The relationship between early emergency team calls and serious adverse events*

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Objective: **To examine the relationship between early emergency team calls and the incidence of serious adverse events—cardiac arrests, deaths, and unplanned admissions to an intensive care unit—in a cluster randomized controlled trial of medical emergency team implementation (the MERIT study).**

Design: Post hoc **analysis of data from cluster randomized controlled trial.**

Setting and Participants: **Twenty-three public hospitals in Australia and 741,744 patients admitted during the conduct of the study.**

Interventions: **Attendance by a rapid response system team or cardiac arrest team.**

Main Outcome Measures: **The relationship between the proportion of rapid response system team calls that were early emergency team calls (defined as calls not associated with cardiac arrest or death) and the rate (events/1000 admissions) of the adverse events.**

Results: **We analyzed 11,242 serious adverse events and 3700 emergency team calls. For every 10% of increase in the proportion of early emergency team calls there was a 2.0 reduction per 10,000 admissions in unexpected cardiac arrests (95% confidence interval [CI] −2.6 to −1.4), a 2.2 reduction in overall cardiac arrests (95% CI −2.9 to −1.6), and a 0.94 reduction in unexpected deaths (95% CI −1.4 to −0.5). We found no such relationship for unplanned intensive care unit admissions or for the aggregate of unexpected cardiac arrests, unplanned intensive care unit admissions, and unexpected deaths.**

Conclusions: **As the proportion of early emergency team calls increases, the rate of cardiac arrests and unexpected deaths decreases. This inverse relationship provides support for the notion that early review of acutely ill ward patients by an emergency team is desirable. (Crit Care Med 2009; 37:148–153)**

Key Words: medical emergency team; rapid response team; health services research; cluster randomized controlled trial; dose–response

The medical emergency team or rapid response team is based on the concept that early attendance of seriously ill hospital patients may reduce adverse events (1–4). A rapid response system (RRS) team consists of either a medical emergency team (led by a physician) or rapid response team (led by a nurse). RRS teams have now been widely adopted (5–7), largely based on several studies using historical controls (8, 9). However, the intuitive validity of such early intervention has not been formally assessed.

The Medical Early Response Intervention and Therapy (MERIT) study, a 23-hospital cluster randomized controlled trial, attempted to evaluate the effectiveness of the RRS concept (10). We randomized hospitals into two groups: control hospitals and RRS hospitals. The study outcomes included 1) unexpected cardiac arrests (cardiac arrests without a preexisting not-for-resuscitation order); 2) unplanned intensive care unit (ICU) admissions; 3) unexpected deaths (deaths without a preexisting not-for-resuscitation order); and 4) aggregated adverse events of the above three adverse events. It was expected that control hospitals would use the traditional cardiac arrest team (CAT) and that RRS hospitals would respond to patients using a set of standard criteria (10) and so potentially respond earlier in the course of the patient's illness. In contrast to our expectations, we found that nearly half of the CAT calls in the control hospital during the study period were "early" emergency calls (calls not associated with a cardiac arrest or death) (10). We also found that, in RRS hospitals, patients with documented RRS criteria did not have an RRS call. Finally, we found marked variance from hospital to hospital in the incidence of early emergency team calls and outcomes. These features, together with the lower than expected incidence of the primary outcome measure, markedly affected the power of the MERIT study, making it insufficiently powered to address its primary question and, therefore, inconclusive. These limitations of the original analysis of MERIT stimulated us to consider other ways of assessing the original data set. In this regard, although unexpected, the degree of "contamination" in control hospitals and the degree of "penetration" in RRS hospitals, with their spontaneous interhospital variance, offered us the opportunity to assess the relationship between early emergency team calls and adverse outcomes. Accordingly, we used such data to test whether, in the MERIT study, there was a relationship between the proportion of

***See also p. 349.**

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early emergency team calls and the rate of cardiac arrests, deaths, and unplanned admissions to the ICU.

METHODS

During the MERIT study, we collected data on 741,744 patient admissions in 23 Australian hospitals during 12 mos. We recorded information on every RRS and CAT call, including whether a call was associated with a cardiac arrest or death. Only calls for which the team attended to a patient were recorded. We designated those calls not associated with a cardiac arrest or death as early emergency team calls. For example, where a nurse called an RRS or CAT to a patient who was hypotensive and/or tachypneic and who did not have a cardiac arrest, the call was classified as an early emergency call. The proportion of such calls was expressed as early emergency team calls/all attendances × 100.

For the purpose of this study, we measured the occurrence of the following outcomes: 1) unexpected cardiac arrests (cardiac arrests without a preexisting do not attempt resuscitation [DNAR] order); 2) unplanned ICU admissions; 3) unexpected deaths (deaths without a preexisting DNAR order); 4) the aggregate of the above three adverse events; 5) overall cardiac arrests; and 6) overall mortality. Their occurrence is expressed as the ratio of the number of the events divided by the number of inpatient admissions.

The sample recruitment, sample size calculation, ethical approval, randomization scheme, and statistical methodology for the MERIT study have been described previously (10). Data collection was conducted during the 12-mo duration of the MERIT study (from June 2002 to May 2003). This consisted of a 2-mo baseline period, followed by a 4-mo standardized implementation period and a 6-mo study period. The standardized implementation period consisted of lectures, videos, presentations, and awareness raising tutorials to prepare nursing and medical staff for the coming introduction of an RRS. The RRS was operational in the RRS hospitals during the 6-mo study period (10).

Data collection was conducted in control hospitals during the same time periods. The conduct of the study was not publicized in the control hospitals, and the management and resuscitation committees of the control hospitals agreed that the operation of their CATs would not change during the implementation and study periods. The University of New South Wales and participating hospital ethics committees reviewed and approved the study.

Statistical Methods. To test our hypotheses, we analyzed the data by month. This generated a final monthly database of 276 observations (23 hospitals × 12 mos).

We used the random effect model with first-order autoregression (1) as suggested by Baltagi and Wu (11) as our main analytical method. The data structure of this study was that each hospital had 12 observations that amounted to a cluster effect. Furthermore, these 12 mos were consecutive, thus having a time series or seasonal effect. The random effect featured in this model accounted for cluster effect (hospital), and the autoregression (1) accounted for the time series/seasonal effect (12 mos). The predictors used in the model included the proportion of early emergency reviews (early reviews/total emergency team reviews), teaching hospital status (teaching vs. nonteaching), location of hospital (rural vs. metropolitan), number of hospital beds, phases of the study (implementation vs. baseline, study vs. baseline), and RRS status (RRS vs. control).

We tested the interaction effect between the proportion of early emergency reviews and the allocation of the hospital to either RRS or control hospitals. If we did not find an interaction effect, we excluded the interaction term from the model to be parsimonious.

All the predictors were simultaneously entered into the model. Given the multiple tests done in this *post hoc* analysis, we used a p value of 0.01 as indicative of statistical significance. All the analyses were conducted using Stata 9.2 (Stata, College Station, TX) (12).

RESULTS

Table 1 presents the baseline characteristics of the study hospitals and patients. Table 2 presents the median of the

Table 1. Hospital and patient characteristics during the baseline period

	Control Hospitals	RRS Hospitals
Hospital characteristics		
Teaching hospital	8	9
Nonteaching hospital	3	3
Median bed number (IQR)	315 (229–400)	364 (182–457)
Metropolitan location	9	9
Nonmetropolitan location	2	3
Patient characteristics		
Number	56,756	68,376
Median admission number per hospital (IQR)	5856 (2784–6946)	6494 (2812–7961)
Mean age (yrs, SD)	56.9 (20.8)	55.4 (19.9)
Number of male individuals (%)	26,775 (47.2)	33,965 (49.7)

RRS, rapid response system; IQR, interquartile range.

Table 2. Monthly rate of study outcomes (median number of events/1000 admissions) during 12 months for control and RRS hospitals

	Aggregated Outcome		Unexpected Cardiac Arrests		Unplanned ICU Admissions		Unexpected Deaths		All Cardiac Arrests		All Deaths	
Month	Control	RRS	Control	RRS	Control	RRS	Control	RRS	Control	RRS	Control	RRS
1	6.02	5.32	1.46	1.43	2.84	2.97	1.05	1.49	1.49	1.43	9.05	12.18
2	8.13	5.31	3.49	1.50	3.57	2.99	1.91	1.09	3.49	1.62	11.72	11.92
3	6.10	5.57	2.34	1.66	4.43	3.99	1.54	.99	2.60	1.75	11.23	10.71
4	5.44	4.07	1.90	1.91	3.68	3.21	1.38	1.08	1.90	2.04	10.41	10.69
5	5.70	5.37	1.94	1.43	3.63	4.01	0.99	1.05	1.94	1.89	9.50	11.49
6	5.05	4.51	1.99	0.92	3.37	3.85	1.08	0.80	2.15	0.92	9.55	10.72
7	4.55	4.39	1.42	0.85	3.85	3.00	0.63	0.68	1.42	0.85	10.16	8.73
8	4.23	4.67	1.22	1.15	3.27	4.08	1.08	0.73	1.22	1.19	10.83	8.17
9	3.43	5.42	1.17	1.24	2.42	3.51	1.01	1.34	1.62	1.44	9.06	8.92
10	5.25	4.92	1.42	1.59	3.77	3.72	0.88	1.03	1.42	1.59	6.78	8.70
11	5.54	4.80	1.18	1.08	4.73	4.05	1.11	1.06	1.18	1.22	9.70	10.02
12	4.79	5.09	2.09	1.18	3.38	3.48	1.13	1.18	2.09	1.20	10.17	8.30

RRS, rapid response system; ICU, intensive care unit.

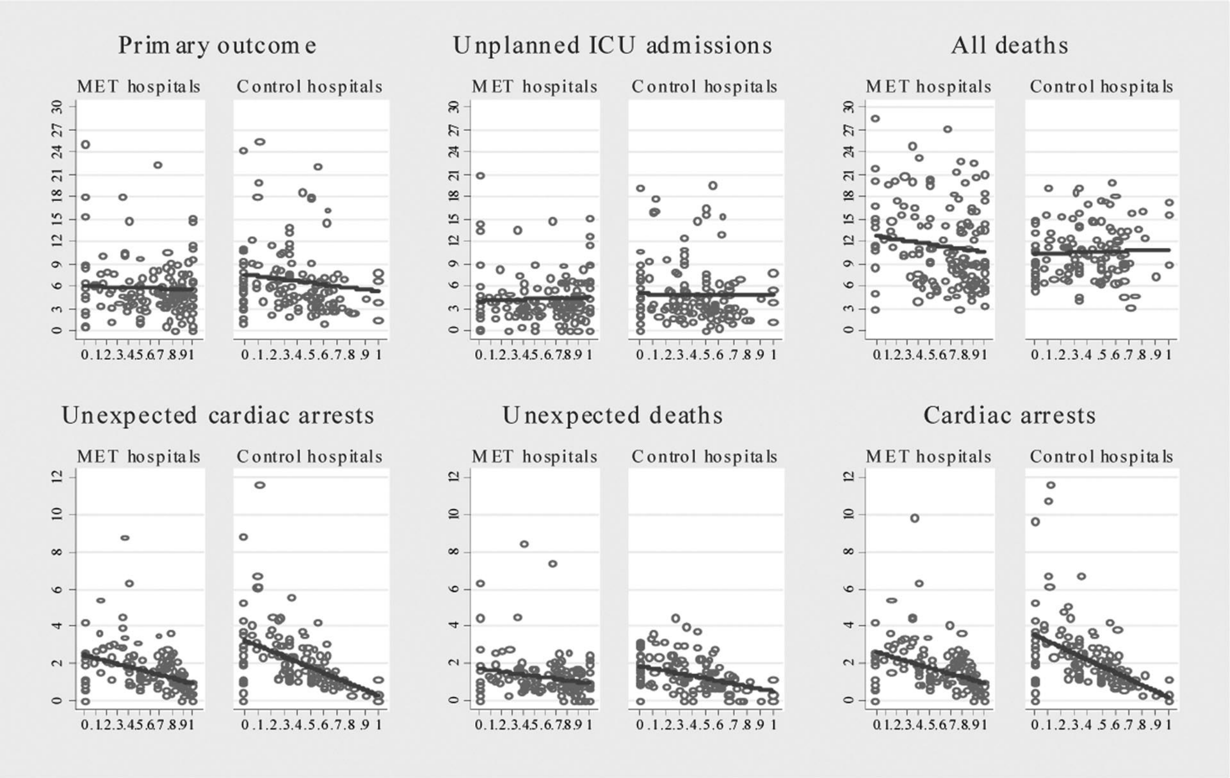

Figure 1. Scatter plot and fitted line for the relationship between the proportion of early emergency team calls (x-axis) and the occurrence of each outcome (y-axis) in rapid response system (RRS) and control hospitals. *The lines were derived using a random effect with first-order autoregression model with the proportion of early emergency team calls as the only predictor for each outcome; the occurrence was measured as the events per 1000 admissions. *MET*, medical emergency team; *ICU*, intensive care unit.

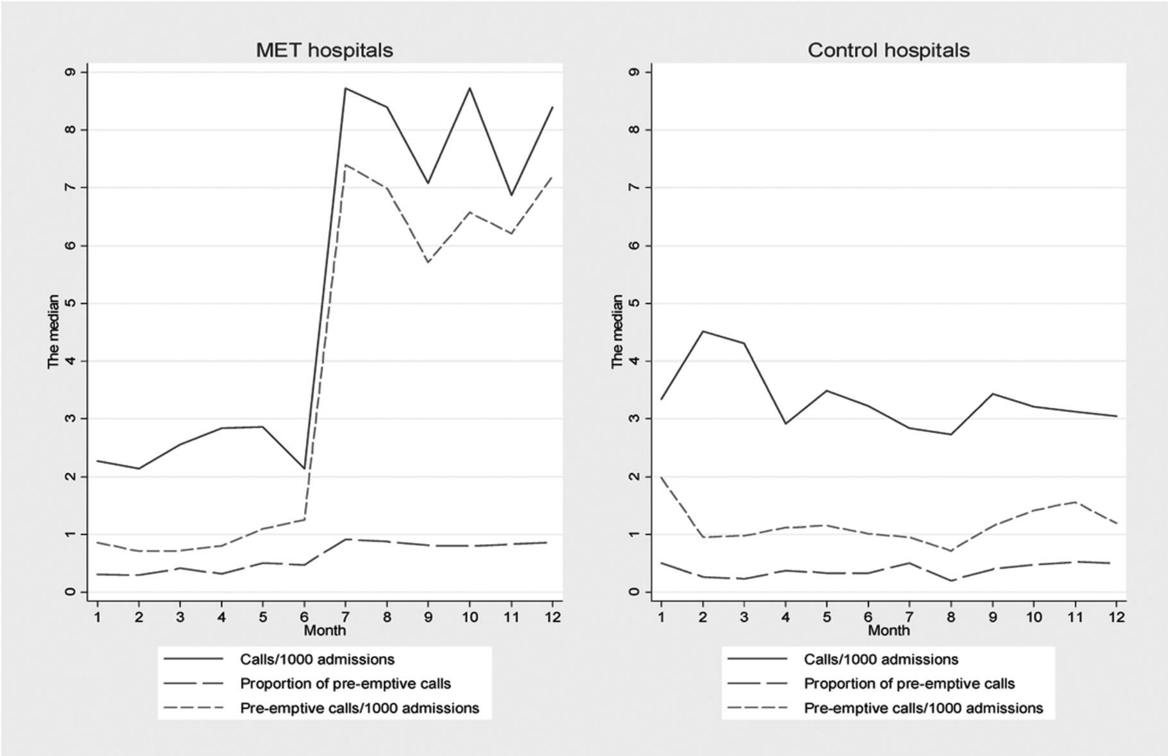

Figure 2. Median rate of total calls, early emergency team calls, and proportion of early emergency team calls during 12 mos (rapid response system [RRS] vs. control hospitals). *Overall emergency team call rate and rate of early emergency team calls were measured as number of calls as per 1000 admissions; proportion of early emergency team calls was defined as rate of early emergency team calls/overall emergency team call rate. The rate and proportion were calculated monthly for each hospital. *MET*, medical emergency team.

monthly study outcomes, for RRS and control hospitals. Figure 1 shows the raw and predicted relationship between study outcomes and the proportion of early emergency team calls for control and RRS hospitals, separately. Figure 2 shows the overall emergency team call rate, the proportion of early emergency team calls, and the *rate* of early emergency team calls. During the study period, there was a downward trend for all outcomes except unplanned ICU admissions in both control and RRS hospitals. There was an increase in overall rate of emergency team calls and in the proportion of early emergency team calls in RRS hospitals (Fig. 2). There was also a marked increase in the rate of early emergency team calls in RRS hospitals during the study period (i.e., after 6 mos). The Pearson correlation coefficients between the proportion of early emergency team calls and the outcomes are presented in Table 3.

There was no significant interaction effect between RRS allocation and proportion of early emergency team calls for all outcomes, except for overall deaths. Thus, study outcomes are presented for all hospitals combined, except for overall deaths (Table 4). There was also no significant relationship (b = −0.94; 95% confidence interval [CI]: −2.13 to 0.26; p = 0.125) (Table 4) between the proportion of early emergency team calls and the aggregate of all the adverse events.

However, there was a significant inverse relationship (b = −1.99; 95% CI: −2.59 to −1.39; $p < 0.001$) between the proportion of early emergency team calls and unexpected cardiac arrests. A 10% increase in the proportion of early emergency team calls was associated with a reduction in unexpected cardiac arrests 1.99 for every 10,000 hospital admissions (Table 4).

There was also a significant inverse relationship (b = −0.94; 95% CI: −1.43 to −0.46; $p < 0.001$) for unexpected deaths and significant inverse relationship (b = −2.21; 95% CI: −2.86 to −1.56; $p < 0.001$) for all cardiac arrests. A 10% increase in the proportion of early emergency team calls was associated with a reduction in unexpected deaths of 0.94 per 10,000 hospital admissions and a reduction in all cardiac arrests of 2.21 per 10,000 hospital admissions (Table 4).

There was no significant relationship for unplanned ICU admissions and early emergency team calls (b = 0.41; 95% CI: −0.57 to 1.38; p = 0.414) (Table 4).

For all deaths, all hospitals combined, there seemed to be a trend toward an interaction effect between RRS allocation (RRS = 1; control = 0) and the proportion of early emergency team calls (b = −3.01; 95% CI: −5.79 to −0.23; p = 0.034). For RRS hospitals, there was a trend toward a significant reduction in overall mortality during the study period compared with baseline (b = −2.38; 95% CI: −4.25 to −0.51; p = 0.012). Being in an RRS hospital was associated with a significant 2.38 reduction in the number of deaths per 1000 admissions during the study period in comparison with the baseline period. In control hospitals, this reduction (0.73/1000 admissions) was not statistically significant (95% CI: −0.63 to 2.09).

DISCUSSION

In a *post hoc* analysis of data collected during the MERIT study, we found a sig-

Table 3. Pearson correlation coefficients between the study outcomes and the proportion of early emergency team calls in control and RRS hospitals separately

Pearson Correlation Coefficient	Aggregate Outcome/1000 Admissions	Cardiac Arrest—DNAR/1000 Admissions	Unplanned ICU Admissions/1000 Admissions	Death—DNAR/1000 Admissions	Cardiac Arrest/1000 Admissions	Death/1000 Admissions
Control hospitals	−0.193	−0.440	−0.075	−0.371	−0.427	0.120
p	0.027[a]	<0.001[b]	0.393	<0.001[b]	<0.001[b]	0.169
RRS hospitals	−0.116	−0.410	−0.020	−0.244	−0.440	−0.269
p	0.167	<0.001[b]	0.811	0.003 [b]	<0.001[b]	0.001[b]

RRS, rapid response system; DNAR, do not attempt resuscitation; ICU, intensive care unit.
[a]$p < 0.05$; [b]$p < 0.01$.

Table 4. Regression coefficients (b) and their 95% confidence intervals for relevant study variables using the proportion of early emergency team calls as the proxy for dose (values derived from the random effect model with auto regression)

Predictors	Aggregate Outcome/1000 Admissions All Hospitals	Cardiac Arrest—DNAR/1000 Admissions All Hospitals	Unplanned ICU Admissions/1000 Admissions All Hospitals
Early emergency team calls/total calls	−0.94 (−2.13 to 0.26)	−1.99 (−2.59 to −1.39)[a]	0.41 (−0.57 to 1.38)
Teaching vs. nonteaching	2.39 (−1.45 to 6.23)	0.22 (−0.55 to 0.99)	2.84 (−0.57 to 6.25)
Rural vs. metro	1.96 (−2.05 to 5.97)	−0.37 (−1.18 to 0.43)	2.30 (−1.26 to 5.86)
Hospital beds (using 100 beds as unit)	−0.60 (−1.77 to 0.56)	0.01 (−0.22 to 0.24)	−0.60 (−1.63 to 0.44)
Implementation period vs. baseline	−0.16 (−1.08 to 0.76)	−0.08 (−0.54 to 0.38)	0.05 (−0.69 to 0.79)
Study vs. baseline	−0.35 (−1.34 to 0.64)	−0.10 (−0.60 to 0.39)	−0.22 (−1.01 to 0.57)
RRS vs. control	−0.92 (−3.67 to 1.83)	−0.14 (−0.70 to 0.43)	−0.94 (−3.37 to 1.50)
Constant	2.82 (−6.46 to 12.09)	2.97 (1.09 to 4.85)[a]	−0.78 (−9.01 to 7.44)
Observations	276	276	276
Number of hospitals	23	23	23

95% confidence intervals are given in parentheses.
RRS, rapid response system; DNAR, do not attempt resuscitation; ICU, intensive care unit.
[a]Significant at 1%; [b]Significant at 5%.

nificant inverse relationship between the proportion of early emergency team calls and unexpected deaths, unexpected cardiac arrests, and overall cardiac arrests across all study hospitals such that an increased proportion of early emergency team calls was associated with a reduction in the rate of these serious adverse events.

Our findings are consistent with the concept that the incidence of unexpected deaths, unexpected cardiac arrests, and overall cardiac arrests may be reduced by the early delivery of emergency patient care. Responding earlier to the needs of the critically ill patient is the principle underlying rapid response and outreach systems. It seems intuitive that the more frequently an emergency team reviews a critically ill patient before the occurrence of a cardiac arrest or death, the less likely such an outcome will be. The benefit of early intervention in the care of critically ill patients is supported by studies of patients with the acute conditions, such as myocardial infarction, stroke, and trauma (13–15). However, there is no prospective, multicenter study to support this concept across the overall population of hospital ward patients. Our study provides evidence to support this concept. The observation of an inverse dose–response relationship may be important in the decision to implement an RRS. For example, if increasing the proportion of early emergency team calls reduces serious adverse events in hospital patients, tracking the number of calls may assist in assessing the effectiveness of any implementation strategy for an RRS.

The observed trend toward a reduction in deaths for hospitals assigned to the RRS was not explained by a dose–response relationship. This observation may represent a chance finding or may indicate that, at a sufficiently high dose, early emergency team activity may reduce hospital mortality. This latter concept is consistent with the results of a cluster-randomized trial of the outreach system, which also showed a significant reduction in the overall mortality rate (16), and a historical control study of the RRS (17). Other studies, however, have not shown a reduction in overall hospital mortality after implementing an RRS (18) or when comparing hospitals with and without an RRS (19). The mechanisms responsible for these effects remain unknown. It is possible that one important mechanisms is related to the educational effect of introducing an RRS and increasing awareness of the adverse consequences of physiologic instability (20).

Another possible mechanism by which early emergency team calls might decrease the incidence of unexpected cardiac arrests and deaths is that emergency teams evaluate patients and help clinicians decide that cardiopulmonary resuscitation should not be attempted (DNAR orders). As more than 90% of deaths in the study hospitals were preceded by a formal DNAR order, this activity might be important. Thus, in RRS hospitals, patients may still die but not be counted as an unexpected cardiac arrest or unexpected death. However, the trend toward reduced overall mortality in RRS hospitals is not consistent with this "re-classification" theory. A future formal investigation of how the introduction of an RRS affects the designation of DNAR orders would be a valuable addition to current knowledge.

Early emergency team calls did not seem to affect the incidence of unplanned ICU admissions. The effect of early emergency team calls on unplanned ICU admissions may be more complex and vary between hospitals. It could increase ICU admissions by better identifying acutely ill patients or it may also reduce ICU admissions by preventing clinical deterioration through earlier intervention. It may also be related to individual hospital characteristics, such as differences in case mix or ICU bed availability. For example, we found that teaching hospital status was associated with a higher likelihood of unplanned ICU admissions. Other contributing factors may include the quality of clinical skills in general wards and emergency team training. We do not have sufficient data to gain further insight into these complex factors.

Our study has several limitations. First, it is a *post hoc* study, and it reports multiple outcomes. As such it carries a greater risk of reporting false-positive results. The relationship we report may represent an association rather than evidence of causation. It is possible that other uncontrolled factors, such as changes in the pattern of patient care or patient case mix influenced early emergency team calls, and the occurrence of adverse outcomes and so may have been solely or partly influenced our results. Our study has several strengths. The data come from the MERIT study that is the largest cluster-randomized controlled trial of an acute care intervention to date. The data were collected prospectively in

Table 4.—*Continued*

Death—DNAR/1000 Admissions All Hospitals	Cardiac Arrest/1000 Admissions All Hospitals	Death/1000 Admissions RRS Hospitals	Death/1000 Admissions Control Hospitals
−0.94 (−1.43 to −0.46)[a]	−2.21 (−2.86 to −1.56)[a]	−0.11 (−2.41 to 2.19)	0.85 (−1.29 to 2.99)
−0.63 (−1.13 to −0.12)[b]	0.19 (−0.62 to 1.00)	−10.23 (−15.11 to −5.35)[a]	2.37 (−0.98 to 5.73)
0.04 (−0.49 to 0.56)	−0.43 (−1.28 to 0.42)	−1.45 (−6.63 to 3.74)	0.28 (−3.24 to 3.80)
0.07 (−0.08 to 0.23)	0.01 (−0.23 to 0.26)	0.60 (−0.79 to 1.98)	0.29 (−0.80 to 1.38)
−0.30 (−0.67 to 0.08)	−0.07 (−0.57 to 0.43)	−0.93 (−2.50 to 0.64)	0.03 (−1.39 to 1.45)
−0.24 (−0.64 to 0.17)	−0.13 (−0.66 to 0.40)	−2.38 (−4.25 to −0.51)[b]	−0.73 (−2.09 to 0.63)
0.10 (−0.27 to 0.48)	−0.12 (−0.72 to 0.47)		
2.70 (1.46 to 3.93)[a]	3.31 (1.33 to 5.30)[a]	30.61 (17.61 to 43.61)[a]	5.08 (−2.40 to 12.56)
276	276	144	132
23	23	12	11

multiple centers using standardized definitions with formal data monitoring and verification. The statistical analysis plan was set before any knowledge of the findings and was applied as planned.

Our study focused on a question that was not addressed in the initial MERIT study results (10). Our results suggest that increasing the number of early emergency team calls may have a beneficial effect on important patient-centered outcomes. Clinicians and policy makers should consider the formal implementation of an early warning system in any acute hospital for which they are responsible. The decision whether to implement such a system or change the structure of the system where one already exists might be guided by knowledge of the proportion of emergency team calls in the existing system that occur before cardiac arrest or death. Although a number of early warning systems have been proposed, they have not been compared head-to-head; thus, it is not possible to recommend one over another. Regardless of the approach chosen, tracking the proportion of early emergency team calls may provide an objective way to monitor such systems and audit their performance over time.

Our analysis also points toward the need for further investigations. For example, to what extent is the reduction in unexpected deaths and cardiac arrests due to designating more patients as DNAR? Is any one early warning system better than another? How do the type and quality of interventions delivered during early emergency team calls affect these outcomes, if at all? In addition, we have no knowledge of the impact of such systems on patients' longer-term survival or health-related quality of life or on healthcare costs. Future research should address these issues.

In summary, we have conducted a *post hoc* analysis that supports the existence of an inverse "dose–response relationship" between the proportion of early emergency team calls and serious adverse events. The greater the proportion of early emergency team calls, the lower the occurrence of such events. These findings provide support for the concept of early warning and response systems in the care of acutely ill-ward patients.

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