

The epidemiology of in-hospital cardiac arrests in Australia: a prospective multicentre observational study

The Australia and New Zealand Cardiac Arrest Outcome and Determinants of ECMO (ANZ-CODE) Investigators

Despite improved care, about 200 000 patients have an in-hospital cardiac arrest (IHCA) annually in the United States.¹ In 2013–2014 there were 1162 intensive care unit (ICU) admissions following IHCA from wards in Australia.² The prognosis associated with IHCA is poor, as 60–80% of patients will die during that admission.^{3–5} In historical studies, return of spontaneous circulation occurred in less than half of patients and about half of initial survivors subsequently died from hypoxic brain injury or cardiogenic shock with multiple organ failure.⁶

A recent systematic review of 30 studies reported on the epidemiology of IHCA in Australia and New Zealand between 1964 and 2014.³ The frequency of IHCA ranged from 1.31 to 6.11 per 1000 admissions in four population studies and from 0.58 to 4.59 per 1000 admissions in 16 cohort studies.³ Among the 12 studies in hospitals with rapid response teams (RRTs), the frequency of IHCA was 1.32 per 1000 admissions in the time period with an RRT, compared with 4.11 per 1000 in the time period without an RRT.³ Data on patient demographics, however, were limited, as were details of life support provided during the IHCA. To our knowledge, no study has reported on the nature and duration of ICU support for patients with IHCA in the Australian context.

Therefore, we conducted a prospective multicentre observational study to explore the contemporary epidemiology of ward IHCA in the environment of mature RRTs. Specifically, we evaluated the frequency of IHCA and recorded patient demographics in detail. In addition, we assessed the timing, initial rhythm and nature of resuscitation of the IHCA event. Finally, we recorded the details of ICU management, IHCA-related management, and hospital discharge status. We hypothesised that the in-hospital mortality of IHCA would be high and that ICU resource use after IHCA would be extensive.

Methods

Ethics and overarching governance

Ethics approval was obtained at the lead site (Austin Health; HREC/16/Austin/168) and all participating sites. The study

ABSTRACT

Background: Australian in-hospital cardiac arrest (IHCA) literature is limited, and mostly published before rapid response teams (RRTs). Contemporary data may inform strategies to improve IHCA outcomes.

Study design: Prospective observational study of ward adult IHCA in seven Australian hospitals.

Participants and outcomes: IHCA was defined as unresponsiveness, no respiratory effort, and commencement of external cardiac compressions. Data included IHCA frequency, patient demographics, resuscitation management, intensive care unit (ICU) management, and hospital discharge status.

Results: There were 15 953 RRT calls, 185 896 multiday admissions and 159 IHCA in 152 patients (median age, 71.5 years; interquartile range [IQR], 61.6–81.3 years). The median IHCA frequency was 0.62 IHCA per 1000 multiday admissions (IQR, 0.50–1.19). Most patients (93.4%) were admitted from home, and 68.4% (104/152) were medical admissions. Eighty-two IHCA (51.6%) occurred within 4 days of admission, and 66.0% (105/159) of initial rhythms were non-shockable. The median resuscitation duration was 6.5 minutes (IQR, 2.0–18.0 minutes) and adrenaline was the most common intervention (95/159; 59.8%). Death on the ward occurred in 30.2% of IHCA (48/159), and 49.7% (79/159) were admitted to the ICU, where vasoactive medications (75.9%), ventilation (82.3%), and renal replacement therapy (29.1%) use was extensive. Overall, 92 patients (60.5%) died and 40 (26.3%) were discharged home.

Conclusion: Among seven Australian hospitals, IHCA were infrequent, mostly occurred in older medical patients early in the hospital admission. Most were non-shockable, ICU therapy was extensive and nearly two-thirds of patients died in hospital. Further strategies are needed to prevent and improve IHCA outcomes.

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was overseen by a writing and management committee (online Appendix, available at cicm.org.au/Resources/Publications/Journal). Participating sites were recruited following expressions of interest at the 2015 meeting of the Australian and New Zealand Intensive Care Society Clinical Trials Group.

Site investigators signed the prospectively developed study protocol, and dedicated investigators screened all RRT calls for cases at each site. Data collection was performed using a standardised case report form, and consistency of collection was enhanced via the use of a data dictionary. Data were submitted to the lead investigators using encrypted transfer where data queries were generated and subsequently responded to by site investigators.

Patient inclusion and exclusion criteria

Patients were included if they were adults (aged ≥ 18 years) and had an IHCA. The diagnosis of IHCA was defined by all of the following: unresponsiveness, no observed respiratory effort, and external cardiac compressions commencement. Patients were excluded if there was a previously documented "not for resuscitation" order or the patient received electrical cardioversion but no external cardiac compressions (eg, for atrial fibrillation or conscious ventricular tachycardia). We also excluded IHCA's occurring in non-ward areas, such as the ICU, the emergency department, the cardiac catheterisation laboratory and the operating theatre. These areas were excluded because of the difficulties with capturing IHCA's in non-ward environments and to focus on the potential preventability of IHCA's in an era of mature RRTs.

Details of hospital rapid response teams

The study was conducted in seven Australian hospitals, of which four were tertiary university teaching hospitals, two were secondary university-affiliated hospitals and one was a university-affiliated private hospital. In six hospitals there were separate teams for code blue calls (for immediate review for potentially life-threatening emergencies) and RRT calls, and in one hospital a single team managed all emergencies. All services operated 24 hours per day, 7 days per week. For the purposes of this study, all emergency calls are referred to as RRT calls.

Study design

This was a prospective multicentre observational study conducted between 1 July 2017 and 9 August 2018. The length of participation for each site varied according to the time of attaining local ethics approval and the resources available to conduct the study.

Details of data collected

We collected hospital administrative data related to the dates of study commencement and conclusion including the total number of hospital admissions (including same day admissions) and the number of multiday admissions (lasting at least 24 hours and excluding dialysis, endoscopy, emergency department visits with discharge on the same date, and patients with day procedures who did not stay overnight) over that time period. We also recorded the total number of RRT calls for each hospital's study period.

Patient demographics included age, gender, usual place of residence, comorbidities needed to calculate the Charlson Comorbidity Index,⁷ the nature of the admitting unit (medical, surgical, other), the organ system associated with the admission diagnosis, and whether the patient had documented limitations of medical treatment (in addition to "not for resuscitation" status) before the IHCA. In instances where the patient had multiple hospital admissions, we used the demographic information related to the last hospital admission, as this event was more closely linked to the hospital outcome.

Details of the IHCA included the date, day and time, initial rhythm, whether the patient was in a monitored environment at the time of the arrest, and whether the event was witnessed or not. We also recorded the medications used during the IHCA, the number of electrical cardioversions, the total duration of cardiopulmonary resuscitation, whether the patient was successfully resuscitated on the ward, and whether they were admitted to the ICU.

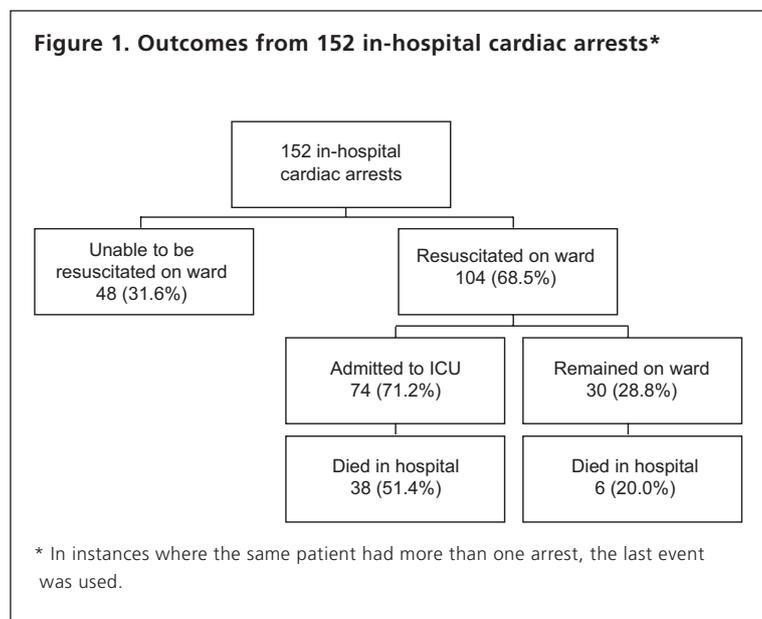


Table 1. Summary of frequency of in-hospital cardiac arrests (IHCAs) among seven Australian hospitals

Variable	Median (IQR)	Range
Months of enrolment (<i>N</i> = 62.7)	9.1 (5.7–12.4)	4.0–13.2
Total hospital admissions (<i>N</i> = 472 288)	75 926 (35 379–99 057)	33 795–99 694
Multiday hospital admissions (<i>N</i> = 185 896)	22 613 (15 189–37 241)	15 055–37 916
Number of RRT calls (<i>N</i> = 15 953)	2270 (1438–3367)	739–3550
Number of IHCAs (<i>N</i> = 159)	18 (9–33)	7–60
Proportion of RRT calls due to IHCA	0.67% (0.53%–1.76%)	0.40%–2.64%
IHCAs per month	2.2 (1.4–3.2)	1.15–4.53
IHCAs per 1000 admissions (total admissions)	0.27 (0.19–0.51)	0.13–0.66
IHCAs per 1000 multiday admissions	0.62 (0.50–1.19)	0.31–1.63

IQR = interquartile range; *N* = total number of events for each variable; RRT = rapid response team.

In patients admitted to the ICU after an IHCA, we recorded details of treatment, including the use and duration of vasoactive medications, extracorporeal membrane oxygenation (ECMO) and ventricular assist devices, mechanical and non-invasive ventilation, and use of renal replacement therapy. For the second and subsequent ICU admissions (not immediately following an IHCA), we documented the length of stay only. Data related to ICU admissions are presented in relation to the admission episode, and the number of patients requiring ICU admission is also indicated.

Finally, we recorded the status at hospital discharge. As patients may have had more than one IHCA and more than one hospital admission, we recorded this information both for the hospital admissions overall and, at a patient level, for the final admission in the study period, in the case of repeat hospital admissions.

Data analysis

Data were analysed according to a prospectively developed analysis plan, similar to that published previously for IHCA data in this region.⁸ Numerical data are presented as number and percentages. In cases where there were missing values, the data are presented as *n* (number of cases) and *N* (number of instances where the value was known), with no assumptions made about missing data. All continuous data were non-normally distributed and are presented as median and interquartile range (IQR). Differences in non-normally distributed data were assessed using the Mann–Whitney U or Kruskal–Wallis test, and differences in categorical data were analysed with the χ^2 or Fisher exact test, as appropriate. A two-sided $P < 0.05$ was taken to indicate statistical significance.

Results

Details of the patient cohort

During the study period, there were 159 cardiac arrests that occurred in 152 patients (Figure 1). A single cardiac arrest occurred in 147 patients and three patients had two cardiac arrests. A further two patients had three arrests which occurred across three hospital admissions for one of these patients.

The study period varied between hospitals from 4 to 13.2 months. Overall, there were 472 288 total hospital admissions, 185 896 multiday admissions and 15 953 RRT calls. The median frequency of IHCAs among the seven hospitals was 2.2 IHCAs per hospital per month (IQR, 1.4–3.2) or 0.62 IHCAs per 1000 multiday admissions (IQR, 0.50–1.19) (Table 1).

Among the 152 patients, 51 (33.6%) were female, and the median age at the time of the last hospital

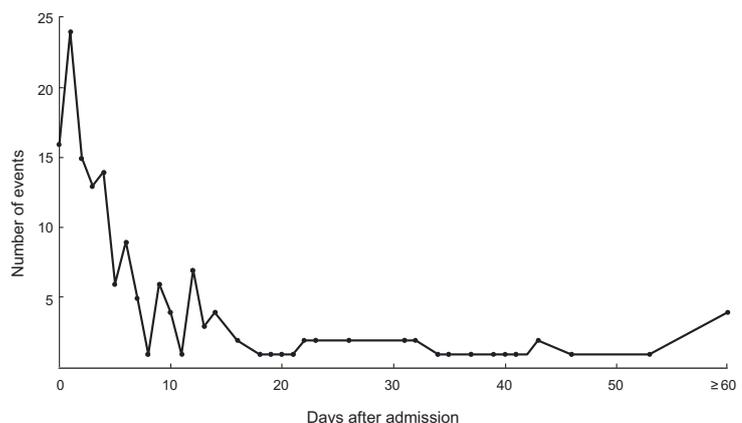
Figure 2. Timing of 159 in-hospital cardiac arrests in relation to hospital admission

Table 2. Demographic and clinical characteristics of patients with in-hospital cardiac arrest

Patient demographic	Details
Number of patients	152
Female gender, <i>N</i> (%)	51 (33.6%)
Patient age (years); median (IQR)	71.5 (61.6–81.3)
Usual place of residence, <i>N</i> (%)	
Home	142 (93.4%)
Nursing home	3 (2.0%)
Supported accommodation	4 (2.6%)
Other	3 (2.0%)
Previous cardiovascular risk factors, <i>N</i> (%)*	
Myocardial infarction	40 (26.3%)
Congestive cardiac failure	48 (31.6%)
Peripheral vascular disease	23 (15.1%)
Cerebrovascular disease	24 (15.8%)
Diabetes without complications	26 (17.1%)
Diabetes with complications	35 (23.0%)
Moderate to severe renal failure	34 (22.4%)
Type of admitting unit <i>N</i> (%)	
Medical	104 (68.4%)
Surgical	45 (29.6%)
Other	3 (2.0%)
Charlson Comorbidity Index, median (IQR)	2 (1–4)
Organ system for admission diagnosis, <i>N</i> (%)	
Cardiovascular	65 (42.8%)
Gastrointestinal	24 (15.8%)
Central nervous system	14 (9.2%)
Respiratory system	14 (9.2%)
Musculoskeletal	8 (5.3%)
Urological	6 (3.9%)
Haematological	3 (2.0%)
Other	18 (11.8%)
Prior limitations of medical treatment, <i>N</i> (%)	
None	142 (93.4%)
Not for intensive care	4 (2.6%)
Not for intubation	4 (2.6%)
Other	2 (1.3%)

IQR = interquartile range; *N* = total number of events for each variable.

* Patients may have more than one comorbidity.

admission was 71.5 years (IQR, 61.6–81.3 years) (Table 2). In 93.4% of cases, patients resided at home and had no prior documented limitations of medical treatment. Patients were admitted under a medical unit in about two-thirds of cases, cardiovascular disease and cardiovascular risk factors were each present in at least 15.1% of instances, and the median Charlson Comorbidity Index was 2 (IQR, 1–4). Only 42.8% of the admission diagnoses related to problems of the cardiovascular system (Table 2).

Timing, initial rhythm treatment and initial outcome of the in-hospital cardiac arrest

Eighty-two IHCA (51.6%) occurred in the first 4 days of hospital admission (Figure 2) and the median time between admission and the arrest was 4.0 days (IQR, 1.0–12.0 days). The number of events was evenly distributed among the days of the week. In contrast, events peaked between 10:00 and 20:00 (Figure 3). Seventy-eight events (49.1%) occurred between 08:00 and 18:00, and the median number of IHCA each hour during working hours (08:00–18:00) was 8.0 (IQR, 6.3–10.3), compared with 5.0 (IQR, 4.0–7.3) out of hours (18:01–7:59) ($P = 0.096$).

The initial rhythm was non-shockable in 105 arrests (66%), and the IHCA was witnessed in 121 cases (76.1%), respectively (Table 3).

Adrenaline was given in 95 events (59.7%) and the median number of adrenaline doses administered was 1.0 (IQR, 0–3.0). Amiodarone, atropine and sodium hydrogen carbonate were each administered in less than 14.0% of events (Table 3). The median duration of cardiopulmonary resuscitation was 6.5 minutes (IQR, 2.0–18.0 minutes) and in 32 IHCA (20.1%) the duration of resuscitation was less than 2 minutes.

Among the 159 IHCA, 48 patients (30.2%) could not be resuscitated and died on the ward. In 79 IHCA (49.7%), the patient was admitted to the ICU, and 32 patients (20.1%) were initially resuscitated during the arrest but were not admitted to ICU. For the 152 patients, the outcome of the final IHCA is shown in Figure 1.

Details of intensive care supports

There were 79 admissions (in 75 patients) to the ICU related to the IHCA, most of which required ICU-level support (Table 4). Vasoactive medications were administered during 60 admissions (75.9%), and 65 admissions (82.3%) required some form of ventilation. Noradrenaline and adrenaline were given in about two-thirds and one-third of admissions, respectively. ECMO was used in eight patients, two of whom subsequently underwent insertion of a ventricular assist device.

Diagnostic and therapeutic angiograms were performed in 14 (17.7%) and five (6.3%) instances, respectively. The median ICU length of stay for ICU admissions immediately following the IHCA was 4.0 days (IQR, 3.0–8.0 days). Seven patients had a further 14 ICU admissions with a median ICU length of stay of 5.0 days (IQR, 2.8–6.3 days), and used an additional total of 75 ICU days.

Details of patients not admitted to intensive care

Among patients not admitted to ICU, the remaining 32 cardiac arrests interventions that appeared to be related

Table 3. Features and management of 159 in-hospital cardiac arrests*

Feature	Present n (%)
Number of events	159
Weekday	114 (76.7%)
Weekend	45 (28.3%)
Initial rhythm	
Asystole	50 (31.4%)
PEA	55 (34.6%)
Ventricular tachycardia	18 (11.3%)
Ventricular fibrillation	18 (11.3%)
Unsure/other	18 (11.3%)
Arrest witnessed	
Yes	121 (76.1%)
No	35 (22.0%)
Unsure	3 (1.9%)
Patient monitored at time of arrest	
Yes	69 (43.4%)
No	87 (54.7%)
Unsure	3 (1.9%)
Adrenaline administration (N = 157)	
Not given	62 (39.0%)
Single dose	33 (20.8%)
Two doses	16 (10.1%)
Three doses	12 (7.5%)
Four or more doses	34 (21.4%)
Amiodarone administration (N = 158)	
Not given	135 (84.9%)
Single dose	18 (11.3%)
Two doses	4 (2.5%)
Atropine administration (N = 158)	
Not given	137 (86.2%)
Single dose	15 (9.4%)
Two or more doses	7 (4.4%)
NaHCO ₃ administration (N = 158)	
Not given	148 (93.1%)
Single dose	9 (5.7%)
Two doses	1 (0.6%)
Number of defibrillations (N = 158)	
Not given	113 (71.1%)
One	26 (16.4%)
Two	7 (4.4%)
Three	1 (0.6%)
Four or more	11 (6.9%)

n = number of cases in which the event occurred. N = number of cases for which data were available; NaHCO₃ = sodium hydrogen carbonate; PEA = pulseless electrical activity. * The percentage reflects the proportion of the 159 in-hospital cardiac arrests where the event occurred.

to the IHCA included diagnostic angiograms (two), transvenous pacing (three), permanent pacemaker (two), isoprenaline infusion (one), implantable defibrillator (one), exploratory laparotomy (one) and interhospital transfer for urgent cardiac surgery (one).

In-hospital outcomes of patients with cardiac arrest

The 152 patients had 154 discrete admissions, and in-hospital death occurred in 92/154 cases (59.7%). The median hospital length of stay was 10.0 days (IQR, 5.0–26.0 days) for the 154 discrete hospital admissions. Among the 152 patients, 92/152 (60.5%) died either because they could not be resuscitated or died after initially surviving the IHCA. Overall, 40 patients (26.3%) were discharged home (Table 5). The in-hospital mortality associated with the last IHCA is shown in Figure 1.

Discussion

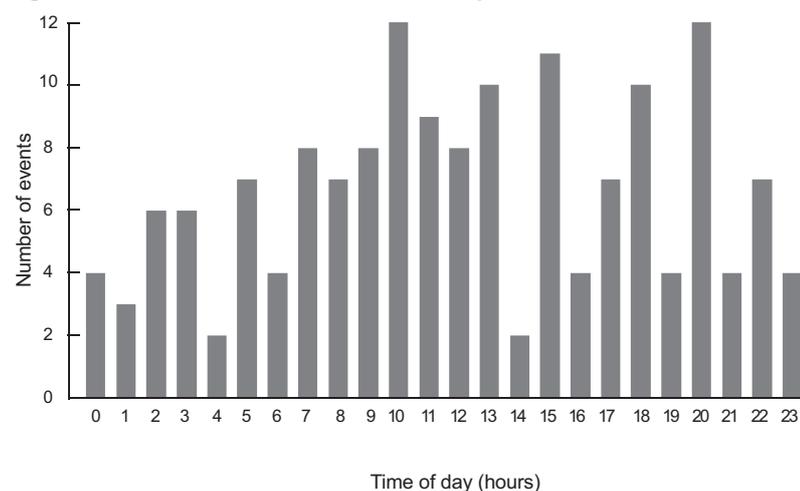
Summary of findings

We conducted a prospective observational study among seven hospitals during more than 472 000 hospital admissions and found that 152 patients had 159 IHCA on hospital wards. We found that ward IHCA were infrequent, occurring on average twice per month in each hospital. Patients were typically admitted from home, with few prior limitations of medical treatment and mostly under medical units. Less than half of admissions related to the cardiovascular system. About half of IHCA occurred in the first 4 days of hospital admissions, three-quarters were witnessed, and two-thirds of initial rhythms were non-shockable. Admission to the ICU occurred in half of the events, and vasoactive medications, ventilation and renal replacement therapy use was frequent and often prolonged. Overall, six of ten patients died in hospital, and about a quarter were discharged home.

Comparison with previous studies

This is the first prospective multicentre study to evaluate the epidemiology of IHCA in the context of hospitals with a mature RRT. A recent systematic review of IHCA in Australia and New Zealand included 12 publications in which an RRT had been introduced.³ In such hospitals, the frequency of IHCA was 1.33 per 1000 admissions, twice the value seen in our study.

The prevalence of IHCA (events/1000 admissions) reported here is also lower than in studies from the United States (1.4–11.8/1000),⁹ Poland (2.9/1000),¹⁰ China (17.5/1000)¹¹ and Italy (1.5/1000).¹² Such differences may relate in part to differences in case definition, inclusion of

Figure 3. Circadian variation of 159 in-hospital cardiac arrests

in association with a cardiac arrest. In the period from 1 January 2013 to 31 December 2014 there were 1162 such admissions, of which 63.4% received mechanical ventilation in the first 24 hours, with a median ICU length of stay of 8.4 days (IQR, 3.2–18.5 days) and with 50.5% in-hospital mortality.² In alignment with such observations, we found that 79.7% of patients received mechanical ventilation during their ICU stay, their median ICU length of stay related to the IHCA was 4.0 days (IQR, 3.0–8.0 days), and about half of ICU-admitted patients died in hospital (Figure 1).

Finally, we found an in-hospital survival of 39.5%, which is higher than that reported in the recent studies from the United States (18.8%),¹⁶ Finland (19%),¹⁵ China (9.1%)¹¹ and Poland (25.8%).¹⁰

IHCAs in critical care areas, presence of variably mature RRTs, or the inclusion of different types of hospital admission.

The median age and gender distribution reported here strongly accord with the corresponding studies within the Australasian systematic review.³ We found that half of IHCAs occurred in the first 4 days of admission, similar to two previous studies.^{8,13} Furthermore, we found that 66% of initial rhythms were non-shockable, which is lower than in studies from the United States (78.8%),¹⁴ Finland (85%)¹⁵ and Italy (81.1%).¹²

We are not aware of any studies that have reported the elements of resuscitation and organ support after IHCA during ICU admissions. A recent retrospective registry study evaluated the epidemiology of ICU admissions from the ward

Study strengths and limitations

The strengths of the study include the study oversight, prospective and multicentre nature, use of data dictionary and standardised collection tool, and detailed inclusion of patient demographics, novel elements of resuscitation and ICU management, and the provision of contemporary data on the frequency of IHCAs in ward patients.

Limitations of the study include lack of detail on recurrent ICU admissions. In addition, we cannot comment on the potential preventability of the IHCAs, or associations with in-hospital mortality. Moreover, our study included only seven hospitals and may not represent the findings of a broader cohort. However, many of the details presented

Table 4. Details of treatments provided for 79 patients admitted to intensive care after in-hospital cardiac arrest

Details of treatment	Number of patients receiving treatment (%)	Duration of treatment in patients treated (hours); median (IQR)
Total number of patients	79	
Cardiovascular support		
Noradrenaline infusion	56 (70.9%)	41.5 (16.3–90.8)
Adrenaline infusion	29 (36.7%)	10 (3.5–50)
Milrinone infusion	13 (16.5%)	43 (26.0–108.5)
Dobutamine infusion	12 (15.2%)	32 (9.5–76.3)
ECMO [†]	8 (10.1%)	101 (47.8–338)
Levosimendan infusion	4 (5.1%)	24 (21.8–31.5)
Ventricular assist device	2 (2.5%)	–
Ventilatory support		
Mechanical ventilation	63 (79.7%)	48.0 (17.5–155.0)
Non-invasive ventilation	14 (17.7%)	10.0 (2.8–25.0)
Renal replacement therapy	23 (29.1%)	60.0 (27.0–181.0)

ECMO = extracorporeal membrane oxygenation; IQR = interquartile range. † In two patients, ECMO was used as a bridge to a ventricular assist device with a duration of treatment of 645 hours and 1699 hours.

Table 5. Outcome at hospital discharge for 152 patients with in-hospital cardiac arrest

Outcome of patients	Number (%)
Total number of patients	152
Died in hospital during the study period	92 (60.5%)
Did not die in hospital during the study period	60 (39.5%)
Discharge to home	40 (26.3%)
Discharge to hostel or nursing home	6 (3.9%)
Discharge to rehabilitation	8 (5.3%)
Hospital transfer	6 (3.9%)

in our study accord well with previously published studies where data are available.

Implications for clinicians, educators and policy makers

We found that two-thirds of IHCA had an initial non-shockable rhythm. Despite the favourable in-hospital outcome of this cohort compared with historical studies, 60% of patients died during the study period. Combined, these findings support previous opinion that there should be increased emphasis on education on pre-arrest resuscitation and less on mandatory annual advanced cardiac life support for all hospital staff.¹⁷

We found that about 20% of IHCA involved cardiopulmonary resuscitation for less than 2 minutes. This may be attributable to more recent basic life support guidelines that suggest avoiding pulse checking before commencing external cardiac compressions for unresponsive patients who are not breathing.

Finally, we have revealed that only 50% of IHCA are admitted to the ICU. A previous Australian study reported that there were 1162 ICU admissions following IHCA from wards in 2013–2014,² suggesting there may be 2300 IHCA annually. If the in-hospital mortality risk of 60% observed in our study was applicable Australia-wide, this would equate to 1300 deaths from IHCA annually.

Areas for future research

The aims of the present study were to evaluate the frequency of IHCA, detailed patient demographics, nature and management of the IHCA and ICU care. This study is part of a larger research program to evaluate the preventability of IHCA, associations with in-hospital outcomes, and functional status after hospital discharge.

Conclusion

In seven Australian hospitals, IHCA occurred on average once per fortnight, within the first 4 days of hospital admission, and primarily in medical patients with comorbidities. Most initial rhythms were non-shockable, and 50% of events required intensive and prolonged critical care support. Although in-hospital mortality was lower than in historical studies, almost two-thirds of patients died in hospital. Further strategies are needed to prevent and improve outcomes from IHCA.

Competing interests

None declared.

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Appendix

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

The Australia and New Zealand Cardiac arrest Outcome and Determinants of ECMO (ANZ-CODE) investigators

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