Introduction

In-hospital cardiac arrest (IHCA) is a major problemin modern healthcare. In the United States there are approximately 209,000IHCAs per yearwith an in-hospital mortality of 60-80%[1], a mortality which has remained unchanged over 40 years[2].

Training and education of hospital staff in the recognition and treatment of IHCAs requires considerable resources. The major focus of such trainingis basic life support (BLS) and advanced cardiac life support (ACLS) which emphasises the importance of administration of early and effective chest compressions, as well asearly and appropriate cardiac defibrillation. A previous single centre study[3], however, suggested that less than a quarter of IHCAs had an initial defibrillation responsive rhythm. The generalisability of this finding to other hospitals in Australia and New Zealand (ANZ) is unknown.Whilethe epidemiology of IHCA has been extensively studied in the United States and Europe[4-11]less in known on the epidemiology of these patients in ANZ.

We undertook a systematic review of studies reporting onthe incidence, characteristics and outcomes of IHCA in ANZ to examinethe frequency of IHCA. Furthermore, we assessed for an associated between RRS presence and the incidence of IHCA. In addition, we assessed thedocumentation of pre-morbid patient demographics and co-morbidities, the details of the initial detected rhythm, and aspects of BLS and ACLS. Finally, we examined the outcomes of IHCA and associations with such outcomes.

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/imj.13039

Materials and methods

Search strategy and cross checking of data

We reviewed Medline for studies published between January 1964 and November 2014 to detect all original studies and reviews using the following medical subject heading terms; “arrest AND hospital AND Australia”, “arrest AND hospital AND New Zealand”, “inpatient AND arrest AND Australia”, and “inpatient AND arrest AND New Zealand”.

Studies were included if they reported on the characteristics and outcomes of cardiac arrests occurring in adult patients (>18 years) on a general hospital ward. We excluded papers that involved exclusively out-of-hospital cardiac arrests or studies that were not conducted in Australia or New Zealand. We also excluded studies that examined cardiac arrests within the Intensive Care Unit (ICU). A single investigator (GF) screened all abstracts, reviewed all manuscripts and populated the study tables. Two additional investigators (AH and SR) double-checked all abstracts blindly to ascertain if any potential manuscripts were missed.

We assessed and reported separately on population studies and studies presenting detailed patient cohort analysis. Population studies were those from which overall IHCA data were available without investigators being able to extract original (raw) data.

Research questions and data collected

All authors agreed *a priori*on the major research questions for the study, as well as the final analysis plan. These questions included evaluation of the cohort size, number of IHCAs, number of hospital admissions during the study period, the incidence of IHCAs per 1000 hospital admissions, and whether the study was conducted before or after the introduction of a rapid response system (RRS).

In studies where data were available, we also collected information of the demographics of the patients who suffered IHCA including; age and gender, place of residence, functional status, documented co-morbidities and admission diagnoses. In addition, we evaluated studies for the details of initial rhythm (ventricular tachycardia (VT), ventricular fibrillation (VF), pulseless electrical activity (PEA), asystole) or whether the rhythm was "shockable" (VT, VF) or "not shockable" (asystole, PEA, non-VF/VT). Furthermore, we assessed whether the IHCA was witnessed or monitored, as well as the time of day and day of week that the arrest was detected.

Details of the provision of BLS and ACLS were obtained. In particular, we documented whether there was a return of spontaneous circulation (ROSC) and the time to ROSC. We also recorded the outcome of the arrest including death during the cardiac arrest, death in-hospital, medium term mortality and functional outcome. Finally, we assessed manuscripts for analysis reporting on predictors or associations with in-hospital cardiac mortality, which we classified prospectively as "patient factors", "initial rhythm", "aspects of BLS / ACLS", "logistic factors" and "other".

Results

Details of literature review and included studies

We identified 934 studies, of which 60 were further analysed for suitability for inclusion,and 30 were finally included (Figure 1). Of the 30 studies included, four publications were “population studies” (IHCAs presented as aggregate data) and 26 studies were “cohort studies” (IHCAs presented as detailed data). The earliest study identified was published in 1987.

Frequency of IHCAs

Population studies

Four population studies reported aggregate data on the frequency and outcomes of IHCAs, representing the findings from more than 11.5 million hospital admissions (Table 1). The frequency of IHCAs in these studies ranged from 1.31 to 6.11 per 1000 admissions.

Cohort studies

Sixteen single centre studies and one multi-centre study reported specific data on the frequency of IHCAs, with values rangingfrom 0.58 to 4.59 per 1000 admissions (Table 2). Ofthese,13studies simultaneously reported data on both hospital admissions and the number of IHCAs, a total of 2,302 IHCAs in 1,021,262admissions (aggregate frequency 2.25 IHCAs per 1000 admissions).

Presence of Rapid Response System (RRS)

Overall,12 studiesdocumented information on both IHCAs and the presence of a RRS(Tables 3A and3B).Where there was no RRS, the frequency of IHCAs ranged from 2.90 to 5.06 per 1000 admissions (Table 3A) with raw data from three studiesreportingan aggregated value of 4.11 IHCAs per 1000 admissions. In contrast, in the presence of a RRSthe frequency of IHCAs ranged from 0.58 to 3.76 per 1000 admissions (Table 3B) with raw data from seven studiesreporting an aggregated value of1.32 IHCAs per 1000 admissions. The respective frequenciesreflect an odds ratio of0.32 for IHCA where a RRS is present(95% CI 0.28-0.37; $p < 0.001$).

Demographics of patients suffering IHCA

Only sevenstudies reportedsome demographic details of IHCA (Table 4). In aggregated data from fivestudies providinginformation on patient gender,63.5%were male and in sixstudies providinginformation onpatient age, the average rangedbetween 66.5 and 74.9 years. Three studiesreported on the type of admission,and when combined, 72.5% of IHCAs occurredin non-surgical admissions.Co-morbidities were only reported by Smith et al[28] for 91 IHCAs. The Charlson co-morbidity index was 1 to 4 in 68% and greater than 4 in 7% of patients. No study provided information on initial place of residenceor admission diagnosis.

Initial cardiac rhythm and details of treatment

The initial rhythm was documented in ten studies (Table 5). When combined, the initial rhythm was VT or VF in 31.4% of IHCAs, with a rangeof 19.0 to 48.8%. However, the documentation of whether IHCAs were witnessed or monitored was poor with only three studies reporting whether the IHCA was witnessed, and four reporting whether the patient was monitored..

No studies reported on specific details of adherence to BLS or ACLS guidelines. Jones et al[25]reported median times to CPR (0.5 mins), to defibrillation (1 mins), to adrenaline (4 mins) and to intubation (8 mins). Two studies reported on time intervals from collapse to ROSC[25,35] and one on automated external defibrillator (AED) use[38]. The median time from collapse to ROSC was reported as 10 minutes (IQR 3-20) by Jones et al[25] and 12 minutes (IQR 4-26) by Boyde et al[35].No studies reported on number of DC-shocks or other details of medications used.

Smith et al[38] reported on differences in patient characteristics and outcomes before and after implementation of AEDs. Although they found a similar percentage of witnessed and shockable events, and ROSC improved from 36% to 54% in the post–AED group (p=0.02), there was no difference in mortality (19 vs 22%, p=0.56).

Outcomes

Table 6 shows the reported outcomes of IHCA. ROSCwas achieved in 46% of patients. Mortality in population studies ranged from 59.4 to 77.5% (Table 1). In 19cohort studies, the aggregatedin-hospital mortality was 74.6%(Table 6).Mortality was similar in the presence or absence of aRRS (Table 3). In the three

studiesreporting on IHCAs prior to RRS,the aggregated mortality was 75.0%, versus75.4% in the five studies reportingafter RRS implementation (OR = 1.02 ; 95% CI 0.73-1.41; p = 0.91).

Cohn et al[36] reports no correlation between survival and major co-morbidities.

Two studies provided data on the discharge destination. Amongst the combined data on the 85 survivors reported by Smith et al[28] and Jones et al[25], only 63.5% were discharged home.Only four studies provided data onlonger term survival after hospital discharge. All 34 survivors reported by Smith et al[28] were alive at 90 days. For patients discharged alive, one-year survival was high, ranging from 85.7 to 97.0%[14,25,31].

The longer term functional status of survivors of IHCA was also reported to be good, with 93.3 to 97.1% having Cerebral Performance Category (CPC)of 1 or 2 at one year[25,36]. Rankin[31] reported that 44% of patients with shockable rhythmswere alive at one year, and all had CPC of 1, whereas if the rhythm was non-shockable, only 12% were alive at one year and only 73%of these had CPC of 1.

Associations with in-hospital mortality following cardiac arrest

Eight studiesprovided information on the outcome associated with monitoring or the initial cardiac rhythm (Table7).

Monitored or witnessed arrest

ROSC was higher in monitored arrests (64.3% vs 36.4%, Cohn et al[36] p=0.038 and 66.1% vs 42.8%, Jones et al[25] p<0.001) and in witnessed or monitored arrests (71.8% vs 21.4%, Boyde et al[35]p<0.001). Smith et al[28] report thatpatients in monitored areas were more likely to have shockable rhythms (48.3%) than those in non monitoredareas (19.4%, p=0.022).This was also the only study that showed a survival advantage (58.6% vs 27.4%,p=0.012) among patients who had an IHCA during monitoring. Jones et al[25] reported that patients in non-"cardiac arrest team" areas were more likely to die (63% vs 39%, p<0.001).

Initial cardiac rhythm

An initial shockable rhythm (VT or VF) was associated with greater rates of ROSCin two studies(66.3% vs 24.4%, Smith et al[37],p<0.0001 and81.5% vs 41.7%, Boyde et al[35], p<0.001), and greater survival to discharge (56.4% vs 15.6%)Jones et al[25] reported that survivors had shorter CPR (6.4 min vs 20.4 min, p=<0.001). No asystolic unwitnessed events survived in the study by Cohn et al[36].

Patient age

Increasing age was associated with an increased mortality in three studies[12,25,37], with one[37] finding that ROSC was reduced by 35% (p=0.0002) and survival to discharge was reduced by 36% (p=0.0004) with each decade of life.

Time of day

Four studiesfound that daytime cardiac arrests were associated withbetteroutcome with tworeportinggreater ROSC (41.4% vs 17.0%,p=<0.001[25] and 58.9% vs 41.0%,p=0.04[35]), and two others[34,37] reporting higher survival.

Discussion

Summary of major findings

We conducted a systematic review on the epidemiology of IHCAs in ANZ between January 1964 and November 2014. The overall frequency of IHCAs was approximately 2 per 1000 admissions but varied from 1.3 to 6 per 1000. The incidence of IHCA was significant lower in hospitals with a RRS. Although IHCAs were often witnessed, the initial cardiac rhythm was often non-shockable. In addition, ROSC was achieved in a minority of cases and overall survival was uncommon. However, for those surviving to hospital discharge, long-term survival and functional statuswas generally acceptable.

Comparison with previous studies

Multiple international studies[4-11]have reported on the epidemiology of IHCAs. Peberdy et al[11]found 0.17 IHCAs per bed per year, an average of 54 events per year for a notional 260 bed hospital.In keeping with our findings, several studies outside of ANZ also confirmworse patient outcomes with increasing age[4-8],IHCAS occurring on general wards[4],when unwitnessed[6] and occurring after hours[7,8].

Previous international studies provide findings which are consistent with those in our study. Several studies have reported that the initial cardiac rhythm is mostly

non-shockable (65 to 80%)[8,9,11], that non-shockable rhythms have worse survival when compared to shockable rhythms[6-8,11] and that older people with non-shockable rhythms havea particularly low survival[5]. Other studies report that ROSC occurs in 20.8 to 54.1%[5,7,9,11], that survival is higher if CPR is begun within one minute[8] and if the total duration of CPR is shorter[6,7].Survival is verylow (2.6%) in older people who had greater than 4 minutes of CPR[5].Only half of patients with ROSC survive to discharge[5-7] and overall survival is reported to be between15.2 to 18.7%[5-7,9,11]. Peberdy et al[11] reported no changes in the overall outcome of IHCA over 40 years.

In keeping with our findings, international studies have reported an overall mortality of 83% and that nearly 90% of all people who suffer IHCA are dead at one year[6,7]. In another study[11], 51% of the few immediate survivors returned home, yet 44% were discharged to a nursing home, other hospital or rehab facility, compared to only 14% of those who originally resided in these places.In contrast to our findings, at least two international studies reveal that about 10% of survivors hadsevere disability (classed as CPC greater than 2) and 44% of patients had aCPC score less than what they were admitted with[9], whichwas worse if the patient was older than 70 years[8]. A large number of older patients had reduced functional outcome post discharge[5].

Implications for clinicians and policy makers

It has previously been argued that sub-optimal end of life care, sub-optimal detection and recognition of deterioration, and “sudden and unexpected”deterioration may all predispose to IHCAs[41]. The data available in current literature does not permit allocation to these three categories.

However irrespective of predisposing factors, our findings imply that in ANZ hospitals, IHCAs are infrequent. This makes it unlikely that an individual ward staff member will see more than one or two such events per year. Moreover, two thirds of such events have an initial non-shockable rhythm and more than two thirds of patientsdie. These observations imply that prevention is more logical than intervention in this field and that current approaches to treatment are broadly ineffective.

Study limitations

The major limitation of our study relates to the quality of the data contained within the publications.Such data do not report many important details of patient management before, during and after IHCA. However, the key findings are consistent and repeated across populations and cohorts. As many of the studies assessed are small and single centred, there is a high risk of bias in many of the outcome measures. Such bias is likely to affect the aggregated rates and proportions presented in our article.

The association of hospital with a RRS and decreased frequency of cardiac arrests is consistent with previous observations, but due to the nature of our study, no causative inference is possible. Finally, we have no data on the cost of care of such patients after IHCA.

Areas for future research

There is a need to better understand the factors leading up to IHCA and what can be doneto prevent them by improving end of life care planning and the detection of deteriorating patients. Such research might also help identify which patients are most at risk of IHCA, so that prevention can be targeted. In addition, knowledge of the patho-physiological mode of death may be helpful. If progressive cardiogenic shock is a more common mode of death than neurological damage then extra-corporeal membrane oxygenation (ECMO) may improve outcomes[41]for selected cases of IHCA.

Conclusions

IHCAs appear to be relatively infrequent in ANZ hospitals and often not amenable to electrical cardioversion. Three quarters of patients die in hospital, but long-term functional status in hospital survivors appears acceptable. The incidence of IHCAs appear to be lower in hospitals with an RRS. Better treatment strategies are need to improve outcomes of IHCA.

References

1. Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, et al. Heart disease and stroke statistics - 2014 update: a report from the American Heart Association. Circulation. 2014 Jan 20;129(3):e28–92.

2. McGrath RB. In-house cardiopulmonary resuscitation - after a quarter of a century. Annals of Emergency Medicine. 1987 Dec;16(12):1365–8.

3. Jones D, Bellomo R, Bates S, Warrillow S, Goldsmith D, Hart G, et al. Long term effect of a medical emergency team on cardiac arrests in a teaching hospital. Crit Care. 2005;9(6):R808–15.

4. Ballew KA, Philbrick JT. Causes of variation in reported in-hospital CPR survival: a critical review. Resuscitation. 1995.

5. van Gijn MS, Frijns D, van de Glind EMM, C van Munster B, Hamaker ME. The chance of survival and the functional outcome after in-hospital cardiopulmonary resuscitation in older people: a systematic review. Age and Ageing. 2014 Jun 23;43(4):456–63.

6. Saklayen M, Liss H, Markert R. In-hospital cardiopulmonary resuscitation survival in 1 hospital and literature review. Medicine. 1995 Jul;74(4):163–75.

7. Cooper S, Janghorbani M, Cooper G. A decade of in-hospital resuscitation: outcomes and prediction of survival. Resuscitation. 2006 Feb;68(2):231–7.

8. Sandroni C, Nolan J, Cavallaro F, Antonelli M. In-hospital cardiac arrest: incidence, prognosis and possible measures to improve survival. Intensive Care Med. 2007 Feb;33(2):237–45.

9. Girotra S, Nallamothu BK, Spertus JA, Li Y, Krumholz HM, Chan PS. Trends in survival after in-hospital cardiac arrest. N Engl J Med. 2012 Nov 15;367(20):1912–20.

10. Reisfield GM, Wallace SK, Munsell MF, Webb FJ, Alvarez ER, Wilson GR. Survival in cancer patients undergoing in-hospital cardiopulmonary resuscitation: a meta-analysis. Resuscitation. 2006 Nov;71(2):152–60.

11. Peberdy MA, Kaye W, Ornato JP, Larkin GL, Nadkarni V, Mancini ME, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation. 2003 Sep;58(3):297–308.

12. Weerasinghe DP, MacIntyre CR, Rubin GL. The epidemiology of cardiac arrests in a Sydney hospital. Resuscitation. 2002 Apr;53(1):53–62.

13. Hillman K, Chen J, Cretikos M, Bellomo R, Brown D, Doig G, et al. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. Lancet. 2005 Jun;365(9477):2091–7.

14. Chen J, Ou L, Hillman KM, Flabouris A, Bellomo R, Hollis SJ, et al. Cardiopulmonary arrest and mortality trends, and their association with rapid response system expansion. Med J Aust. 2014 Jul 29;201(3):167–70.

15. Chen J, Ou L, Hillman K, Flabouris A, Bellomo R, Hollis SJ, et al. The impact of implementing a rapid response system: a comparison of cardiopulmonary arrests and mortality among four teaching hospitals in Australia. Resuscitation. 2014 Sep;85(9):1275–81.

16. Bristow PJ, Hillman KM, Chey T, Daffurn K, Jacques TC, Norman SL, et al. Rates of in-hospital arrests, deaths and intensive care admissions: the effect of a medical emergency team. Med J Aust. 2000 Jun 3;173(5):236–40.

17. Salamonson Y, Kariyawasam A, van Heere B, O'Connor C. The evolutionary process of medical emergency team (MET) implementation: reduction in unanticipated ICU transfers. Resuscitation. 2001 May;49(2):135–41.

18. Buist MD, Moore GE, Bernard SA, Waxman BP, Anderson JN, Nguyen TV. Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. BMJ. 2002 Feb 16;324(7334):387–90.

19. Jacques T, Harrison GA, McLaws M-L, Kilborn G. Signs of critical conditions and emergency responses (SOCCER): a model for predicting adverse events in the inpatient setting. Resuscitation. 2006 May;69(2):175–83.

20. Buist M, Harrison J, Abaloz E, Van Dyke S. Six year audit of cardiac arrests and medical emergency team calls in an Australian outer metropolitan teaching hospital. BMJ. 2007 Dec 8;335(7631):1210–2.

21. Peters R, Boyde M. Improving survival after in-hospital cardiac arrest: the Australian experience. Am J Crit Care. 2007 May;16(3):240–6.

22. Smith RJ, Hickey BB, Santamaria JD. Automated external defibrillators and survival after in-hospital cardiac arrest: early experience at an Australian teaching hospital. Crit Care Resusc. 2009 Dec;11(4):261–5.

23. Santamaria J, Tobin A, Holmes J. Changing cardiac arrest and hospital mortality rates through a medical emergency team takes time and constant review. Crit Care Med. 2010 Feb;38(2):445–50.

24. Vetro J, Natarajan DK, Mercer I, Buckmaster JN, Heland M, Hart GK, et al. Antecedents to cardiac arrests in a hospital equipped with a medical emergency team. Crit Care Resusc. 2011 Sep;13(3):162–6.

25. Jones P, Miles J, Mitchell N. Survival from in-hospital cardiac arrest in Auckland City Hospital. Emerg Med Australas. 2011 Oct;23(5):569–79.

26. Kansal A, Havill K. The effects of introduction of new observation charts and calling criteria on call characteristics and outcome of hospitalised patients. Crit Care Resusc. 2012 Mar;14(1):38–43.

27. Drower D, McKeany R, Jogia P, Jull A. Evaluating the impact of implementing an early warning score system on incidence of in-hospital cardiac arrest. NZ Med J. 2013.

28. Smith RJ, Santamaria JD, Reid DA, Faraone EE. The mortality associated with review by the rapid response team for non-arrest deterioration: a cohort study of acute hospital adult patients. Crit Care Resusc. 2014 Jun;16(2):119–26.

29. Herod R, Frost SA, Parr M, Hillman K, Aneman A. Long term trends in medical emergency team activations and outcomes. Resuscitation. 2014 Aug;85(8):1083–7.

30. Husband A, Mercer I, Detering KM, Eastwood GM, Jones DA. The epidemiology of respiratory arrests in a teaching hospital. Resuscitation. 2014 Mar;85(3):364–8.

31. Rankin A. The in-hospital Utstein style: use in reporting outcome from cardiac arrest in Middlemore Hospital 1995-1996. Resuscitation. 1998 Feb;36(2):91–4.

32. Lee A, Bishop G, Hillman KM, Daffurn K. The medical emergency team. Anaesth Intensive Care. 1995 Apr;23(2):183–6.

33. Trinkle RM, Flabouris A. Documenting rapid response system afferent limb failure and associated patient outcomes. Resuscitation. 2011 Jul;82(7):810–4.

34. Twidale N, Beltrame J, Tonkin A. Results of cardiopulmonary resuscitation in adult patients managed in a teaching hospital: clinical outcome and implications. Aust Clin Rev. 1989 Mar;8(32):223–8.

35. Boyde MS, Padget M, Burmeister E, Aitken LM. In-hospital cardiac arrests: effect of amended Australian Resuscitation Council 2006 guidelines. Aust Health Rev. 2013 May;37(2):178–84.

36. Cohn AC, Wilson WM, Yan B, Joshi SB, Heily M, Morley P, et al. Analysis of clinical outcomes following in-hospital adult cardiac arrest. Intern Med J. 2004 Jul;34(7):398–402.

37. Smith S, Shipton EA, Wells JE. In-hospital cardiac arrest: different wards show different survival patterns. Anaesth Intensive Care. 2007 Aug;35(4):522–8.

38. Smith RJ, Hickey BB, Santamaria JD. Automated external defibrillators and in-hospital cardiac arrest: patient survival and device performance at an Australian teaching hospital. Resuscitation. 2011 Dec;82(12):1537–42.

39. Woog RH, Torzillo PJ. In-hospital cardiopulmonary resuscitation: prospective survey of management and outcome. Anaesth Intensive Care. 1987 May;15(2):193–8.

40. Cox SV, Woodhouse SP, Weber M, Boyd P, Case C. Rhythm changes during resuscitation from ventricular fibrillation. Resuscitation. 1993 Aug;26(1):53–61.

41. Jones D, Hilton A, Bellomo R. Extracorporeal membrane oxygenation for inhospital cardiac arrests: The rise of the machines. 2015.

Table 1: Frequency and mortality of IHCA in Australia and New Zealand, derived from four population studies

Study	Hospitals, n (location)	Admissions, n	IHCA frequency, per 1000 (range)	IHCA mortality, per 1000 (range)	IHCA mortality, %	RRS
Weerasinghe et al, 2002[12]	19+ (NSW)	1,824,510†	2.04	-	67.7	Unknown
Hillman et al, 2005[13]	23 baseline (ANZ)	125,132	- (1.60 - 2.61)	-	-	No
Hillman et al, 2005[13]	11 control (ANZ)	150,000†	1.64	-	-	No
Hillman et al, 2005[13]	12 intervention (ANZ)	190,840†	1.31	-	-	Yes
Chen et al, 2014[14]	82 (NSW)	9,221,138	- (1.85 - 3.72)	- (1.26-2.71)	67.7-72.7	Mix
Chen et al, 2014[15]	4 (NSW)	1,346,484	- (1.47 - 6.11)	- (1.18-4.72)	-	Mix
Chen et al, 2014[15]	1 (NSW)	479,194	- (1.47 - 2.64)	1.62 (1.18-2.18)	77.5	Yes
Chen et al, 2014[15]	3 (NSW)	942,368	- (2.98 - 6.11)	2.72 (1.99-4.72)	68.5	No
Chen et al, 2014[15]	2 (NSW)	103,049	- (2.47 - 2.73)	1.84 (1.70-1.94)	70.2	Yes
Chen et al, 2014[15]	1 (NSW)	43,074	- (3.25 - 4.52)	1.93 (1.93-3.20)	59.4	No

Abbreviations: ANZ = Australia and New Zealand, NSW = New South Wales, Australia, IHCA = in-hospital cardiac arrest, RRS = rapid response system

Notes: These 10 data-sets are derived from 4 population based studies, each data-set comprising different time periods or different institutions.

Both papers from Chen et al[14,15] used the same database with some overlap.

†= admissions were estimated from reported 3722 IHCAs[12], 246 IHCAs[13], and 250 IHCAs[13] respectively.

Table 2: Frequency of IHCA in cohort centre studiesin Australia and New Zealand

Study	IHCA, n	Admissions, n	IHCA frequency, per 1000 admissions	RRS
Bristow et al, 2000[16]	234	50942	4.59	Mixed
Salamonson et al, 2001[17]	43	-	0.7-0.8	Yes
Buist et al, 2002[18]	120	53995	2.22	Mixed
Weerasinge et al, 2002[12]†	201	57975	3.47	Unknown
Jones et al, 2005[3]	279	145463	1.92	Mixed
Jacques et al, 2006[19]	5	3160	1.58	Yes
Buist et al, 2007[20]	271	186070	1.46	Yes
Peters et al, 2007[21]	128	36727	3.49	Unknown
Smith et al, 2009[22]	152	58098	2.62	Unknown
Santamaria et al, 2010[23]	-	-	0.58 - 2.93	Mixed
Vetro et al, 2011[24]	22	16142	1.36	Yes
Jones et al, 2011[25]‡	415	235205	1.76	Unknown
Kansal et al, 2012[26]	-	53665	0.95-1.30	Yes
Drower et al, 2013[27] ‡	168	44184	3.80	Unknown
Smith et al, 2014[28]	91	43385	2.10	Yes
Herod et al, 2014[29]	-	-	1.1-1.4	Yes
Husband et al, 2014[30]	259	143581	1.80	Yes
Totals	**2345**	**1074927**	**2.25** [2302/1021262]	

Abbreviations: IHCA = in-hospital cardiac arrest, RRS = rapid response system

Notes:

†All were single centre studies, except Weerasinge et al[12].

‡All studies were Australian except Drower et al[27]and Jones et al[25]which were from New Zealand.

Table 3: Frequency and mortality of IHCA before and after implementation of RRS

Table 3A: Pre-RRS					
Study	**Admissions, n**	**IHCA, n**	**IHCA frequency, per 1000 admissions**	**IHCA mortality, % [n]**	**IHCA mortality, per 1000 admissions**
Rankin, 1998[31]†	-	133	-	73.7 [98]	-
Bristow et al, 2000[16] (pre-RRS)	32604	165	5.06	-	-
Buist et al, 2002[18] (pre-RRS)	25194	73	2.90	76.7 [56]	2.22
Jones et al, 2005[3] (pre-RRS)	16246	66	4.06	75.8 [50]	3.08
Santamaria et al, 2010[23] (pre-RRS)	-	-	2.93	-	-
Totals	**74044**	**437**	**4.11** [304/74044]	**75.0** [204/272]	**2.56** [106/41440]

Table 3B: Post-RRS					
Study	**Admissions, n**	**IHCA, n**	**IHCA frequency, per 1000 admissions**	**IHCA mortality, %[n]**	**IHCA mortality, per 1000 admissions**
Lee et al, 1995[32]	-	148	-	-	-
Bristow et al, 2000[16] (post-RRS)	18338	69	3.76	-	-
Salamonson et al, 2001[17]	-	43	0.7-0.8	-	-
Buist et al, 2002[18] (post-RRS)	28801	47	1.63	55.3 [26]	0.90
Jones et al, 2005[3] (1 yr post-RRS)	25216	51	2.02	82.4 [42]	1.67
Jones et al, 2005[3] (4 yrs post-RRS)	104001	162	1.56	84.0 [136]	1.31
Jacques et al, 2006[19]	3160	5	1.58	-	-
Buist et al, 2007[20]	186070	271	1.46	-	-
Santamaria et al, 2010[23] (1-2 yrs post-RRS)	-	-	2.90	-	-
Santamaria et al, 2010 (3-4 yrs post-RRS)[23]	-	-	1.51	-	-
Santamaria et al, 2010[23] (5-8 yrs post-RRS)	-	-	0.58	-	-
Trinkle et al, 2011[33]	-	31	-	90.3 [28]	-
Husband et al, 2014[30]	143581	259	1.80	63.3 [194]	1.35
Smith et al, 2014[28]	43385	91	2.10	62.6 [57]	1.31
Totals	**552552**	**955**	**1.33** [733/552552]	**75.4** [483/641]	**1.32** [455/344994]

Abbreviations: IHCA = in-hospital cardiac arrest, RRS = rapid response system

Note:

† all studies were Australian except Rankin[31]which was from New Zealand.

Table 4: Demographics of patients suffering IHCA

Study	IHCA, n	Age, years	Male, % [n]	Non-surgical, % [n]
Twidale et al, 1989[34]	34	-	82.4 [28]	-
Jones et al, 2005[3]	279	71.3†	-	68.5 [191]
Trinkle et al, 2011[33]	31	74.9 (12.2)†	-	-
Jones, et al, 2011[25]§	415	66.5 (15.5)†	59.3 [246]	-
Boyde et al, 2013[35]	519	69 (56-78)‡	63.1 [328]	-
Smith et al, 2014[28]	91	70 (62-78)‡	67.0 [61]	60.4 [55]
Husband et al, 2014[30]	259	71.3 (61-81) ‡	67.2 [174]	81.1 [210]
Totals	**1733**	-	**63.5** [837/1318]	**72.5** [456/629]

Abbreviation: IHCA = in-hospital cardiac arrest

Notes:

† = mean (+/- standard deviation), ‡ = median (inter-quartile range)

§all studies were Australian except Jones et al[25], which was from New Zealand

Table 5: Details of monitoring and the initial detected rhythm for patients suffering IHCA

Study	IHCA, n	Witnessed, % [n]	Monitored, % [n]	Shockable (VF or VT), % [n]	Non-shockable, % [n]	PEA, % [n]	Asystole, % [n]	Other rhythm, % [n]†
Twidale et al, 1989[34]	56	-	39.3 [22]	41.1 [23]	58.9 [33]	-	-	-
Rankin, 1998[31]	133	-	-	32.3 [43]	67.7 [90]	-	20.3 [27]	47.4 [63]
Salamonson et al, 2001[17]	43	-	-	48.8 [21]	51.2 [22]	-	-	-
Cohn et al, 2004[36]	105	47.6 [50]	26.6 [28]	19.0 [20]	81.0 [85]	33.3 [35]	47.6 [50]	-
Jones et al, 2005[3]	279	-	-	22.6 [63]	77.4 [216]	25.1 [70]	43.7 [122]	8.6 [24]
Smith et al, 2007[37]	243	-	-	34.2 [83]	65.8 [160]	-	-	-
Jones et al, 2011[25]	415	88.2 [366]	66.7 [277]	35.7 [148]	64.3 [267]	22.4 [93]	22.4 [93]	19.5 [81]
Boyde et al, 2013[35]	519	73.8 [383]	-	31.2 [162]	68.8 [357]	-	-	-
Drower et al, 2013[27]	168	-	-	33.3 [56]	66.7 [112]	35.1 [59]	24.4 [41]	7.1 [12]
Smith et al, 2014[28]	91	-	31.9 [29]	28.6 [26]	71.4 [65]	-	-	-
Totals	**2052**	**80.2** [749/934]	**53.4** [356/667]	**31.4** [645/2052]	**68.6** [1407/2052]§	**26.6** [257/967]	**26.5** [292/1100]	**18.1** [180/995]

Abbreviations: IHCA = in-hospital cardiac arrest, VF = ventricular fibrillation, VT = ventricular tachycardia, PEA = pulseless electrical activity

Notes:

† "Other rhythm" can include PEA, asystole, bradycardia, not recorded, respiratory arrest or otherwise classified as "non-shockable".

‡ New Zealand based studies, the rest were from Australia.

§Individual totals for non-shockable rhythms (PEA, asystole and other rhythm) add to >68.6% because of irregular classification of non-shockable rhythms.

Table 6: Clinical outcomes of patients suffering IHCA in Australia and New Zealand

Study	Admissions, n	IHCA, n	IHCA frequency, per 1000 admissions	ROSC, % [n]	IHCA mortality, % [n]
Woog et al, 1987[39]	-	76	-	34.2 [26]	89.5 [68]
Twidale et al, 1989[34]	-	56	-	37.5 [21]	80.3 [45]
Cox et al, 1993[40]	-	44	-	31.8 [14]	81.8 [36]
Lee et al, 1995[32]	-	148	-	-	71.0
Rankin, 1998[31]†	-	133	-	35.3 [47]	73.7 [98]
Weerasinghe et al, 2002[12]	57975	201	3.47	-	69.7 [140]
Buist et al, 2002[18]	53995	120	2.22	-	68.3 [82]
Cohn et al, 2004[36]	-	105	-	43.8 [46]	79.0 [83]
Jones et al, 2005[3]	145463	279	1.92	39.1 [109]	81.7 [228]
Smith et al, 2007[37]†	-	243	-	38.7 [94]	79.0 [192]
Peters et al, 2007[21]	36727	128	3.49	-	68.0 [87]
Smith et al, 2009[22]	58098	152	2.62	-	65.1 [99]
Trinkle et al, 2011[33]	-	31	-	-	90.3 [28]
Jones, et al, 2011[25]†	235205	415	1.76	58.3 [242]	72.8 [302]
Smith et al, 2011[38]	-	166	-	-	80.1 [133]
Vetro et al, 2011[24]	16142	22	1.36	-	72.7 [16]
Boyde et al, 2013[35]	-	519	-	54.1 [281]	69.6 [361]
Smith et al, 2014[28]	43385	91	2.10	-	62.6 [57]
Husband et al, 2014[30]	143581	259	1.80	-	74.9 [194]
Totals	**1128592**	**4188**	**2.14** [2624/1074927]	**46.0** [989/2149]	**74.6** [2477/3319]

Abbreviations: ROSC = return of spontaneous circulation, IHCA = in-hospital cardiac arrest.

Note:

† New Zealand based studies, the rest were from Australia.

Table 7: Associations with in-hospital mortality and survival for patients suffering IHCA

Study	Type of arrest	Shockable, % [n/N]	ROSC, % [n/N]	Survival to discharge, % [n/N]
Twidale et al, 1989[34]	Monitored	50.0 [11/22]	36.4 [8/22]	13.6 [3/22]
	Unmonitored	35.3 [12/34]	38.2 [13/34]	23.5 [8/34]
Rankin, 1998[31]§	Monitored	65.1 [28/43]	-	-
	Unmonitored	38.9 [35/90]	-	-
	Shockable	-	-	46.5 [20/43]
	Non-shockable	-	-	16.7 [15/90]
Cohn et al, 2004[36]	Witnessed	-	38.0 [19/50]	-
	Unwitnessed	-	49.0 [27/55]	-
	Monitored	-	64.3 [18/28]†	-
	Unmonitored	-	36.4 [28/77]†	-
	Shockable	-	65.0 [13/20]	45.0 [9/20]†
	Non-shockable	-	38.8 [33/85]	15.3 [13/85]†
Peters et al, 2007[21]	Witnessed	-	-	37.5 [33/88]
	Unwitnessed	-	-	45.0 [18/40]
	Monitored	-	50.0 [23/46]	37.0 [17/46]
	Unmonitored	-	40.1 [33/82]	19.5 [16/82]
	Shockable	-	-	57.1 [24/42]†
	Non-shockable	-	-	19.8 [17/86]†
Smith et al, 2007[37]§	Shockable	-	66.3 [55/83]†	39.8 [33/83]]†
	Non-shockable	-	24.4 [39/160]†	11.3 [18/160]†
Jones et al, 2011[25]§	Witnessed	-	15.7 [14/89]	-
	Unwitnessed	-	10.0 [5/49]	-
	Monitored	-	66.1 [183/277]†	-
	Unmonitored	-	42.8 [59/138]†	-
	Shockable	-	-	52.7 [78/148]†
	Non-shockable	-	-	13.1 [35/267]†
Boyde et al, 2013[35]	Witnessed and/or monitored‡	-	71.8 [242/337]†	-
	Not witnessed nor monitored‡	-	21.4 [39/182]†	-
	Shockable	-	81.5 [132/162]†	57.4 [93/162]†
	Non-shockable	-	41.7 [149/359]†	18.2 [65/357]†
Smith et al, 2014[28]	Monitored	48.3 [14/29]	-	58.6 [17/29]†
	Unmonitored	19.4 [12/62]	-	27.4 [17/62]†
	Totals	**Shockable, % [n/N]**	**ROSC, % [n/N]**	**Survival to discharge, % [n/N]**
	Monitored	56.4 [53/94]	62.2 [232/373]	38.1 [37/97]
	Unmonitored	31.7 [59/186]	40.2 [133/331]	23.0 [41/178]
	Witnessed	-	23.7 [33/139]	37.5 [33/88]
	Unwitnessed	-	30.8 [32/104]	45.0 [18/40]
	Shockable	-	75.5 [200/265]	56.4 [257/456]
	Non-Shockable	-	36.5 [221/604]	15.6 [163/1045]

Abbreviations: ROSC = return of spontaneous circulation, IHCA = in-hospital cardiac arrest, Shockable = VF or VT, Non-Shockable = asystole, PEA, non-VF, non-VT.

Notes:

† p-value for significance reported in body of text, otherwise differences are not significant.

‡ Witnessed or monitored were not differentiated and were reported together.

§ New Zealand based studies, the rest were from Australia..

Title:

The epidemiology of in-hospital cardiac arrests in Australia and New Zealand

Author details:

Gerard FennessyMBChB, FCICM, FRNZCUC, Consultant Intensive Care Specialist, Western Health, Footscray, Melbourne, Australia.

Andrew Hilton FCICM, FANZCA, MBioethics, DDU, Consultant Intensive Care Specialist, Austin Hospital, Heidelberg, Melbourne, Australia.

Sam Radford FCICM, FRACP, The University of Melbourne,Consultant Intensive Care Specialist, Austin Hospital, Heidelberg, Melbourne, Australia.

Rinaldo Bellomo MD, FCICM, FRACP, The University of Melbourne, Austin Hospital, Heidelberg, Melbourne, Australia.

Daryl Jones

Corresponding author:

A/Prof Daryl Jones

BSc(Hons), MB BS, FRACP, FCICM, MD

Adjunct Senior Research Fellow DEPM Monash University

Consultant Intensive Care Specialist, Austin Health

Intensive Care Unit

Austin Hospital, Studley Road, Heidelberg,

Victoria, Australia, 3084

Email: Daryl.Jones@austin.org.au

Tel: +61 3 9496 5000

Fax: +61 3 9496 3932

Acknowledgements :

Nil

Word count :

Abstract – 246 words

Main text – 2518 words

Title:

The epidemiology of in-hospital cardiac arrests in Australia and New Zealand. G Fennessy, A Hilton, S Radford, R Bellomo, D Jones.

Abstract:

Background: The epidemiology of in-hospital cardiac arrests (IHCAs) in Australia and New Zealand (ANZ) has not been systematically assessed.

Aim: To conduct a systematic review of the frequency, characteristics and outcomes of adult IHCAs in ANZ.

Method: Medline search for studies published 1964 to 2014 using MeSH terms "arrest AND hospital AND Australia", "arrest AND hospital AND New Zealand", "inpatient AND arrest AND Australia", and "inpatient AND arrest AND New Zealand".

Results: We screened 934 studies, analysed50 and included 30. Frequency of IHCAsranged from 1.31-6.11 per 1000 admissions in four population studies and 0.58-4.59 per1000 in 16 cohort studies. The frequencywas 4.11 vs 1.32 per 1000 admissionsin hospitals withrapid response system(RRS) compared to those without (OR: 0.32; 95% CI 0.28-0.37; $p < 0.001$). On aggregate, the initial cardiac rhythm was ventricular tachycardia/fibrillation in 31.4% (range 19.0-48.8%) in 10 studies reporting such data. On aggregate, IHCAs were witnessed in 80.2% cases (three studies) and monitored patients in 53.4% cases(four studies). Details of life support were poorly documented. On aggregate, return of spontaneous circulation (ROSC) occurred in 46.0% of patients. Overall, 74.6% (range 59.4-77.5%) died in-hospital but survival was higher among monitored or younger patients,in those with a shockable rhythm, or during working hours.

Conclusions: IHCAs are uncommon in ANZ and three quarters die in hospital. However, their frequency varies markedly across institutions and may be affected by the presence of RRS.Where reported, the long term outcomes survivors appear to have acceptable neurological outcomes.

Keywords:

cardiac arrest, in-hospital, mortality, rapid response, defibrillation