Duration of in-hospital resuscitation: when to call time?

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Cardiopulmonary resuscitation guidelines are fairly standardised and didactic but recommendations on when to terminate in-hospital resuscitation attempts are less precise, which often means that resuscitation teams have to make subjective decisions.[1,2] Validated clinical decision strategies for stopping in-hospital resuscitation exist, but are derived from guidelines no longer in use and thus are rarely used in clinical practice.[3]

In *The Lancet*, Zachary Goldberger and colleagues[4] have used the American Heart Association's Get with the Guidelines—Resuscitation registry (globally, the largest in-hospital cardiac arrest registry) to assess the duration of resuscitation before termination of efforts in non-survivors as an indicator of the overall tendency of a hospital to attempt resuscitation for longer. They analysed data from 64 339 patients with cardiac arrests at 435 US hospitals between 2000 and 2008. Cardiac arrests that lasted less than 2 min were excluded. In the whole study population, the median resuscitation duration was 17 min (IQR 10–26); 31 198 patients (48·5%) achieved return of spontaneous circulation (ie, restoration of a pulse for at least 20 min) and 9912 (15·4%) survived to hospital discharge. Of the 48·5% of patients who achieved return of spontaneous circulation, circulation returned within 10 min in 44·8% and within 30 min in 87·6%. The median resuscitation time was 12 min (IQR 6–21) in patients achieving return of spontaneous circulation and 20 min (14–30) in non-survivors.

Hospitals were classified into quartiles on the basis of the median duration of resuscitation in non-survivors: 16, 19, 22, and 25 min were the median resuscitation durations for the first to fourth quartiles, respectively. Patients at hospitals in the quartile with a median resuscitation duration of 25 min (ie, the longest quartile in non-survivors) were significantly more likely to achieve return of spontaneous circulation (adjusted risk ratio 1·12, 95% CI 1·06–1·18; p<0·0001) and survive to discharge (1·12, 1·02–1·23; 0·021) than were those at hospitals in the quartile with a median duration of 16 min (ie, the shortest quartile in non-survivors). The difference was greatest in cardiac arrests in which the initial rhythm was asystole or pulseless electrical activity. The proportion of patients surviving to discharge with a favourable neurological status (ie, a cerebral performance category score of 1 or 2) did not differ significantly across all quartiles (p=0·858).

730 (8·4%) of the 8724 patients surviving to hospital discharge who had neurological assessments did not achieve return of spontaneous circulation until after 30 min or more of resuscitation attempts; this was broadly the case for all initial cardiac arrest rhythms. A small study[5] of 330 in-hospital resuscitation attempts in Taiwan had similar findings; five of the 58 people who survived to discharge achieved return of spontaneous circulation after 30 min of resuscitation.[5]

To our knowledge, Goldberger and coworkers' study is the first time that analysis of duration of resuscitation attempts in non-survivors has been used to assess a hospital's tendency for longer or shorter duration of resuscitation efforts and to relate this tendency to survival. The study's strength is its use of a large database that includes and adjusts for many of the known variables that affect outcome after cardiac arrest, including pre-existing patients' factors, treatment interventions, and time and location of the cardiac arrest.

Retrospective analyses of databases, such as that done by Goldberger and colleagues, have several limitations. The investigators have reported an association between median duration of resuscitation attempts in non-survivors and outcome in all patients, but it is possible that unmeasured confounders account for this finding. Variation between hospitals in duration of resuscitation attempts and outcome could be associated

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with process (eg, the presence of a rapid response system or the seniority and experience of the resuscitation team), cultural, and behavioural differences that a registry might not detect. Duration of resuscitation attempts could be a surrogate for the delivery of higher quality resuscitation—chest compression fraction (ie, the proportion of time spent delivering chest compressions during resuscitation attempts), depth, and rate are all associated with survival in out-of-hospital cardiac arrest.[6–8] Longer resuscitation attempts might reflect the ability of a hospital's resuscitation team to identify and treat potentially reversible causes of cardiac arrest (eg, echocardiography to detect and treat pericardial tamponade) or to allow time for interventions to work. Hospitals that offer a comprehensive package of care after cardiac arrest (including the use of therapeutic hypothermia and percutaneous coronary intervention), which improves survival,[9] might have a more aggressive approach to resuscitation than do hospitals that do not offer such comprehensive strategies. Infrequent implementation of so-called do-not-attempt resuscitation decisions could lead to shorter median resuscitation durations because the resuscitation team might tend to stop earlier in cases that are clearly futile. Only further observational data from other national audits—such as the UK National Cardiac Arrest Audit—will help to confirm and explain these findings because randomised trials are not ethically feasible.

For the **UK National Cardiac Arrest Audit** see https://ncaa.icnarc.org

Monitoring could provide information about the chances of successful return of spontaneous circulation. Promising technologies include waveform capnography to measure exhaled carbon dioxide and cerebral oximetry with near-infrared spectroscopy.[10,11] Alternatively, interventions such as extracorporeal life support can be used to increase the window for successful resuscitation.[12]

What are the implications for clinical practice? Goldberger and colleagues' study reassures clinicians that prolonged resuscitation attempts do not seem to result in a substantial increase in severe neurological injury in survivors. To improve outcomes, all hospitals should audit their cardiac arrests and benchmark outcomes as part of a quality improvement programme. Duration of resuscitation attempts should be established on a case-by-case basis and take into account other known determinants of survival. Prolonged resuscitation efforts can result in high-quality survival. If the cause of cardiac arrest is potentially reversible, it might be worthwhile to try for a little longer.

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Duration of resuscitation efforts and survival after in-hospital cardiac arrest: an observational study

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Summary

Background During in-hospital cardiac arrests, how long resuscitation attempts should be continued before termination of efforts is unknown. We investigated whether duration of resuscitation attempts varies between hospitals and whether patients at hospitals that attempt resuscitation for longer have higher survival rates than do those at hospitals with shorter durations of resuscitation efforts.

Methods Between 2000 and 2008, we identified 64 339 patients with cardiac arrests at 435 US hospitals within the Get With The Guidelines—Resuscitation registry. For each hospital, we calculated the median duration of resuscitation before termination of efforts in non-survivors as a measure of the hospital's overall tendency for longer attempts. We used multilevel regression models to assess the association between the length of resuscitation attempts and risk-adjusted survival. Our primary endpoints were immediate survival with return of spontaneous circulation during cardiac arrest and survival to hospital discharge.

Findings 31 198 of 64 339 (48·5%) patients achieved return of spontaneous circulation and 9912 (15·4%) survived to discharge. For patients achieving return of spontaneous circulation, the median duration of resuscitation was 12 min (IQR 6–21) compared with 20 min (14–30) for non-survivors. Compared with patients at hospitals in the quartile with the shortest median resuscitation attempts in non-survivors (16 min [IQR 15–17]), those at hospitals in the quartile with the longest attempts (25 min [25–28]) had a higher likelihood of return of spontaneous circulation (adjusted risk ratio 1·12, 95% CI 1·06–1·18; p<0·0001) and survival to discharge (1·12, 1·02–1·23; 0·021).

Interpretation Duration of resuscitation attempts varies between hospitals. Although we cannot define an optimum duration for resuscitation attempts on the basis of these observational data, our findings suggest that efforts to systematically increase the duration of resuscitation could improve survival in this high-risk population.

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Introduction

Between one and five of every 1000 hospital inpatients in developed countries are estimated to have a cardiac arrest, and less than 20% of such patients survive to discharge.[1,2] One of the biggest challenges facing clinicians is the decision about when to stop resuscitation efforts in patients who arrest. Clinicians are frequently reluctant to continue efforts when return of spontaneous circulation does not occur shortly after initiation of resuscitation, in view of the overall poor prognosis for such patients.[3] Furthermore, little empirical evidence is available to guide clinicians about the appropriate length of resuscitation attempts before termination of efforts. Thus, guidelines have not directly addressed this issue,[4,5] and clinicians rely largely on case series and expert opinion to guide their practice.[3,6–9] Although this strategy has probably led to substantial differences between hospitals in the duration of resuscitation attempts in non-survivors, little is known about the extent of such variation in routine practice and the potential relation with survival.

We assessed patterns of duration of resuscitation attempts and risk-adjusted survival at US hospitals. We focused on non-survivors to estimate each hospital's overall tendency for practising long attempts before termination of efforts. We then postulated that the duration of resuscitation in non-survivors would vary substantially between hospitals and that patients at hospitals in which the duration of resuscitation attempts was longer would have a higher likelihood of return of spontaneous circulation and survival to discharge than would those at hospitals with shorter resucitation attempts.

Methods

Data source

Get With The Guidelines—Resuscitation (previously known as the National Registry of Cardiopulmonary Resuscitation) is a large, multicentre observational registry of in-hospital cardiac arrests that previous investigators[10,11] have described in detail. Briefly, trained research personnel at participating hospitals prospectively collect information about consecutive patients with in-hospital cardiac arrests, which are defined by unresponsiveness, apnoea, and the absence of a central palpable pulse. Cases

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are identified by centralised collection of cardiac arrest flow sheets (ie, clinical records of the events and treatments given during cardiac arrest), reviews of logs of hospital electronic pages, routine checks for use of carts stocked with emergency resuscitation equipment, and hospital bills for resuscitation drugs. The registry uses standard Utstein definitions—precisely defined variables for uniform reporting of cardiac arrests developed by international experts.[12]

Study population

Between Jan 1, 2000, and Aug 26, 2008, we identified 93 535 patients aged 18 years or older at 537 acute care hospitals in the USA and Canada with an index in-hospital cardiac arrest (ie, the first arrest for a patient during hospital stay) due to pulseless ventricular tachycardia or fibrillation, pulseless electrical activity, or asystole. Because of the distinct circumstances of cardiac arrests in some settings, we excluded 18 604 patients whose cardiac arrest happened when they were in emergency departments, operating theatres, postoperative areas, procedure areas (eg, cardiac catheterisation, electrophysiology, and angiography suites), or rehabilitation areas, or if the location of the cardiac arrest was unknown or missing. We also excluded 1330 patients with implantable cardioverter defibrillators. We restricted our sample to hospitals that reported at least 6 months of data and in which ten or more cardiac arrests happened during the study. We excluded a further 6099 patients from 96 hospitals who did not meet these criteria. Finally, we excluded 3163 patients whose cardiac arrests lasted less than 2 min to avoid inclusion of so-called partial resuscitations or those for whom data for duration of resuscitation were incomplete (appendix). The institutional review board of the University of Michigan Medical School approved this study and waived the requirement for written informed consent.

See Online for appendix

Study definitions and endpoints

Our primary endpoints were immediate survival with return of spontaneous circulation during cardiac arrest and survival to hospital discharge. Return of spontaneous circulation was specifically defined as the restoration of a pulse for at least 20 min during the cardiac arrest. Additionally, we assessed whether increasing the duration of resuscitation attempts resulted in worse neurological status than did short resuscitation attempts, despite improvements in survival. We classified data for the neurological status of patients who survived to discharge into five groups on the basis of previously developed cerebral performance categories (no major disability, moderate disability, severe disability, coma or vegetative state, and brain death)[13] measured at the time of hospital discharge. Consistent with previous work,[14,15] we defined a favourable neurological status as a score of 1 or 2 (ie, no major disability or moderate disability).

Median duration of resuscitation attempts at a hospital in non-survivors—ie, patients who never achieved return of spontaneous circulation before termination of efforts—was the key independent variable for our analyses. We coded duration in minutes (as integers), and specifically defined it as the time from onset of cardiac arrest to termination of resuscitation efforts and declaration of the patient's death. We defined onset of cardiac arrest as the first recognition of apnoea, unresponsiveness, or the absence of a palpable central pulse. Termination of efforts referred to the time when cardiopulmonary resuscitation was stopped in patients without return of spontaneous circulation. We focused on non-survivors (rather than all patients) when calculating the median duration of resuscitation attempts for a hospital because we postulated that a hospital's overall propensity for long resuscitation efforts would be best shown by the length of attempts in patients who did not survive.

Statistical analysis

We stratified patients by survival status and used Kruskal-Wallis and χ^2 tests, as appropriate, to examine baseline differences in demographics and clinical characteristics across the strata of resuscitation duration (≤10, 11–19, 20–29, and ≥30 min). We then graphed the cumulative rates of return of spontaneous circulation in the entire study cohort and the distribution of duration of resuscitation attempts in non-survivors.

We used multilevel Poisson regression models with hospital-specific random intercepts to establish the association between patients achieving return of spontaneous circulation and the median duration of resuscitation attempts in their hospitals.[16] Because odds ratios generated from logistic regression can overestimate risk when the frequency of the outcome is high,[17,18] we used Poisson regression to directly estimate risk ratios. We classified hospitals into quartiles on the basis of median duration of resuscitation in non-survivors before their inclusion in these models.

On the basis of previous work,[19] the regression models were adjusted for additional patient-related covariates that can be linked to outcomes: shockable initial pulseless rhythms (pulseless ventricular tachycardia or fibrillation), age, race, illness category (medical non-cardiac, medical cardiac, surgical cardiac, trauma and surgical non-cardiac, obstetric, and other), pre-existing disorders (none, myocardial infarction during hospitalisation, hypotension or hypoperfusion, hepatic insufficiency, baseline depression in CNS function, acute stroke, infection or septicaemia, metastatic or haematological malignant disease, renal failure, major trauma), interventions in place at the time of cardiac arrest (invasive airway device, chest tube, assisted or mechanical ventilation, vasopressors, antiarrhythmics, vasodilators), monitoring with an arterial line, a witnessed cardiac arrest, event location (intensive-care unit, general floor or telemetry), and time from admission to event. The models also accounted for off-hours cardiac arrest (ie, between 2300 h and 0700 h or between 2300 h Friday and 0700 h Monday), initiation and time to first chest compressions, and study period (ie, 2000–02, 2003–05, and 2006–08). We also adjusted for hospital characteristics (ie, geographical region, rural location, availability of cardiothoracic surgery, and presence of an emergency department), which were available in 411 of the 435 (94·5%) hospitals after merging of our data with information available from the 2009 American Hospital Association Annual Survey. Missing information about hospital characteristics was accounted for with an indicator variable as a separate covariate.

We constructed similar regression models to assess survival to discharge and survival rates after stratification of patients on the basis of their presenting heart rhythm

For the **American Hospital Association survey** see http://www.ahadataviewer.com

	Overall (n=31 198)	≤10 min (n=13 964)	11–19 min (n=7881)	20–29 min (n=4933)	≥30 min (n=4420)	p value
Age (years)	69 (57–78)	68 (56–78)	69 (57–78)	70 (57–79)	68 (56–78)	0·0001
Male sex	17 405 (55·8%)	7753 (55·5%)	4439 (56·3%)	2750 (55·8%)	2463 (55·7%)	0·723
Race						<0·0001
Black	5921 (19·0%)	2615 (18·7%)	1672 (21·2%)	842 (17·1%)	792 (17·9%)	
Non-black	25 277 (81·0%)	11 349 (81·3%)	6209 (78·8%)	4091 (82·9%)	3628 (82·1%)	
Pre-existing disorders						
Renal insufficiency	11 576 (37·1%)	5064 (36·3%)	3083 (39·1%)	1840 (37·3%)	1589 (36·0%)	<0·0001
Hepatic insufficiency	2748 (8·8%)	1244 (8·9%)	699 (8·9%)	412 (8·4%)	393 (8·9%)	0·676
Malignant disease	3725 (11·9%)	1582 (11·3%)	1027 (13·0%)	600 (12·2%)	516 (11·7%)	0·002
Decrease in CNS function	4347 (13·9%)	2064 (14·8%)	1120 (14·2%)	644 (13·1%)	519 (11·7%)	<0·0001
Septicaemia	5534 (17·7%)	2547 (18·2%)	1459 (18·5%)	845 (17·1%)	683 (15·5%)	<0·0001
Major trauma	1082 (3·5%)	577 (4·1%)	247 (3·1%)	132 (2·7%)	126 (2·9%)	<0·0001
Acute stroke	1398 (4·5%)	650 (4·7%)	350 (4·4%)	221 (4·5%)	177 (4·0%)	0·339
None	956 (3·1%)	392 (2·8%)	225 (2·9%)	158 (3·2%)	181 (4·1%)	<0·0001
Hypotension or hypoperfusion	8973 (28·8%)	4166 (29·8%)	2176 (27·6%)	1378 (27·9%)	1253 (28·4%)	0·002
Myocardial infarction during admission	6127 (19·6%)	2903 (20·8%)	1416 (18·0%)	938 (19·0%)	870 (19·7%)	<0·0001
Critical care interventions in place at time of cardiac arrest						
Assisted or mechanical ventilation	9474 (30·4%)	5071 (36·3%)	2067 (26·2%)	1221 (24·8%)	1115 (25·2%)	<0·0001
Invasive airway devices	9360 (30·0%)	4996 (35·8%)	2030 (25·8%)	1217 (24·7%)	1117 (25·3%)	<0·0001
Vasopressors	8772 (28·1%)	4396 (31·5%)	2008 (25·5%)	1235 (25·0%)	1133 (25·6%)	<0·0001
Antiarrhythmics	2327 (7·5%)	1182 (8·5%)	523 (6·6%)	318 (6·5%)	304 (6·9%)	<0·0001
Vasodilators	495 (1·6%)	265 (1·9%)	91 (1·2%)	69 (1·4%)	70 (1·6%)	<0·0001
Arterial line	3480 (11·2%)	1875 (13·4%)	730 (9·3%)	440 (8·9%)	435 (9·8%)	<0·0001
Chest tube	1348 (4·3%)	685 (4·9%)	272 (3·5%)	205 (4·2%)	186 (4·2%)	<0·0001
Location						<0·0001
Intensive-care unit	18 528 (59·4%)	9323 (66·8%)	4160 (52·8%)	2602 (52·8%)	2443 (55·3%)	
General floor or telemetry	12 670 (40·6%)	4641 (33·2%)	3721 (47·2%)	2331 (47·3%)	1977 (44·7%)	
Rhythm during cardiac arrest						<0·0001
Ventricular tachycardia or fibrillation	8040 (25·8%)	3912 (28·0%)	1799 (22·8%)	1236 (25·0%)	1093 (24·7%)	
Pulseless electrical activity or asystole	23 158 (74·2%)	10 052 (72·0%)	6082 (77·2%)	3697 (75·0%)	3327 (75·3%)	
Illness category						<0·0001
Medical, cardiac	10 537 (33·8%)	4713 (33·8%)	2611 (33·1%)	1694 (34·3%)	1519 (34·4%)	
Medical, non-cardiac	13 442 (43·1%)	5808 (41·6%)	3646 (46·3%)	2174 (44·1%)	1814 (41·0%)	
Surgical, cardiac	2907 (9·3%)	1419 (10·2%)	574 (7·3%)	439 (8·9%)	475 (10·8%)	
Trauma and surgical, non-cardiac	4263 (13·7%)	2007 (14·4%)	1038 (13·2%)	619 (12·6%)	599 (13·6%)	
Obstetric	29 (0·09%)	11 (0·08%)	7 (0·09%)	4 (0·08%)	7 (0·16%)	
Other	20 (0·06%)	6 (0·04%)	5 (0·06%)	3 (0·06%)	6 (0·14%)	
Cardiac arrest witnessed						<0·0001
Witnessed	25 367 (81·3%)	11 907 (85·3%)	6162 (78·2%)	3790 (76·8%)	3508 (79·4%)	
Not witnessed	5831 (18·7%)	2057 (14·7%)	1719 (21·8%)	1143 (23·2%)	912 (20·6%)	
Cardiac arrest at night* or weekend†	12 929 (41·4%)	5518 (39·5%)	3430 (43·5%)	2071 (42·0%)	1910 (43·2%)	<0·0001

Data are median (IQR) or n (%) unless otherwise stated. Because of rounding, percentages might not add up to 100% exactly. *Night=2300 h–0700 h. †Weekend=2300 h Friday–0700 h Monday.

Table 1: **Baseline characteristics of patients achieving return of spontaneous circulation, stratified by duration of resuscitation**

(asystole or pulseless electrical activity *vs* pulseless ventricular tachycardia or fibrillation).

Finally, we assessed whether high survival rates in patients at hospitals with long median resuscitation attempts were associated with poor neurological status in survivors because of prolonged resuscitation efforts. For these analyses, we constructed regression models that examined the likelihood of survival with a favourable neurological status (defined as a cerebral performace category score of 1 or 2) across the quartiles of hospitals.

During all analyses, we deemed p values of less than 0·05 to be significant, and all tests were two sided. We used Stata (version 11·2) for all analyses.

Role of the funding source

The American Heart Association, its Executive Database Steering Committee and the staff at its national centre,

	Overall (n=33 141)	≤10 min (n=5221)	11–19 min (n=10 083)	20–29 min (n=9061)	≥30 min (n=8776)	p value
Age (years)	70 (57–80)	72 (59–82)	72 (59–81)	70 (57–79)	67 (55–77)	0·0001
Male sex	19 736 (59·6%)	3103 (59·4%)	6023 (59·7%)	5483 (60·5%)	5127 (58·4%)	0·040
Race						<0·0001
Black	7188 (21·7%)	1058 (20·3%)	2213 (22·0%)	2092 (23·1%)	1825 (20·8%)	
Non-black	25 953 (78·3%)	4163 (79·7%)	7870 (78·1%)	6969 (76·9%)	6951 (79·2%)	
Pre-existing disorders						
Renal insufficiency	11 458 (34·6%)	1884 (36·1%)	3545 (35·1%)	3088 (34·1%)	2941 (33·5%)	0·007
Hepatic insufficiency	2724 (8·2 %)	557 (10·7%)	859 (8·5%)	698 (7·7%)	610 (7·0%)	<0·0001
Malignant disease	4995 (15·1%)	923 (17·7%)	1656 (16·4%)	1301 (14·4%)	1115 (12·7%)	<0·0001
Decrease in CNS function	4855 (14·7%)	934 (17·9%)	1619 (16·1%)	1255 (13·9%)	1047 (11·9%)	<0·0001
Septicaemia	5752 (17·4%)	1150 (22·0%)	1915 (19·0%)	1413 (15·6%)	1274 (14·5%)	<0·0001
Major trauma	1173 (3·5%)	263 (5·0%)	354 (3·5%)	280 (3·1%)	276 (3·2%)	<0·0001
Acute stroke	1503 (4·5%)	262 (5·0%)	471 (4·7%)	412 (4·6%)	358 (4·1%)	0·059
None	1302 (3·9%)	162 (3·1%)	378 (3·8%)	383 (4·2%)	379 (4·3%)	0·001
Hypotension or hypoperfusion	9734 (29·4%)	1881 (36·0%)	2908 (28·8%)	2419 (26·7%)	2526 (28·8%)	<0·0001
Myocardial infarction during admission	5300 (16·0%)	685 (13·1%)	1419 (14·1%)	1516 (16·7%)	1680 (19·2%)	<0·0001
Critical care interventions in place at time of arrest						
Assisted or mechanical ventilation	10 140 (30·6%)	2304 (44·1%)	3052 (30·3%)	2258 (24·9%)	2526 (28·8%)	<0·0001
Invasive airway devices	9967 (30·1%)	2271 (43·5%)	3030 (30·1%)	2232 (24·6%)	2434 (27·7%)	<0·0001
Vasopressors	9856 (29·7%)	2163 (41·4%)	2956 (29·3%)	2258 (24·9%)	2479 (28·3%)	<0·0001
Antiarrhythmics	1468 (4·4%)	288 (5·5%)	385 (3·8%)	361 (4·0%)	434 (5·0%)	<0·0001
Vasodilators	379 (1·1%)	40 (0·8%)	93 (0·9%)	113 (1·3%)	133 (1·5%)	<0·0001
Arterial line	2853 (8·6%)	587 (11·2%)	808 (8·0%)	633 (7·0%)	825 (9·4%)	<0·0001
Chest tube	941 (2·8%)	164 (3·1%)	220 (2·2%)	215 (2·4%)	342 (3·9%)	<0·0001
Location						<0·0001
Intensive-care unit	17 886 (54·0%)	3339 (64·0%)	5181 (51·4%)	4371 (48·2%)	4995 (56·9%)	
General floor or telemetry	15 255 (46·0%)	1882 (36·1%)	4902 (48·6%)	4690 (51·8%)	3781 (43·1%)	
Rhythm during cardiac arrest						<0·0001
Ventricular tachycardia or fibrillation	4884 (14·7%)	641 (12·3%)	1326 (13·2%)	1408 (15·5%)	1509 (17·2%)	
Pulseless electrical activity or asystole	28 257 (85·3%)	4580 (87·7%)	8757 (86·8%)	7653 (84·5%)	7267 (82·8%)	
Illness category						<0·0001
Medical, cardiac	10 040 (30·3%)	1419 (27·2%)	2836 (28·1%)	2821 (31·1%)	2964 (33·8%)	
Medical, non-cardiac	16 701 (50·4%)	2841 (54·4%)	5445 (54·0%)	4572 (50·5%)	3843 (43·8%)	
Surgical, cardiac	1692 (5·1%)	193 (3·7%)	359 (3·6%)	401 (4·4%)	739 (8·4%)	
Trauma and surgical, non-cardiac	4667 (14·1%)	766 (14·7%)	1435 (14·2%)	1255 (13·9%)	1211 (13·8%)	
Obstetric	26 (0·08%)	1 (0·02%)	5 (0·05%)	6 (0·07%)	14 (0·16%)	
Other	15 (0·05%)	1 (0·02%)	3 (0·03%)	6 (0·07%)	5 (0·06%)	
Cardiac arrest witnessed						<0·0001
Witnessed	24 551 (74·1%)	4023 (77·1%)	7158 (71·0%)	6471 (71·4%)	6899 (78·6)	
Not witnessed	8590 (25·9%)	1198 (23·0%)	2925 (29·0%)	2590 (28·6%)	1877 (21·4%)	
Cardiac arrest at night* or weekend†	15 504 (46·7%)	2408 (46·1%)	4749 (47·1%)	4253 (47·0%)	4094 (46·7%)	<0·0001

Data are median (IQR) or n (%) unless otherwise stated. Because of rounding, percentages might not add up to 100% exactly. *Night=2300 h–0700 h. †Weekend=2300 h Friday–0700 h Monday.

Table 2: **Baseline characteristics of non-survivors, stratified by duration of resuscitation**

and the Get With The Guidelines—Resuscitation Clinical Working Group oversaw data collection, analysis, and reporting. Research proposals to Get With The Guidelines—Resuscitation are sequentially reviewed by a data manager, the research task force, and a Clinical Working Group sponsor; final approval is granted by the Executive Database Steering Committee. The original draft of the report was reviewed by the Executive Database Steering Committee and appropriate revisions were made before submission. The final draft was approved by the American Heart Association's Clinical Working Group. ZDG and BKN had full access to the study data and had final responsibility to submit for publication. The National Institutes of Health and the Robert Wood Johnson Foundation had no role in study design or data collection.

Results

We identified 64 339 patients with an in-hospital cardiac arrest at 435 hospitals (appendix). The initial cardiac arrest rhythm was ventricular tachycardia or fibrillation in 12 924 (20·1%) patients and pulseless electrical activity or asystole in 51 415 (79·9%). Median duration of resuscitation in the study population (including both survivors and non-survivors) was 17 min (IQR 10–26). 31 198 (48·5%) patients achieved return of spontaneous circulation and 33 141 (51·5%) died after termination of resuscitation efforts. The median duration of resuscitation was 12 min (IQR 6–21) for patients achieving return of spontaneous circulation and 20 min (14–30) for non-survivors.

Mean length of stay in hospital (truncated at death or hospital discharge) was 8·3 days (SD 15·0) in patients achieving return of spontaneous circulation. 9912 (15·4%) patients survived to discharge with a mean hospital stay after return of spontaneous circulation of 16·6 days (SD 18·0). Information about neurological status was available for 8724 of 9912 (88·0%) patients who survived to discharge. 7034 of the 8724 patients (80·6%) who survived to discharge and had assessments of cerebral performance category had a favourable neurological status (ie, scored ≤2). The rate of favourable neurological status in survivors to discharge did not significantly differ on the basis of resuscitation duration (4738 of 5838 [81·2%] people in whom resuscitation was done for <15 min *vs* 1724 of 2156 [80·0%] for durations between 15 and 30 min *vs* 572 of 730 [78·4%] for durations >30 min; p for comparison 0·131). However, mean and median scores on assessments of cerebral performance categories were slightly higher in patients in whom duration of resuscitation was longer than in those in whom duration was short (appendix). The appendix includes a complete breakdown of assessments of cerebral performance categories by resuscitation duration.

Table 1 shows baseline characteristics of patients who achieved return of spontaneous circulation, and table 2 those of non-survivors, both stratified by resuscitation duration. Because of the large size of the study population, several significant differences were noted in baseline characteristics between different strata of resuscitation duration; however, sizeable differences were less frequent. In patients who achieved return of spontaneous circulation, a lower proportion of patients with pre-existing disorders such as septicaemia or major trauma, critical care interventions in place at time of cardiac arrest, arrests in the intensive-care unit, or witnessed arrests had resuscitation attempts that lasted for 30 min or more than had attempts that lasted for 10 min or less (table 1). In non-survivors, excluding those with myocardial infarction during admission, the proportion of patients with pre-existing disorders resuscitated for 30 min or more was smaller than that resuscitated for 10 min or less (table 2).

Figure 1 shows the cumulative rates of return of spontaneous circulation for the overall study cohort. Of the 31 198 (48·5%) who achieved return of spontaneous circulation, 27 332 (87·6%) had restoration of a pulse by

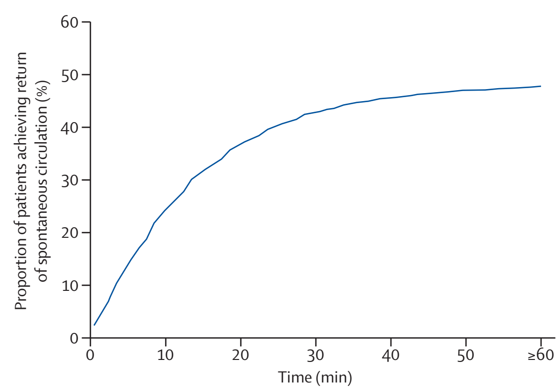

***Figure 1:* Cumulative proportion of patients achieving return of spontaneous circulation**

N=64 339. Overall, 48·5% of the total population achieved return of spontaneous circulation. By 30 min, 42·5% achieved return of spontaneous circulation.

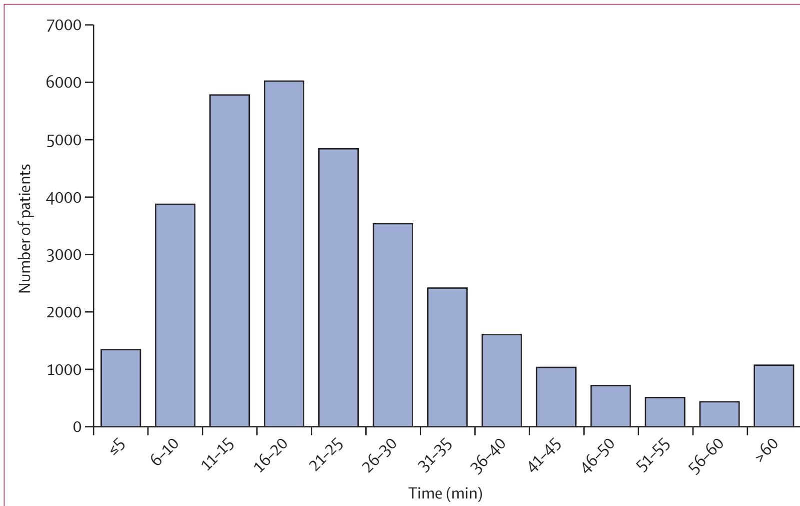

***Figure 2:* Duration of resuscitation attempts in non-survivors**

N=33 141.

30 min (representing 42·5% of the study sample). These patterns were consistent across different groups on the basis of cardiac rhythm at presentation (appendix). Resuscitation efforts were terminated within 10 min in 5221 (15·8%) and within 30 min in 25 382 (76·6%) of non-survivors (figure 2).

The median duration of resuscitation attempts in non-survivors of hospitals in the shortest quartile was 16 min (IQR 15–17), rising to 19 min (18–20), 22 min (21–23), and 25 min (25–28) in subsequent quartiles of hospitals. Overall, patients who had cardiac arrests at hospitals with longer median resuscitation durations had higher overall survival than did those who arrested in hospitals with shorter median durations of resuscitation attempts. For example, patients at hospitals with the longest median resuscitation attempts were significantly more likely to achieve return of spontaneous circulation than were those at hospitals with the shortest attempts (table 3). This effect was most prominent in patients with cardiac arrests due to pulseless electrical activity or asystole (p for interaction 0·002; table 4).

Similarly, patients at hospitals in the quartile with the longest median resuscitation attempts had a significantly higher rate of survival to discharge than did those at hospitals in the quartile with the shortest attempts (table 3). When we analysed by presenting rhythm survival to discharge between the first and fourth quartiles, our findings were significant for cardiac arrests due to pulseless electrical activity and asystole, but not ventricular tachycardia or fibrillation (p for interaction <0·0001; table 5).

We noted that the likelihood of patients surviving to discharge with a favourable neurological status did not differ significantly between hospital quartiles. For example, patients at hospitals in the longest quartile were as likely to be discharged with a favourable neurological status as were those at hospitals in the shortest quartile (adjusted risk ratio 1·00, 95% CI 0·95–1·06; p=0·858).

	Return of spontaneous circulation*			Survival to discharge†		
	Adjusted risk ratio (95% CI)	Adjusted rate	p value	Adjusted risk ratio (95% CI)	Adjusted rate	p value
Quartile 1 (13 994 patients at 113 hospitals)	1·00	45·3%	..	1·00	14·5%	..
Quartile 2 (18 783 patients at 121 hospitals)	1·04 (0·99–1·09)	47·0%	0·116	1·05 (0·96–1·14)	15·2%	0·304
Quartile 3 (19 106 patients at 107 hospitals)	1·08 (1·03–1·13)	48·8%	0·002	1·05 (0·96–1·14)	15·2%	0·280
Quartile 4 (12 456 patients at 94 hospitals)	1·12 (1·06–1·18)	50·7%	<0·0001	1·12 (1·02–1·23)	16·2%	0·021

*p for trend <0·0001. †p for trend 0·031.

Table 3: **Return of spontaneous circulation and survival to discharge in all patients, by hospital quartile**

	Pulseless electrical activity or asystole†			Ventricular tachycardia or fibrillation‡		
	Adjusted risk ratio (95% CI)	Adjusted rate	p value	Adjusted risk ratio (95% CI)	Adjusted rate	p value
Quartile 1 (13 994 patients at 113 hospitals)	1·00	41·6%	..	1·00	60·6%	..
Quartile 2 (18 783 patients at 121 hospitals)	1·04 (0·99–1·09)	43·1%	0·158	1·03 (0·98–1·08)	62·4%	0·224
Quartile 3 (19 106 patients at 107 hospitals)	1·10 (1·04–1·16)	45·6%	0·001	1·02 (0·98–1·07)	61·8%	0·400
Quartile 4 (12 456 patients at 94 hospitals)	1·15 (1·08–1·22)	47·7%	<0·0001	1·06 (1·01–1·11)	64·1%	0·027

*p for interaction 0·002. †p for trend <0·0001. ‡p for trend 0·065.

Table 4: **Return of spontaneous circulation in patients stratified by presenting rhythm of pulseless electrical activity or asystole versus ventricular tachycardia or fibrillation, by hospital quartile***

	Pulseless electrical activity or asystole†			Ventricular tachycardia or fibrillation‡		
	Adjusted risk ratio (95% CI)	Adjusted rate	p value	Adjusted risk ratio (95% CI)	Adjusted rate	p value
Quartile 1 (13 994 patients at 113 hospitals)	1·00	10·2%	..	1·00	32·1%	..
Quartile 2 (18 783 patients at 121 hospitals)	1·06 (0·94–1·18)	10·7%	0·351	1·03 (0·96–1·11)	33·2%	0·399
Quartile 3 (19 106 patients at 107 hospitals)	1·09 (0·97–1·23)	11·1%	0·132	0·98 (0·90–1·06)	31·4%	0·570
Quartile 4 (12 456 patients at 94 hospitals)	1·20 (1·05–1·36)	12·2%	0·006	1·02 (0·93–1·12)	32·8%	0·662

*p for interaction <0·0001. †p for trend 0·005. ‡p for trend 0·886.

Table 5: **Survival to discharge in patients stratified by presenting rhythm of pulseless electrical activity or asystole versus ventricular tachycardia or fibrillation, by hospital quartile***

Discussion

Despite several advances in resuscitation care, overall survival after in-hospital cardiac arrest remains poor.[20,21] Clinicians have raised concerns that prolongation of resuscitation efforts could be futile,[4] but few empirical data are available to guide clinical practice (panel). We showed substantial variation between hospitals in the duration of resuscitation attempts in non-survivors. We also noted that patients at hospitals in which the median duration of resuscitation attempts was longer had a higher likelihood of return of spontaneous circulation and survival to discharge than did those at hospitals with shorter median resuscitation durations.

When we arranged hospitals into quartiles on the basis of duration of resuscitation attempts, attempts in hospitals in the longest quartile lasted more than 50% longer than did efforts in hospitals in the shortest quartile. This additional time might seem to be a slight increase, but could have substantial implications in critically ill patients if it is thought of as time for reassessment of clinical responses and provision of further treatments.

Studies of the effect of resuscitation duration on clinical outcomes are few. Ballew and colleagues[6] reported that in a series of 313 patients, the proportion surviving to discharge was 45% when attempted resuscitation time was shorter than 5 min but less than

5% when resuscitation efforts continued beyond 20 min. In another series of 266 patients,[9] only 2% of those in whom resuscitation attempts lasted longer than 10 min achieved return of spontaneous circulation. Bedell and coworkers[7] showed that resuscitation duration was an independent predictor of mortality both during and after cardiac arrest. A 2007 analysis[22] from a single-hospital registry in Taiwan showed that the rate of return of spontaneous circulation was greater than 90% in patients resuscitated for less than 10 min but roughly 50% for those in whom resuscitation was attempted for 30 min or more.

Partly on the basis of these published findings that long resuscitation durations are associated with worse survival, earlier recommendations suggested a reassessment of efforts when responses to treatment are not apparent early after initiation of efforts.[3] Although such an approach is reasonable, this interpretation in isolation could result in misleading inferences about how the length of resuscitation attempts affects survival because of several important limitations.[3] First, previous studies included survivors and non-survivors, which shifts the distribution of resuscitation duration towards shorter times overall and makes duration less optimum as an explanatory variable because return of spontaneous circulation typically occurs early in most survivors. Second, the investigators did not consider cumulative survival rates with time or examine the specific effects of prolongation of resuscitation attempts. In Ballew and colleagues' study,[6] more than 50% of survivors were resuscitated for longer than 5 min and 10% for more than 20 min. In the analysis from Taiwan,[22] more than 30% of patients who achieved return of spontaneous circulation did so only after 30 min of resuscitation. Finally, previous studies were usually done in one hospital, which means that they could not take into account interinstitutional differences in resuscitation practice.

Our analysis addresses limitations of previous studies and extends this previous work. It takes advantage of potential differences in resuscitation practices between hospitals. Because we analysed the distribution of resuscitation duration in survivors and non-survivors of cardiac arrest separately, we were able to confirm that most survivors achieve return of spontaneous circulation early during resuscitation attempts, but noted that some survivors were resuscitated for more than 30 min before spontaneous circulation returned. However, less than 25% of people who died during cardiac arrest were resuscitated for at least 30 min, suggesting that attempts in most patients are not typically continued for this long.

Our most notable result was that long resuscitation attempts might be linked to increased rates of return of spontaneous circulation and survival to discharge. Patients at hospitals where resuscitation efforts lasted longer had higher survival rates than did those at hospitals where attempts were shorter, independent of measured patient characteristics. The reason for this improved survival to discharge could be that hospitals that reliably implement guidelines for resuscitation care systematically attempt resuscitation for longer than do hospitals that do not reliably follow guidelines. Such a finding would suggest that duration of resuscitation is a marker of more comprehensive care. However, it also suggests an opportunity to improve care in this high-risk population through standardisation of duration of resuscitation attempts before termination of efforts.

Some evidence supports the stopping of resuscitative efforts if asystole has been present for more than 10 min without an identifiable and reversible cause.[3] van Walraven and coworkers[23] reported that admitted patients who have an unwitnessed pulseless electrical activity or asystole for more than 10 min are unlikely to survive. In our sample of patients with in-hospital patients, return of spontaneous circulation and survival to discharge were significantly less likely when the initial rhythm was pulseless electrical activity or asystole than when the rhythm was ventricular tachycardia or fibrillation. However, patients with pulseless electrical activity or asystole seemed the most likely to benefit

***Panel:* Research in context**

Systematic review

We searched Medline with the terms "in-hospital cardiac arrest" and "survival" in combination to identify published work relevant to our study. We noted no previous medical literature about variation in the duration of resuscitation attempts in non-survivors between hospitals, or whether patients treated at hospitals with longer resuscitation attempts have higher survival rates than do those at hospitals where resuscitation attempts are shorter. However, we identified previous work broadly related to resuscitation duration and outcomes, including specific articles about rules for termination of cardiac arrests in both the in-hospital and out-of-hospital settings. We reviewed these titles and abstracts, and the reference lists of selected studies. We have included single and multicentre observational studies,[6–9,20–23] reviews,[3] and national guidelines[4,5] in our discussion.

Interpretation

Our observational study focused on hospital-level variation in the duration of resuscitation attempts in patients who did not achieve return of spontaneous circulation. We assessed the possible association between increased duration of resuscitation attempts in these non-survivors (ie, before termination of efforts) and survival with the Get With the Guidelines—Resuscitation, a large observational registry of in-hospital cardiac arrests from hospitals across the USA. Although the results of previous investigations have shown that survival is lower in patients who need longer resuscitation efforts than in those who are resuscitated after short efforts, our study develops these findings through examination of the potential effect of extension of resuscitation efforts on return of spontaneous circulation and survival to discharge. We noted that patients at hospitals with longer median resuscitation attempts in non-survivors were more likely to survive to discharge than were those in hospitals at which the median length of resuscitation attempts was shorter, independent of measured characteristics of patients. Although we cannot define an optimum duration for resuscitation attempts, our findings suggest that efforts to systematically increase the duration of resuscitation efforts could improve survival in this high-risk population.

from long resuscitation attempts. The effect of long resuscitation attempts on survival was less pronounced in patients with ventricular tachycardia or fibrillation, which could be because survival in these patients is frequently driven mostly by the immediate response to defibrillation, rather than other factors.

Our study has several limitations. First, Get With The Guidelines—Resuscitation is a voluntary registry. Although the final study population included patients from 435 hospitals with broad regional representation from across the USA, our findings might not be representative of all hospitals, since the participating hospitals tend to be large. Second, the study was observational and thus we cannot directly show a causal relation between increasing the duration of resuscitation attempts and survival rates. Factors related to good resuscitation care—eg, reliable implementation of guidelines—could be associated with prolonged resuscitation attempts and improved survival. Unmeasurable variables that affect the duration of resuscitation—namely, the quality of chest compressions and standard of the code team's work—could have roles in decisions related to resuscitation care and outcomes, but are not collected in this registry, adding to the potential for residual confounding.[24,25] Rates of survival to discharge could also be affected by hospital-specific administrative practices such as discharge planning after resuscitation.

Third, as with any observational registry, errors can occur during data collection, and the method by which cardiac arrests were recorded might have varied between hospitals. However, a previous study examined the overall accuracy of Get With The Guidelines—Resuscitation through a random, reauditing process, which showed that mean error rates are low overall (roughly 2·4%).[10] Finally, we could not measure long-term outcomes in survivors of resuscitation, including functional status, after hospital discharge. The extent to which critically ill patients benefit from survival months to years after cardiac arrest should be the ultimate measure of the usefulness of resuscitation measures.

How do our results affect clinical practice? In one of the earliest studies[8] of in-hospital cardiac arrest, Edward Stemmler noted that in 103 patients at his institution, the “duration of a single resuscitative attempt varied from a few minutes to almost 3 hours”, with most attempts terminated when return of spontaneous circulation did not happen after 15–30 min. Since this study in 1965, little progress has been made towards establishment of when resuscitation efforts should be terminated. Our findings, which are based on data from the largest representative sample of patients with in-hospital cardiac arrest in the USA, provide empirical evidence that clinical practice still varies greatly and suggest that standardisation of a minimum length for resuscitation attempts could improve survival. We are unable to provide a specific cutoff from these data and are hesitant to speculate. Clinical judgment will always be needed for this aspect of care, since the benefits of increasing the length of resuscitative measures should be balanced with the potential downside of futile care. Prolongation of resuscitation attempts by 10 or 15 min might have only slight effects on resources once efforts have already begun, but could improve outcomes. Further research is needed on this topic.

Contributors
ZDG, PSC, RAB, SLK, and BKN conceived and designed the study. BKN and PSC provided the overall supervision for the study. ZDG, PSC, and BKN drafted the report. All authors contributed to the statistical analysis and critical revision of the report, and have approved the final revision.

Conflicts of interest
HMK is the recipient of a research grant from Medtronic through Yale University and is chair of a cardiac scientific advisory board for UnitedHealth. All other authors declare that they have no conflicts of interest.

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Tobacco industry lobbyists and their health-care clients

Tobacco consumption is responsible for 8·8% of deaths worldwide,[1] but the introduction of plain pack legislation in Australia, a strategy intended particularly to make smoking less appealing to children, is an important step forward. The tobacco industry has a long and well documented history of mendacity on an industrial scale in its attempts to resist public health measures such as this. As health professionals, we were therefore unsurprised to learn that the industry had engaged lobbying agencies, including Crosby Textor and Luther Pendragon, to oppose its introduction.[2]

In the UK, Luther Pendragon's clients have included the Department of Health, the Royal Pharmaceutical Society, Air Products, the All Party Pharmacy Group, the Association of Optometrists, the Federation of Ophthalmic and Dispensing Opticians, the National Pharmacy Association, NHS Skills for Health, and St George's Healthcare NHS Trust.[3] Public relations companies might take their own view of what they regard as ethical, but it would clearly be unacceptable for any health-care organisation to engage with a company that is simultaneously working to oppose public health legislation. We therefore call on all health-care organisations, and especially the UK Department of Health, to send out a clear message by severing any links they have with public relations companies that work to promote the interests of the tobacco industry. Additionally, they should adopt clear, ethical policies to ensure that they will not give contracts to such companies in the future.

Other organisations on Luther Pendragon's client list,[3] such as John Lewis Partnership and Oxford University, will also undoubtedly be unhappy to have their brands associated with a company that promotes the interests of manufacturers of a product that kills more than 80 000 people in England each year.[4]

Finally, it is deeply concerning that the Conservative Party will be receiving "strategic direction" at the next election, from Lynton Crosby. Given scandals including Members of Parliament accepting corporate hospitality at the Chelsea Flower Show from Japan Tobacco International,[5] and concerns over Health Minister Earl Howe's briefings in 2009, while in opposition, from Philip Morris's lobbyists on the industry's opposition to tobacco advertising display bans,[6] such a central role for one of the key opponents of Australia's tobacco control measures is unfortunate.

We declare that we have no conflicts of interest.

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Duration of resuscitation efforts and survival after in-hospital cardiac arrest

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Zachary Goldberger and colleagues' study (Oct 26, p 1473)[1] of cardiac arrests at hospitals within the Get With The Guidelines—Resuscitation registry showed that increased duration of resuscitation efforts improved immediate survival and survival to hospital discharge. An important question raised by this study is whether this increased survival translates into a valuable improvement in patients' long-term outcomes.

For resuscitated patients, quality of life is surely as important as survival itself. However, survival is not always associated with good quality of life, which is highly dependent on the patient's neurological status after resuscitation.[2] Thus successful resuscitation necessitates the preservation of adequate cerebral function to permit return of independent

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activities of daily life. In Goldberger and colleagues' study, prolonged resuscitation efforts did not result in significant improvement in favourable neurological status at hospital discharge.

Additionally, the goal of resuscitation should be to avoid premature death, not prolong inevitable death.[3] Thus, only when the cause of cardiac arrest is potentially reversible are aggressive and prolonged resuscitation efforts worthwhile.[4] Elderly patients made up a large component of the study population, and a substantial number of patients had end-stage organ insufficiency, cancers, myocardial infarction, hypotension, and septicaemia. Given that older age and the aforementioned premorbid factors are associated with a reduced likelihood of successful resuscitation,[2,5] and that Goldberger and colleagues did not stratify the study population according to these risk factors, we cannot exclude the possibility that irreversible cardiac arrests are the reason for early termination of resuscitation in hospitals with short resuscitation attempts in non-survivors.

We declare that we have no conflicts of interest.

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1 Goldberger ZD, Chan PS, Berg RA, et al, for the American Heart Association Get With The Guidelines—Resuscitation (formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of resuscitation efforts and survival after in-hospital cardiac arrest: an observational study. *Lancet* 2012; **380:** 1473–81.
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In their Article on duration of resuscitation efforts and survival after in-hospital cardiac arrest,[1] Zachary Goldberger and colleagues assert that "The rate of favourable neurological status in survivors to discharge did not significantly differ on the basis of resuscitation duration."

However, according to the results for mean cerebral performance category (see appendix[1]), there is a significant worsening of neurological status in patients with longer resuscitation duration—1·73 compared with 1·83 in patients resuscitated for less than 15 min and greater than 30 min, respectively (p=0·0001).

There is a significant difference in survival to discharge only when comparing the hospitals in the shortest and longest quartiles for length of resuscitation overall and for pulseless electrical activity and asystole arrests. However, Goldberger and colleagues state that "patients at hospitals in which the median duration of resuscitation attempts was longer had a higher likelihood of... survival to discharge than did those at hospitals with shorter median resuscitation durations." It is unfair for them to represent results with similar levels of significance so differently.

Despite a call for further research, this research is likely to influence decision making. For example, the UK Resuscitation Council has stated "It reassures us that prolonged resuscitation attempts do not result in a substantial increase in survivors with severe neurological injury".[2] This is quite simply not the case. Goldberger and colleagues should have been aware of the influence of these results and a greater effort should have been made to highlight the potential detrimental effect on neurological status. Indeed, it would be fairer to assert that longer resuscitation duration *is* associated with worsened neurological status at discharge.

I declare that I have no conflicts of interest.

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Zachary Goldberger and colleagues[1] report significantly improved survival by extending the duration of cardiopulmonary resuscitation (CPR). Although the relative benefit is 12%, the absolute benefit is only 1·9%. Most performers of CPR work with high levels of skill and judgment and without regard to specific time constraints. It is likely that the overall small benefits seen can be accounted for by accurate clinical judgments of the CPR teams.

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After reviewing the paper from Zachary Goldberger and colleagues[1] about duration of resuscitation efforts and survival, we have some comments about the methods used that could change the conclusions of the paper.

First, 29 196 patients were not considered in the analysis: 6099 because they did not fit with inclusion criteria and 23 097 for other reasons (including "distinct circumstances") that could affect the external and internal validity of results.

Second, 68 hypothesis tests were done, meaning a high level of α error in the paper. A Bonferroni correction should have been done, after which the acceptable level of significance is p<0·00075, meaning that conclusions based on results with a higher level of significance are not valid. One of them is the main conclusion: survival to discharge.

Finally, when we compare patients in the first quartile with others (Q1 *vs* Q2–Q4) in a sensitivity analysis, using cases not included for not having at least 6 months of data and in whom ten or more cardiac arrests happened during the study (n=6099), and assuming follow-up losses by the size of quartiles, the other main conclusion of the paper—in terms of return of spontaneous circulation—is not supported either.

We declare that we have no conflicts of interest.

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Authors' reply

Fu Shan Xue and colleagues express concern that longer resuscitation efforts did not significantly improve neurological outcomes and could simply prolong "inevitable death" in the highest-risk patients. We worry that they misunderstand key aspects of our study.[1] First, the assertion that, in order for longer resuscitation efforts to be effective, they would have to improve neurological outcomes in those with longer resuscitations is erroneous. Indeed, we found that hospitals with longer efforts had *similar* neurological outcomes but *higher* survival rates than those with shorter efforts, suggesting a greater absolute number of patients surviving with favourable neurological outcomes in hospitals with longer efforts. Second, although residual confounding might exist, our multivariable models included many factors, such as age and comorbid conditions, to account for the potential effects of early termination due to patients' illness.

Andy Young notes a significant association between increasing mean cerebral performance category (CPC) scores in the overall cohort and longer resuscitation. However, this finding requires caution. This was an *unadjusted* association at the patient level, and longer resuscitation efforts are typically required in sicker patients. By contrast, our adjusted analyses of whether hospitals that typically practice longer efforts have worse neurological outcomes showed no differences. Also, Young's primary focus on mean or median values (as opposed to CPC scores ≤2) presumes that the CPC index represents equally spaced intervals, which is not the case.[2] Moving from "death" to "persistent vegetative state" (ie, CPC 5 to 4) is not the same as from "severe" to "moderate" cerebral disability (ie, CPC 3 to 2). Finally, statistical tests for trends across the four hospital categories were significant with the exception of survival to discharge in patients with ventricular tachycardia or fibrillation; for this reason, we summarised our findings as we did.

We largely agree with David Hoch. We specifically avoided recommendations for an optimum resuscitation length for an individual so as not to supersede bedside decision making. However, on average, longer times did achieve better results, so the challenge is to determine how best to affect current practice favourably without constraining individual decisions. Eschewing "short codes", unless there are special clinical circumstances, is one potential take-home message.

Finally, Javier Eslava-Schmalbach and Jose Navarro-Vargas raise several issues. Cardiac arrests that occur in surgical and procedure areas are quite different from those occurring elsewhere in the hospital, often having distinct causes that can be treated and reversed immediately. Previous studies by our group have typically excluded these patients; we agree that our findings are not generalisable to them. We disagree, however, with the suggestion to do Bonferroni corrections. Epidemiologists increasingly agree that indiscriminate use of this approach is unnecessary (and even potentially harmful).[3] Correction for multiple comparisons would be appropriate if we had reported statistics for all 68 covariates (age, gender, comorbid conditions, etc). But we tested only one a-priori hypothesis—the potential effect of resuscitation duration (ie, exposure variable of interest) on outcomes. The other covariates were included simply to control for potential confounding and are all known to be related to outcomes.[4] Finally, Get With The Guidelines—Resuscitation is a voluntary hospital registry. Since our exposure variable of interest required stable participation for at least a set period of time, we excluded patients at hospitals that had not participated for long periods. We agree that caution should be made in applying these results to all hospitals.

We declare that we have no conflicts of interest.

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