In-hospital cardiac arrest epidemiology in a mature rapid response system

An audit examined the epidemiology of in-hospital cardiac arrests 5 years after a rapid response system was introduced, exploring the frequency of arrests in monitored and unmonitored areas. Details of the initial cardiac rhythm and what proportion of events were preceded by a medical emergency team call were also assessed.

The recognition of and response to deteriorating patients in acute hospital settings is essential for ensuring optimal patient outcomes (Australian Commission on Safety and Quality in Health Care, 2010; Jones et al, 2012, 2013). Important strategies to address this problem include staff education, improved documentation of vital signs and the use of medical emergency teams (Australian Commission on Safety and Quality in Health Care, 2010; Jones et al, 2011, 2012). The ultimate aim of these interventions is to prevent deterioration to the point of cardiac arrest which traditionally has been associated with an in-hospital mortality of approximately 80% (McGrath, 1987; Jones et al, 2005; Smith et al, 2011).

The mainstay of cardiac arrest treatment is early and effective basic life support, and early defibrillation for rhythms amenable to cardiac defibrillation (Hazinski et al, 2010). However, many in-hospital cardiac arrests may have an initial cardiac rhythm that is 'non-shockable' (Jones et al, 2005; Smith et al, 2011). Few studies have documented details about the timing of cardiac arrests, the presence of antecedent medical emergency team calls or the nature of the admission diagnosis.

This article reports a retrospective audit of cardiac arrests performed over 5.7 years in the period 5–10 years after implementing a medical emergency team. Specifically, the article reports on patient age and the timing of cardiac arrests in relation to time of day, day of week, and days after admission. The article also categorizes the nature of the hospital admission and the occurrence and timing of medical emergency team calls in the 24 hours before the cardiac arrest, the nature of the initial cardiac rhythm and the disposition at hospital discharge. Finally, it reports on differences in these variables in patients suffering a cardiac arrest in the general hospital ward *vs* those in the coronary care areas of the hospital.

Methodology

Ethics approval

Approval to conduct the study was obtained from the hospital research and ethics committee (H2010/04199). The need for informed patient consent was waived by the committee as the study was audit in nature.

Details of study design

A retrospective observational study was conducted of patients identified prospectively in Respond Blue and medical emergency team databases. To maximize data accuracy, the details of all Respond Blue and medical emergency team calls were obtained from several sources: the hospital switchboard log, an electronic database completed by the intensive care unit registrar, and a written log documented by nurses immediately after the call. A senior intensive care unit nurse cross-referenced the various data sources to capture all calls. The study period ran from January 2005 to August 2010.

Details of the hospital setting

The Austin Hospital is a tertiary level teaching hospital in metropolitan Melbourne, Australia. It has 400 acute care beds and is a state-wide referral centre for spinal cord injuries, chronic ventilatory failure, complex aortic vascular surgery and liver transplant medicine. There are more than 25 000 multi-stay admissions each year.

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Hospital emergency response systems

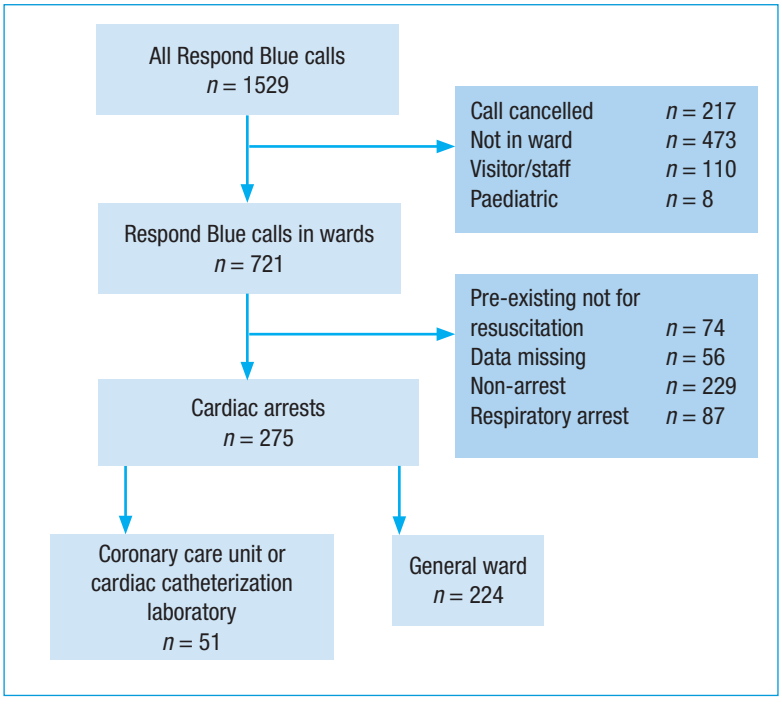
The hospital operates a Respond Blue team and medical emergency team which run in parallel (Jones et al, 2006a). The medical emergency team includes an intensive care unit registrar and nurse, and the medical registrar when able to attend. The Respond Blue team includes the medical emergency team members as well as a coronary care nurse and anaesthetic doctor.

The Respond Blue team is called when there is a cardiac or respiratory arrest, or otherwise immediate life-threatening situation (particularly involving an airway emergency). The medical emergency team is called for all other emergency calls, and is expected to arrive within 10 minutes. In cases where there is progressive deterioration during a medical emergency team call, the call can be 'upgraded' to a Respond Blue call.

Data sources and classification of Respond Blue calls

Two investigators (DJ, IM) concurrently examined all Respond Blue calls to classify calls into the following categories: call cancelled, not in ward area, visitor/staff, paediatric, pre-existing not for resuscitation documented, data missing, Respond Blue in ward area. In the case of Respond Blue calls in ward areas, calls were further classified into 'non-arrest', 'respiratory arrest' and 'cardiac arrest'. A cardiac arrest was defined by the presence of all of the following: no palpable pulse, no measurable blood pressure, unresponsiveness, and the commencement of basic life support. A respiratory arrest was defined either as an apnoeic patient who maintained spontaneous cardiac output, or a patient who was in such profound respiratory distress that urgent intubation on the ward was required.

Figure 1. Breakdown of 1529 Respond Blue calls occurring between January 2005 and August 2010.



Non-arrest Respond Blue calls were classified as previously described faint, seizure, bleeding from intestinal tract, surgical bleeding, respiratory distress, altered conscious state, hypotension, arrhythmia, chest pain, and other (Jones et al, 2005).

Respond Blue calls outside the ward environment were not included as these areas are not covered by the medical emergency team. These areas include the car park, outpatient clinics, outpatient pathology area and hospital cafeterias. These non-ward environments are covered by staff from the emergency department and involve a single Respond Blue response.

Details of data collected

Further data were obtained for patients who fulfilled criteria for cardiac arrest, in whom there was no previous not for resuscitation order. Data included patient demographics including age, gender and admission parent unit, and the nature of the admitting diagnosis. Data were also collected on the type of ward where the cardiac arrest occurred. In addition, the timing of the cardiac arrest was documented, in relation to the time of day and day of week, as well as the number of days between hospital admission and the occurrence of the arrest.

Details of the cardiac arrest included the initial rhythm, and whether there had been a documented medical emergency team call within 24 hours of the cardiac arrest. Finally, the outcome of the hospital admission was recorded, classified as: death, campus transfer, hospital transfer, nursing home, home, or unknown. Analysis of these variables was conducted for cardiac arrests overall, and separately for cardiac arrests occurring in the coronary care unit or cardiac catheterization laboratory (CCU or cath lab) *vs* those not occurring in these two areas. The Respond Blue log only captured calls in the CCU or cath lab where the cardiac arrest team attended. It did not capture instances where a patient may have received electrical cardioversion or a brief period of cardiac compressions where the patient achieved prompt return of circulation.

Statistical analysis

Descriptive statistics are presented as crude numbers and percentage of totals, and distributed data are presented as median and interquartile range. Comparison of distributed data was performed using the Mann–Whitney U test. Comparison of categorical data was assessed using the chi-square, with continuity correction for non 2x2 tables. For all statistical analyses, a two-sided P value <0.05 was taken to indicate statistical significance. Univariable analysis was conducted to assess for associations with in-hospital death. Statistical analysis was performed using SPSS-version 20 (IBM, New York, USA).

Results

Details of Respond Blue calls

Over the 5.7-year study period there were 1529 Respond Blue calls. The majority of these were not classified as a

'Respond Blue call occurring in the ward' (*Figure 1*) and related to Respond Blue calls in non-ward areas. A Respond Blue call was called in a patient with a pre-existing not for resuscitation order in 74 (4.8%) of calls, and data were missing in 56 (3.7%) of calls.

Among the remaining 591 Respond Blue calls occurring in ward areas, 87 were classified as respiratory arrests – the details of these calls have been published elsewhere (Husband et al, 2014). A further 229 calls were classified as non-arrests and included: altered conscious state (55, 24%), faint (46, 20.1%), arrhythmia (39, 17%), respiratory distress (36, 15.7%), seizure (26, 11.4%), gastrointestinal bleeding (8, 3.5%), hypotension (8, 3.5%), surgical bleeding (7, 3.1%), chest pain (2, 0.9%), and other (2, 0.9%).

Thus there were 275 cardiac arrests occurring in hospital wards, 224 of which occurred in non-monitored ward areas (general wards) and 51 of which occurred in the CCU or cath lab.

Over the study period there were 154 795 admissions where the patient stayed for at least one night (i.e. excluding same day admissions). Thus there were 1.8 cardiac arrests per 1000 hospital admissions overall, and 1.4 cardiac arrests per 1000 admissions for patients on the ward.

Demographics of patients suffering cardiac arrests

The median (interquartile range) age of patients suffering a cardiac arrest was 71.5 years (61.6–80.6 years) and 182 (66.2%) were male. The age and gender distribution was similar for cardiac arrests occurring in the ward CCU or cath lab (P=0.402) (*Table 1*). However, the admission diagnosis (P<0.001) and documented parent unit (P<0.001) at the time of the cardiac arrest was different for ward events compared with those in the CCU or cath lab (*Table 2*). Only 13.4% of patients on the ward were admitted with ischaemic heart disease, compared with 60.8% in the CCU or cath lab (P<0.001). Similarly, 74.5% of patients suffering cardiac arrest in CCU or cath lab were under cardiology, compared with only 9.8% on the ward (P<0.001).

Timing of cardiac arrests

The detection of cardiac arrest was not distributed uniformly over the 24-hour period (*Figure 2*) and tended to cluster around observation times (2 am, 6 am, 10 am, 2 pm, 6 pm, 10 pm). The majority (203/275, 73.8%) of

Table 1. Patient demographics for cardiac arrest patients occurring in the ward *vs* cath lab or CCU over 5.7 years

Variable	Ward (*n*=224)	Cath lab or CCU (*n*=51)	*P* value
Patient age (years) Median (interquartile range)	71.0 (61.1–80.7)	73.3 (63.1–80.1)	0.402
Male gender; N (%)	148 (66.1)	34 (66.7)	0.94

Cath lab = cardiac catheterization laboratory; CCU = coronary care unit

Table 2. Admitting parent unit and diagnosis of cardiac arrest patients occurring in the ward *vs* cardiac catherization laboratory or coronary care unit

Variable		
Usual treating team n (%)	**Ward (*n*=224)**	**Cath lab or CCU (*n*=51)**
Cardiology	22 (9.8)	38 (74.5)
General medicine	53 (23.7)	0
Renal medicine	25 (11.1)	5 (9.8)
Cardiac surgery	16 (7.1)	6 (11.8)
General surgery	17 (7.6)	1 (2.0)
Neurology	12 (5.4)	0
Respiratory	11 (4.9)	0
Oncology	10 (4.5)	0
Orthopaedic surgery	9 (4.0)	0
Spinal	8 (3.6)	0
Haematology	7 (3.1)	0
Infectious diseases	7 (3.1)	0
Vascular	6 (2.7)	1 (2.0)
Liver transplant unit	6 (2.7)	0
Other	15 (6.7)	0
Admission diagnosis n (%)		
Ischaemic heart disease	30 (13.4)	31 (60.8)
Medical respiratory illness	40 (17.9)	3 (5.9)
Musculoskeletal or rheumatological	28 (12.5)	1 (2.0)
Cerebral disease or syncope	19 (8.5)	0
Gastrointestinal medical condition	19 (8.5)	0
Other	19 (8.5)	0
Surgery: cardiac, vascular, thoracic, ear nose and throat	13 (5.8)	5 (9.8)
Metabolic and genitourinary disease	18 (8.0)	0
Arrhythmia or arrest	8 (3.6)	6 (11.8)
Gastrointestinal surgical condition	13 (5.8)	0
Heart failure	9 (4.0)	1 (2.0)
Neuromuscular and spinal cord illness	5 (2.2)	0
Valvular heart disease	2 (0.9)	3 (5.9)
Unknown	1 (0.4)	1 (2.0)

Cath lab = cardiac catheterization laboratory; CCU = coronary care unit

Figure 2. Circadian variation of cardiac arrest detection for 275 cardiac occurring between January 2005 and August 2010.

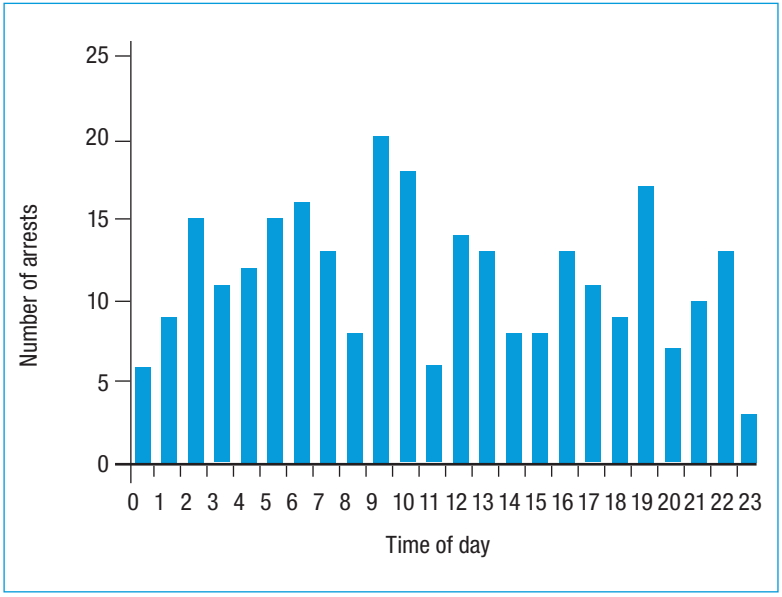


Table 3. Comparison of timing of cardiac arrest detection in relation to date of admission according to location of arrest

	Ward (*n*=223)	CCU or cath lab (*n*=50)	Total (*n*=273*)
Same day N (%)	31 (13.9)	27 (54.0)	58 (21.1)
Day 1 N (%)	26 (11.7)	4 (8.0)	30 (10.9)
Day 2 N (%)	24 (10.8)	3 (6.0)	27 (9.8)
Day 3 N (%)	19 (8.5)	3 (6.0)	22 (8.0)
Day 4 N (%)	16 (7.2)	3 (6.0)	19 (6.9)
Day 5 N (%)	12 (5.4)	0.0	12 (4.4)
Day 6 N (%)	11 (4.9)	3 (6.0)	14 (5.1)
Day 7 N (%)	3 (1.3)	1 (2.0)	4 (1.5)
After day 7 N (%)	223 (36.3)	50 (12.0)	273 (31.6)

** Data missing for two cases. Cath lab = cardiac catherization laboratory; CCU = coronary care unit.*

Table 4. Details of antecedents MET calls and the time interval between MET and cardiac arrest activation

Occurrence and timing of MET call before cardiac arrest	Cardiac arrests ward (*n*=224)	Cardiac arrests CCU-cath lab (*n*=51)	Overall (*n*=275)
No MET prior 24 hour N (%)	141 (62.9)	42 (82.4)	183 (66.5)
MET <10 min before N (%)	58 (25.9)	6 (11.8)	64 (23.3)
MET 11–30 min before N (%)	14 (6.2)	2 (3.9)	16 (5.8)
MET 31–60 min before N (%)	3 (1.3)	0.0	3 (1.1)
MET >60 min before N (%)	8 (3.6)	1 (2.0)	9 (3.3)

Cath lab = cardiac catherization laboratory; CCU = coronary care unit; MET = medical emergency team.

cardiac arrests occurred on weekdays, and this proportion was similar in the ward (73.2%) and the CCU or cath lab (76.5%, *P*=0.763). However, the odds of a cardiac arrest occurring on a weekday (203/275) were not different to the proportion of weekdays in the week (5/7, 71.4%, odds ratio 1.1, 95% confidence interval 0.21–5.94, *P*=0.769).

There were marked differences in the timing of cardiac arrests in relation to the days following hospital admission (*P*<0.001) (*Table 3*). Thus cardiac arrests in CCU or the cath lab occurred shortly after admission, whereas cardiac arrests on the ward occurred mostly after day 7.

Details of antecedent medical emergency team calls before cardiac arrests

Overall, 66.5% of cardiac arrests were not preceded by a medical emergency team call (*Table 4*). The occurrence and timing of antecedent medical emergency team calls differed between cardiac arrests occurring in the two treatment areas, but this did not reach statistical significance (*P*=0.12).

Details of initial cardiac rhythm of cardiac arrests

Overall, 80.3% of all the initial cardiac rhythms were either asystole or pulseless electrical activity (*Table 5*). The initial rhythm was not known in three cases. The distribution of initial cardiac rhythms was similar in both clinical areas (*P*=0.409). Among the cases where the initial rhythm was shockable, 30/51 (58.8%) were ventricular fibrillation (*Table 5*).

The proportion of rhythms that were asystole or pulseless electrical activity rose from 75.9% in day hours (8 am–5 pm) to 82.1% in the evening (5 pm–midnight) and 86.6% overnight (midnight–8 am), although these differences were not statistically significant across the three groups (*P*=0.145). There was a trend for less non-shockable rhythms to occur during the day when compared with overnight (odds ratio 0.49, 95% confidence interval 0.24–1.02, *P*=0.052).

Hospital outcome of cardiac arrests

Overall, 73.5% of patients suffering a cardiac arrest died in hospital, and only 17.5% were discharged home (*Table 6*). The disposition at discharge was similar among both groups (*P*=0.11), even when the in-hospital outcome was dichotomised to alive *vs* dead (*P*=0.39). The median age (interquartile range) of patients who died (72.6 years (63.7–81.1 years)) was higher than that of survivors (68.1 years (55.2–78.8 years), *P*=0.053). In addition, survival was strongly associated with initial cardiac rhythm (*P*=0.004; *Table 5*). In patients with ventricular tachycardia or ventricular fibrillation the in-hospital mortality was 56.9% (29/51) *vs* 77.8% (172/221) in those with asystole or pulseless electrical activity (odds ratio 0.38, 95% confidence interval 0.20–0.71, *P*=0.002). The following were not associated with in-

Table 5. Details of initial rhythm of cardiac arrests

Initial rhythm	Cardiac arrests ward (*n*=224)	Cardiac arrests CCU or cath lab (*n*=51)	Overall (*n*=275)	Mortality according to initial rhythm
Asystole N (%)	89 (39.7)	20 (39.2)	109 (39.6)	91/109 (83.5)
Pulseless electrical activity (electro-mechanical dissociation) N (%)	93 (41.5)	19 (37.3)	112 (40.7)	81/112 (72.3)
Ventricular fibrillation N (%)	25 (11.2)	5 (9.8)	30 (10.9)	17/30 (56.7)
Ventricular tachycardia N (%)	14 (6.3)	7 (13.7)	21 (7.6)	12/21 (57.1)
Unknown N (%)	3 (1.3)	0.0	3 (1.1)	1/3 (33.3)

Cath lab = cardiac catherization laboratory; CCU = coronary care unit.

Table 6. Outcome – discharge destination for 275 patients suffering cardiac arrest depending on location

Hospital outcome	Cardiac arrests ward (*n*=224)	Cardiac arrests CCU or cath lab (*n*=51)	Overall (*n*=275)
Death	167 (74.6)	35 (68.6)	202 (73.5)
Discharged home	35 (15.6)	13 (25.5)	48 (17.5)
Transfer to another campus	12 (5.4)	0.0	12 (4.4)
Transfer to another hospital	7 (3.1)	2 (3.9)	9 (3.3)
Nursing home	2 (0.9)	0.0	2 (0.7)
Unknown	1 (0.5)	1 (2.0)	2 (0.8)

Cath lab = cardiac catherization laboratory; CCU = coronary care unit.

hospital mortality: presence of a medical emergency team in the 24 hours before arrest (P=0.62), gender (P=0.44), time of day (P=0.74) or timing of arrest in relation to admission (P=0.28).

Discussion

Summary of major findings

A retrospective audit of Respond Blue calls was conducted over a 5.7-year period at the authors' hospital. The vast majority of calls were not true cardiac arrests, with only 275 confirmed cardiac arrests. Most cardiac arrests were not preceded by medical emergency team activation and there were important differences in the characteristics of cardiac arrests between those in the ward and those in the CCU or cath lab. Most cardiac arrests did not have an initial rhythm amenable to electric cardioversion. Finally, this study confirmed previous reports of a high in-hospital mortality of cardiac arrests, and associations with in-hospital death.

Comparison with previous studies

The characteristics and outcome of cardiac arrests at this hospital have previously been reported which also highlighted the low incidence of shockable rhythms (23.4%) (Smith et al, 2011; Vetro et al, 2011) and a high in-hospital mortality (81%) (Jones et al, 2005; Smith et al, 2011; Vetro et al, 2011).

The current study shows that only one-third of cardiac arrests were preceded by a medical emergency team call, and that in many instances the medical emergency team activation occurred very closely to cardiac arrest team activation. The authors have previously reported that 28% of cardiac arrests occurring in the first 4 years of medical emergency team (Jones et al, 2006b) also occurred shortly after the activation of a medical emergency team call.

The frequency of cardiac arrests was 1.8/1000 admissions. This compares favourably with other Australian studies which report a frequency of cardiac arrests between 1.46 and 3.76/1000 admissions in the context of a medical emergency team (Bristow et al, 2000; Buist et al, 2007; Santamaria et al, 2010; Smith et al, 2014).

Study strengths and weaknesses

This study is the largest to examine the epidemiology of cardiac arrests within the context of a mature medical emergency team. There was a low incidence of missing cases and a low incidence of missing data within cases. Two investigators confirmed the diagnosis of cardiac arrest, and an analysis plan was developed a priori. To the authors' knowledge this is the first study to reveal important differences in the timing and patient demographics for cardiac arrests occurring in the ward and CCU or cath lab in a single study cohort.

KEY POINTS

- Cardiac arrests occurred approximately once per week in the authors' hospital.
- Most patients who had a cardiac arrest on the general ward were not admitted with ischaemic heart disease.
- In total, 80.3% of the initial cardiac rhythms were 'non-shockable' and most did not have a medical emergency team review in the prior 24 hours.
- Overall, 73.5% of patients suffering a cardiac arrest died in hospital.

Despite this the current study has the important limitations of retrospective study design and incomplete data capture. In addition, although antecedent medical emergency team call activation was documented, the patient files were not examined for the presence of medical emergency team call criteria which were not acted on. In addition, the authors cannot comment on the occurrence of cardiac arrests in the CCU or cath lab which were resolved by the local team with a brief period of cardiac compression or electric cardioversion. Such patients would be likely to have a better outcome, and thus there is a chance of selection or participant bias in this study. This may in part explain the relatively low proportion of patients with ventricular tachycardia or ventricular fibrillation in the CCU or cath lab.

Implications for clinicians and policy makers

This study shows that at least one quarter of patients were aged over 81 years. In addition, patients suffering cardiac arrest on the ward often did so beyond 7 days of admission. Combined, these observations may suggest the need to improve advance care and end of life care planning in the authors' hospital. Most patients did not have a preceding medical emergency team call, which may suggest either suboptimal patient monitoring, or the fact that many arrests are sudden and unexpected in the context of a mature medical emergency team.

To the authors' knowledge this is the first study to assess differences in the nature of cardiac arrests in general ward patients with those in the cath lab or CCU. Not surprisingly, it revealed that most patients who suffered a cardiac arrest in the cath lab or CCU had cardiac-related admission diagnoses. However, in contrast, those on the ward were admitted with a large number of different diagnoses and under several different units. Combined these findings suggest that cardiac arrest on the ward is more likely to be related to general deterioration rather than primary cardiac pathology.

This study confirms previous reports of a high in-hospital mortality associated with cardiac arrest, even when they occurred after medical emergency team activation. This emphasizes the need to prevent cardiac arrest occurring in the first place. It also reinforces the authors' previous opinion that alternative strategies are urgently needed to resuscitate in-hospital cardiac arrest patients, including extracorporeal membrane oxygenation (Jones et al, 2015).

Areas for future research

There is a need to further understand the epidemiology of patients suffering in-hospital cardiac arrest. In particular, improved understanding of factors predicting patient outcome is needed, especially in patients who had a high level of pre-morbid function. There is also a need to better understand how many patients have missed opportunities for escalation of care, and which patients should not have been resuscitated in the first place. **BJHM**

Conflict of interest: none.

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