay—adjusted ratio of means		
Trend at 9 mo pre-RRT	0.98 (0.96, 1.00)	0.05
Trend at 3 mo pre-RRT	1.02 (0.99, 1.04)	0.19
Change in trend at 3 mo pre-RRT	1.03 (1.00, 1.07)	0.07
Change at RRT implementation	0.92 (0.80, 1.06)	0.27
Post-RRT trend	1.00 (0.99, 1.00)	0.35
Change in trend at RRT implementation	0.98 (0.96, 1.01)	0.14
Net intervention effect	0.60 (0.31, 1.18)	0.14
In-hospital mortality of patients discharged from the ICU—adjusted odds ratio		
Pre-RRT trend	1.02 (0.99, 1.06)	0.15
Change at RRT implementation	0.74 (0.51, 1.08)	0.12
Post-RRT trend	1.00 (0.98, 1.01)	0.68
Change in trend	0.97 (0.94, 1.01)	0.14
Net intervention effect	0.39 (0.14, 1.10)	0.08

NOTE: ICU readmission model adjusted for attending service, age, race/ethnicity, comorbidities (chronic pulmonary disease, weight loss, anemia, neurological disorders, rheumatoid arthritis, and solid tumors without metastasis), and clustering at the attending physician level. Length of stay model adjusted for attending service, age, race/ethnicity, comorbidities (drug abuse, rheumatoid arthritis, anemia, weight loss, paralysis, pulmonary circulation disease, neurological disorders, hypothyroidism, peptic ulcer disease, and solid tumors without metastasis), and clustering at the attending physician level. Mortality model adjusted for attending service, age, race/ethnicity, comorbidities (weight loss, lymphoma, metastatic cancer, chronic pulmonary and pulmonary circulation disease, and paralysis), and clustering at the attending physician level. **Abbreviations:** CI, confidence interval; ICU, intensive care unit; RRT, rapid response teams.
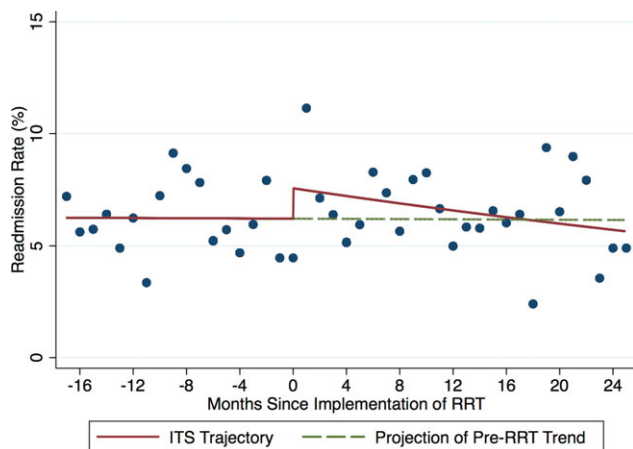

FIG. 1. Adjusted ICU readmission rate before and after implementation of proactive rounding by the RRT. Solid lines represent estimates from multivariable models for each time period, with the hatched line projecting the preintervention trend forward. Circles represent adjusted monthly means. Abbreviations: ICU, intensive care unit; ITS, interrupted time series; RRT, rapid response teams.

In-Hospital Mortality of Patients Discharged From the ICU

Introduction of proactive rounding by the RRT was not associated with unadjusted differences in the mortality of patients discharged from the ICU (6.0% preintervention vs 5.5% postintervention, *P* = 0.24; Table 1). Similarly, in the adjusted ITS model, the intervention had no statistically significant net effect on the mortality outcome (Table 2 and Figure 3).
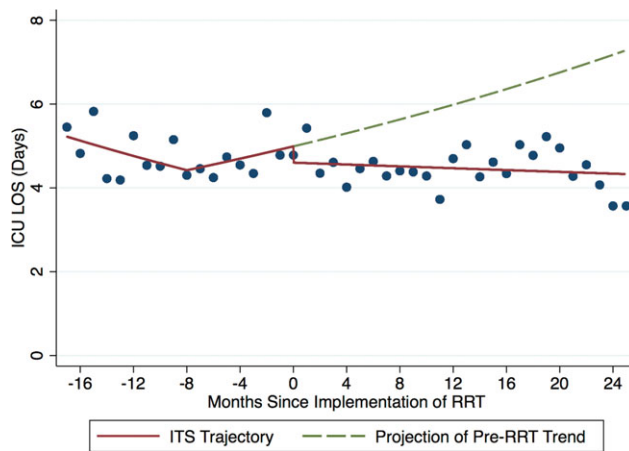

FIG. 2. Adjusted ICU LOS before and after implementation of proactive rounding by the RRT. Solid lines represent estimates from multivariable models for each time period, with the hatched line projecting the immediate preintervention trend forward. Circles represent adjusted monthly means. Abbreviations: ICU, intensive care unit; ITS, interrupted time series; LOS, length of stay; RRT, rapid response teams.
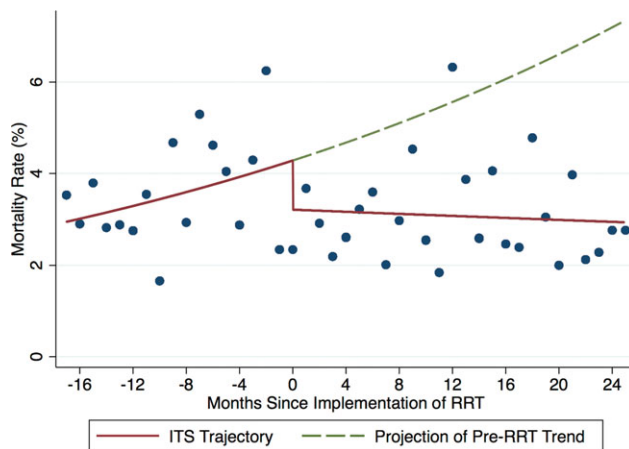

FIG. 3. Adjusted in-hospital mortality for patients discharged from the ICU before and after implementation of proactive rounding by the RRT. Solid lines represent estimates from multivariable models for each time period, with the hatched line projecting the preintervention trend forward. Circles represent adjusted monthly means. Abbreviations: ICU, intensive care unit; ITS, interrupted time series; RRT, rapid response teams.

Secondary Analyses

Apart from weak evidence for a change in trend in ICU LOS in October 2006, no other changes in trend were found within the preintervention or postintervention periods (data not shown). This suggests that the heterogeneity of the preintervention RRT had no significant impact on the 3 outcomes examined, and that the RRT intervention failed to gain efficacy with time in the postintervention period. Additionally, we saw no outcome benefit in sensitivity analyses among all ICU patients or in service-defined analyses (eg, surgical services), where ability to control for illness severity was improved.

DISCUSSION

In this single center study, introduction of an RRT that proactively rounded on patients discharged from

the ICU did not reduce the ICU readmission rate, ICU LOS, or mortality of patients discharged from the ICU, after accounting for secular trends using robust ITS methods and adjusting for patient level factors.

Our study is consistent with 2 smaller studies that assessed the impact of proactive rounding by a CCOT on ICU readmission rate. Leary and Ridley[14] found that proactively rounding by a CCOT did not reduce ICU readmissions or shorten the ICU LOS, although this study was limited by a surprisingly low ICU readmission rate and short ICU LOS prior to the intervention. Another study[15] also observed no change in the ICU readmission rate following introduction of a proactively rounding CCOT but noted small reductions in both ICU and hospital mortality. The sole study showing an effect[16] observed a lower ICU readmission rate and increased survival to hospital discharge (after excluding do not resuscitate [DNR] patients) with implementation of a CCOT, although some of their findings may be explained by their CCOT's use of palliative care services, a function not featured in our model.

Our study adds to the meta-analyses and systematic reviews[8–10] that have questioned the hypothesis that a trained and proactive team of caregivers should be able to prevent patients from returning to the ICU. Perhaps one reason why this is not true is that proactive rounding by RRTs may have minimal effect in systems where "step-down" beds are readily available. At UCSF, nearly every patient transferred out of the ICU is triaged to a step-down unit, where telemetry and pulse oximetry are continuously monitored. Despite this, however, our institution's 2 step-down units generate more calls to our RRT than any other units in the hospital.

We were surprised to see that proactive rounding failed to shorten ICU LOS, hypothesizing that clinicians would be more comfortable discharging patients from the ICU knowing that the RRT would be closely monitoring them afterwards. Although we have no data to support this hypothesis, increased use of the RRT may have also increased step-down bed use, as patients on the general medical–surgical floors were transferred to a higher level of care upon recommendation of the RRT, thereby delaying transfers out of the ICU. Moreover, the opening of an additional 16-bed ICU in October 2008 might have encouraged clinicians to transfer patients back to the ICU simply because beds were more easily accessible than before.

Introduction of proactive rounding by the RRT was also not associated with differences in the mortality rate of patients discharged from the ICU. This finding conflicts with the results of Garcea et al,[15] Ball et al,[16] and Priestley et al[13], all of which found that implementation of a CCOT led to small but statistically significant reductions in in-hospital mortality. All 3 of these studies, however, examined smaller patient populations (1380, 470, and 2903 patients, respectively),

and both the Priestley and Ball studies[13,16] had significantly shorter periods of data collection (24 months and 32 weeks, respectively). Our results are based on models with confidence intervals and *P* values that account for variability in all 3 underlying effect estimates but assume a linear extrapolation of the preintervention trend. This approach allowed us to flexibly deal with changes related to the intervention, while relying on our large sample size to define time trends not dealt with adequately (or at all) in previous research.

The lack of improvement in outcomes cannot be attributed to immaturity of the RRT or failure of the clinical staff to use the RRT adequately. A prespecified secondary data analysis midway through the postintervention time period demonstrated that the RRT failed to gain efficacy with time with respect to all 3 outcomes. The postintervention RRT was also utilized far more frequently than its predecessor (110.6 vs 2.7 calls per 1000 admissions, respectively), and this degree of RRT utilization far surpasses the "dose" considered to be indicative of a mature RRT system.[12]

Our study has several limitations. First, we relied on administrative rather than chart-collected data to determine the reason for ICU admission, and the APR severity of illness and risk of mortality scores. It seems unlikely, however, that coding deficiencies or biases affected the preintervention and postintervention patient populations differently. Even though we adjusted for all available measures, it is possible that we were not able to account for time trends in all potential confounders. Second, we did not have detailed clinical information on reasons for ICU readmission and whether readmissions occurred before or after the RRT proactively rounded on the patient. Therefore, potential readmissions to the ICU that might have been planned or which would have happened regardless of the presence of the RRT, such as for antibiotic desensitization, could not be accounted for. Third, introduction of proactive rounding by the RRT in June 2007 was accompanied by a change in the RRT's composition, from a physician-led model to a nurse-led model. Therefore, inherent differences in the way that physicians and nurses might assess and triage patients could not have been adjusted for. Lastly, this was a retrospective study conducted at a single academic medical center with a specific RRT model, and our results may not be directly applicable to nonteaching settings or to different RRT models.

Our findings raise further questions about the benefits of RRTs as they assume additional roles, such as proactive rounding on patients recently discharged from the ICU. The failure of our RRT to reduce the ICU readmission rate, the ICU average LOS, and the mortality of patients discharged from the ICU raises concerns that the benefits of our RRT are not commensurate with its cost. While defining the degree of impact and underlying mechanisms are worthy of

prospective study, hospitals seeking to improve their RRT models should consider how to develop systems that achieve the RRT's promise in measurable ways.

References

1. Berwick DM, Calkins DR, McCannon CJ, Hackbarth AD. The 100,000 lives campaign: setting a goal and a deadline for improving health care quality. *JAMA*. 2006;295(3):324–327.
2. Clinical Governance Unit, Quality and Safety Branch, Rural and Regional Health and Aged Care Services Division Safer Systems, Department of Human Services, State Government of Victoria. Safer Systems—Saving Lives Campaign. Available at: http://www.health.vic.gov.au/sssl. Accessed April 5, 2012.
3. Canadian Patient Safety Institute. Safer Healthcare Now! Campaign. Available at: http://www.saferhealthcarenow.ca. Accessed April 5, 2012.
4. Steel AC, Reynolds SF. The growth of rapid response systems. *Jt Comm J Qual Patient Saf*. 2008;34:489–495.
5. Lee A, Bishop G, Hillman KM, Daffurn K. The medical emergency team. *Anaesth Intensive Care*. 1995;23(2):183–186.
6. Bristow PJ, Hillman KM, Chey T, et al. Rates of in-hospital arrests, deaths, and intensive care admission: the effect of a medical emergency team. *Med J Aust*. 2000;173:236–240.
7. Goldhill DR, Worthington L, Mulcahy A, Tarling M, Sumner A. The patient-at-risk team: identifying and managing seriously ill ward patients. *Anaesthesia*. 1999;54:853–860.
8. Ranji SR, Auerbach AD, Hurd CJ, O'Rourke K, Shojania KG. Effects of rapid response systems on clinical outcomes: systemic review and meta-analysis. *J Hosp Med*. 2007;2:422–432.
9. Chan PS, Jain R, Nallmothu BK, Berg RA, Sasson C. Rapid response teams: a systemic review and meta-analysis. *Arch Intern Med*. 2010;170(1):18–26.
10. Winters BD, Pham JC, Hunt EA, Guallar E, Berenholtz S, Pronovost PJ. Rapid response systems: a systematic review. *Crit Care Med*. 2007;35(5):1238–1243.
11. Hillman K, Chen J, Cretikos M, et al. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet*. 2005;365:2091–2097.
12. Jones DA, DeVita MA, Bellomo R. Rapid response teams. *N Engl J Med*. 2011;365:139–146.
13. Priestley G, Watson W, Rashidian A, et al. Introducing critical care outreach: a ward-randomised trial of phased introduction in a general hospital. *Intensive Care Med*. 2004;30(7):1398–1404.
14. Leary T, Ridley S. Impact of an outreach team on re-admissions to a critical care unit. *Anaesthesia*. 2003;58:328–332.
15. Garcea G, Thomasset S, McClelland L, Leslie A, Berry DP. Impact of a critical care outreach team on critical care readmissions and mortality. *Acta Anaesthesiol Scand*. 2004;48:1096–1100.
16. Ball C, Kirkby M, Williams S. Effect of the critical care outreach team on patient survival to discharge from hospital and readmission to critical care: non-randomised population based study. *BMJ*. 2003;327:1014–1017.
17. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8–27.