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ORIGINAL ARTICLE

Uncontrolled organ donation following prehospital cardiac arrest: a potential solution to the shortage of organ donors in the United Kingdom?

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Conflicts of Interest
Ethical approval was not sought as this was not appropriate for the study.

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Summary

Uncontrolled donation after cardiac death (DCD) could increase the donor pool in the UK. Air ambulance (AA) teams may be well placed to recruit these donors. They cover large geographical areas, have short transfer times and tasked predominantly to life-threatening cases. The potential to recruit from this pool of donors was reviewed. Seventy-five month activity of an AA unit was analysed identifying patients who entered prehospital cardiac arrest (PHCA). Patients over 70 years of age were excluded as were those whose cardiac arrest was unwitnessed. A minimum potential donor pool was estimated based upon patients dying of medical causes. Rates of bystander resuscitation, mechanism of death and patient demographic data were observed. During 10 022 missions 534 patients entered PHCA. A total of 106 patients met inclusion criteria. There were 12 paediatric cases; 39 cases of 17–50 year olds and 55 cases of 50–70 year olds. Medical and traumatic causes of death accounted for 60 and 46 cases respectively. Bystander resuscitation efforts were provided in 47% of cases. A regional AA could contribute to a national uncontrolled DCD programme. Given that there are 31 AA's in England and Wales, we estimate that there could be a minimum of 300 additional potential donors annually.

Introduction

The divide between the number of organ donors and potential recipients continues to widen despite evolution of strategies such as split liver and living-related liver and kidney donation programmes [1–3]. A further strategy to increase the donor pool is procurement of organs from donation after cardiac death (DCD) [4]. Maastricht criteria classify these donors relative to the location of cardiac death [5]. In the UK, DCD occurs mainly in patients who suffer cardiac death after withdrawal of organ support [4]. These donors are Maastricht category 3, also referred to as controlled DCD. Uncontrolled DCD are Maastricht category 1 and 2 donors who die in the prehospital environment or suffer an unexpected cardiac arrest in hospital. Presently there is no national programme to recruit from this pool, although in other European countries programmes are in place [6] or being developed [7,8].

The clinically important difference between controlled and uncontrolled donation focuses on the duration of warm ischaemia. In controlled donation, this is reasonably short but in uncontrolled donation this can extend up to 60 min. Following an unwitnessed cardiac arrest, this can be difficult to calculate. Initial reports, particularly following liver transplantation, reported high rates of graft nonfunction [9]. A strategy to decrease the ischaemic insult associated with procurement of organs following uncontrolled DCD has been developed and is associated with acceptable rates of function following

transplantation [6]. Following prehospital cardiac arrest (PHCA) cardiopulmonary resuscitation (CPR) is commenced and performed until the patient arrives at the retrieval centre. When all reversible causes of cardiac arrest have been corrected and the resuscitating team is satisfied that cardiac death is irreversible resuscitation efforts cease. The patient is legally declared dead after 5 min of asystole with apnoea. Artificial restoration of cardiac output is commenced maintaining organ perfusion while family is sought to approve donation. Initially this is by external chest compressions with intermittent positive pressure ventilation and can be replaced by extracorporeal membrane oxygenation (ECMO) [6]. Balloon occlusion of the thoracic aorta limits perfusion to the abdominal organs avoiding ethical concerns of cerebral reperfusion in this model of organ donation.

There remains other ethical as well as logistical difficulties inherent when recruiting organs from this donor pool. Technical difficulties are in part overcome by the above technique of organ perfusion delivered at specialist centres. One logistical difficulty is identifying potentially suitable donors. Currently uncontrolled DCD occurs sporadically in the UK utilizing land-based paramedics, although air ambulance teams could offer clear advantages. Suitable patients could be rapidly transferred long distances to an appropriate centre with a retrieval team and ECMO. Air ambulance teams are predominately dispatched to patients triaged with life-threatening conditions [10]. There are just 31 air ambulances covering the majority of the UK.

The purpose of this study was to evaluate the potential contribution to a national uncontrolled DCD programme by air ambulance teams.

Methods

Data capture

This retrospective study was performed using a single air ambulance database. The Warwickshire and Northamptonshire Air Ambulance (WNAA) began operations in October 2003. They developed a bespoke Microsoft Access database that is separate from the UK NHS Ambulance Service database. Data are recorded prospectively after each mission. Data capture is more complete than the standard database with more fields to capture physiological observations, advanced interventions, outcomes and case narrative. Furthermore, it avoids loss of data because of misinterpretation of handwriting when paper forms are scanned and converted to an electronic format.

Data were available from every mission between October 2003 and 31st December 2009. All cases of PHCA were identified by searching the physiological observations for cases where a heart rate or respiratory rate of zero was recorded. Further review of the database occurred using search terms 'cardiac arrest', 'arrest', 'collapse', 'CPR' and 'resuscitation' and yielded no additional cases.

Assessment of suitability for potential uncontrolled DCD and predicted potential impact of a national programme

The following cases were excluded from analysis: where age was unrecorded, patients over 70 years old, patients not receiving efforts at resuscitation by the air ambulance team (reasons for nonresuscitation included the presence of rigour mortis or overwhelming traumatic injury) or if the cardiac arrest was not witnessed (and thus the duration of warm ischaemia could not be calculated). The minimum case load of potential donors was based upon patients who had a witnessed cardiac arrest, who were 70 years old or younger and had died because of a medical cause of death. Deaths following trauma were reviewed separately and provide a maximum potential caseload. We have assumed that all cases of medical cardiac arrest would provide potential DCD donors and that traumatic deaths would be considered on a case by case basis dependent upon a review of the patients injuries. The main injuries were recorded in the database but a detailed assessment of intra-abdominal injury was not usually possible.

Potential contribution to a national programme assumes equal case mix and workload by each air ambulance team.

Population and setting

Warwickshire and Northamptonshire Air Ambulance is based in the UK, serving a mixed urban and rural population in excess of 1.2 million. WNAA operates one helicopter operating 8–12 h a day, 7 days a week during daylight hours. The flight crew consists of a pilot, paramedic and usually a doctor. When a doctor is not available the second crewmember is a paramedic. The team is dispatched by local NHS ambulance controls to a case mix of traumatic and medical emergencies. Allocation of crew-mix and medical practitioner is dependent on availability of staff rather than a mission category specific basis.

Statistical analysis

Descriptive statistics are expressed as mean ± 2 SEM. A two tailed unpaired Student's *t*-test was used to compare continuous data between two groups. Categorical data were compared using the chi-square test. Significance was accepted as $P < 0.05$. PASW v18 (IBM Corporation, NY, USA) was used to perform statistical tests.

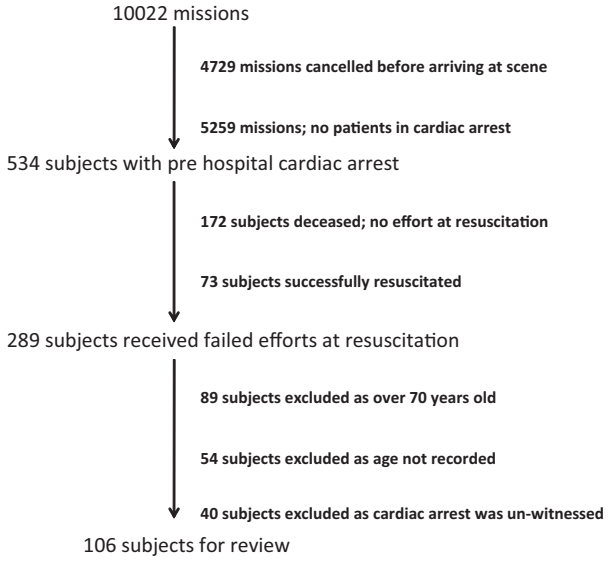

Figure 1 Flow diagram demonstrating the arrival at the study group.

Results

Prehospital cardiac arrest in the unselected cohort

Over 75 months WNAA performed 10 022 missions during which 534 patients were in cardiac arrest at some point in the prehospital phase. A total of 172 were clearly deceased and underwent no efforts at resuscitation. A total of 73 of 362 patients (20%) were successfully resuscitated and arrived at the emergency department alive. A total of 289 patients therefore underwent unsuccessful attempts at resuscitation of which 146 were 70 years old or younger. Of these 106 had a witnessed cardiac arrest and comprise the study group. A further 54 subjects with a witnessed cardiac arrest but no age recorded were excluded (Fig. 1).

Study group

Of 60 subjects who died because of a medical cause, there were two paediatric cases and 16 adults 50 years old or younger. Three patients had a cardiac arrest in the presence of the air ambulance team and of the remaining 57 patients 28 received bystander attempts at resuscitation. Five patients had a temporary return of cardiac output. The suspected cause of death was a primary cardiac problem in 59 cases. One paediatric patient died of asthma.

Of 46 subjects who died because of traumatic injuries, there were 13 paediatric cases and 28 adults 50 years old or younger. Penetrating thoracic trauma was the cause of death in four cases; 28 subjects died following car or motorcycle collisions, seven following a fall from height, six from crush injuries and one from drowning. A total of 15 patients lost cardiac output in the presence of the air ambulance team and of the remaining 31 patients eight had bystander attempts at resuscitation. Seven patients had a temporary return of cardiac output. Figure 2 demonstrates the age distribution of the cases.

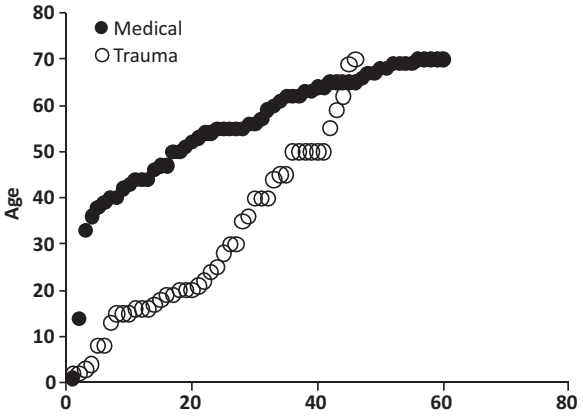

Figure 2 Age distribution of subjects by cause of death (medical $N = 60$, or traumatic $N = 46$).

The mean time from activating the air ambulance to arriving at scene was 10:59 ± 1:08 min and from leaving scene to arriving at hospital 07:19 ± 00:45 min.

Potential contribution to a national uncontrolled DCD programme

Assuming equivalent case mix and workload 31 air ambulance teams could contribute 300 cases following a medical cause of death per 12-month period. There could be an additional 228 cases following traumatic death.

The presence of family at the scene of cardiac arrest could influence organ donation. The presence of witnesses was not routinely recorded in the database. Case narratives were searched to identify and describe the presence of witnesses who were recorded at 18 cases of medical death and 10 cases of traumatic death. Family members were more likely to be present at medical deaths ($P = 0.04$) and were present at 12/18 and 2/10 cases respectively.

Discussion

This study observed a cohort of patients who were unsuccessfully resuscitated by a UK air ambulance team following PHCA. The aim was to quantify which subjects could potentially contribute to an uncontrolled DCD programme. To avoid overestimating this pool, we adopted an age limit based upon previously published data [6] and, importantly, included only those who had a witnessed cardiac arrest. Consequently, we have confidently calculated the duration of warm ischaemia – the time

from cardiac arrest until the arrival of the air ambulance teams. The duration of warm ischaemia is critical when considering patients for uncontrolled DCD; in this series a mean duration of <11 min from cardiac arrest until the arrival of the air ambulance team. In addition, bystander CPR was provided to nearly half of the subjects.

Furthermore, patients dying following a medical cause of cardiac arrest were considered separately to those dying from traumatic causes. We have assumed that all patients dying from medical causes could potentially donate their abdominal organs. In this study, all subjects died from suspected cardiopulmonary causes. A traumatic death does not by necessity prevent DCD and others have transplanted abdominal organs following uncontrolled DCD in similar circumstances [6]. Even donation of a liver damaged during blunt trauma, from controlled DCD, has been successfully transplanted [11]. However, the proportion of suitable donors among the cohort presented here is likely to be low for several reasons. In the UK, blunt trauma predominates as a cause of death [12]. While head injury is the most common mechanism of death following fatal trauma, multisystem injuries affect over half of individuals [12,13]. Massive haemorrhage following trauma is a common mechanism of death [14] and thus external cardiac compressions would be unlikely to provide an effective cardiac output until the point at which ECMO could begin. Individual cases would require careful review. This was not permitted by interrogation of the database used in this study. The higher proportion of deaths among paediatric and young adult patients, however, does make this group potentially very suitable for DCD.

There would be distinct advantages with using air ambulance teams. Prehospital practitioners aiming to identify potential donors would require training and education. Training a small and enthusiastic cohort would present far less challenge than either a selected or unselected cohort of regular land-based NHS paramedics primarily because of the numbers of staff involved. Air ambulances can travel long distances in a short period of time bypassing general hospitals. Patients can be transferred to a specialist centre where there are optimum facilities for resuscitation, and should this fail and the patients wishes are so, organ procurement can occur. A limited number of centres where uncontrolled DCD occur would be required. For example, in the West Midlands, there are four air ambulance teams that routinely transfer patients to Birmingham. A fifth team is within 20 min by air.

There are drawbacks associated with using air ambulance teams to contribute to an uncontrolled DCD programme. Air ambulance teams are limited to capturing only those patients to which they are tasked by NHS ambulance control. Furthermore, air ambulances can only operate during daylight hours because of their mechanism of operation and civil aviation authority regulation. Thus there will be many potential patients who would be missed by using an air ambulance only model.

There are limitations in this study. Firstly, assumptions were made to arrive at the potential cohort of subjects who could be suitable donors. Consent by the next of kin is required. This process to recruit uncontrolled DCD donors presented here is novel and the technique of donation does not currently exist on a national level in the UK. Assuming consent rates based upon controlled DCD or donation after brain death (DBD) is not reasonable. To avoid overestimating the potential number of subjects suitable for uncontrolled DCD strict criteria were selected in this study by excluding elderly patients and those with an unwitnessed cardiac arrest. In practice, patients would be selected on a case by case basis. Some would inevitably be unsuitable following closer scrutiny particularly among those suffering traumatic death. Conversely some excluded here would become suitable. One fifth of unsuccessfully resuscitated patients in this study had no age recorded and were excluded. In addition, on closer review of cases of unwitnessed cardiac arrest, it may be identified that the warm ischaemic time (WIT) would be consistent with potentially successful donation.

A second major limitation surrounds the complexity of the ethics of uncontrolled DCD. These issues do not detract from this study but would need to be addressed prior to implementing an uncontrolled DCD programme. Ethical issues include obtaining consent from next of kin, methods of maintaining organ perfusion following confirmation of death and the role of air ambulance teams. Cerebral reperfusion during ECMO is prevented by balloon occlusion of the descending thoracic aorta, which limits reperfusion solely to the abdominal organs. The UK air ambulance teams rely on charitable donations to operate and their public image is very important. To avoid a perceived conflict in duty to their patients, air ambulance teams would be required to be involved in the process of selecting DCD donors. Resuscitation efforts would be routine, the destination hospital may, however, change. This could be justified as hospitals selected to perform ECMO and uncontrolled DCD would likely be larger highly specialized institutions, typically those that receive the most injured patients currently. It is routine practice for air ambulances to bypass local hospitals transferring patients greater distances to centres with a higher level of care [10,12].

Equal workload and case mix between air ambulance units have been assumed. The WNAA unit was selected because of the robust data capture and as it serves an area that is representative of the majority of the UK. It serves

over a million population spread over a predominantly rural landscape with a central urban conurbation. Contributing to an uncontrolled DCD programme would require a loss of operational time as air ambulance teams transfer potential DCD patients to a suitable hospital. Presently at the majority of cases of PHCA resuscitation, efforts are performed entirely in the prehospital phase, particularly when a doctor is present, avoiding unnecessary transfer to hospital [10].

In conclusion, a national programme utilizing air ambulance teams could contribute a significant number of potential uncontrolled DCD patients. This model addresses logistical and technical problems inherent with uncontrolled DCD. Ethical issues would need to be addressed by the appropriate national regulatory bodies.

Authorship

KR and PM: analysed data. All authors contributed to the methodological design and manuscript preparation. All authors had full access to all of the data in the study and are satisfied with the integrity and accuracy of data analysis.

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References

1. Fan ST. Live donor liver transplantation in adults. *Transplantation* 2006; **82**: 723.
2. Fuggle SV, Allen JE, Johnson RJ, *et al.* Factors affecting graft and patient survival after live donor kidney transplantation in the UK. *Transplantation* 2010; **89**: 694.
3. Perera MT, Mirza DF, Elias E. Liver transplantation: issues for the next 20 years. *J Gastroenterol Hepatol* 2009; **24**(Suppl. 3): S124.
4. Muiesan P, Girlanda R, Jassem W, *et al.* Single-center experience with liver transplantation from controlled non-heartbeating donors: a viable source of grafts. *Ann Surg* 2005; **242**: 732.
5. Kootstra G, Daemen JH, Oomen AP. Categories of non-heart-beating donors. *Transplant Proc* 1995; **27**: 2893.
6. Fondevila C, Hessheimer AJ, Ruiz A, *et al.* Liver transplant using donors after unexpected cardiac death: novel preservation protocol and acceptance criteria. *Am J Transplant* 2007; **7**: 1849.
7. Fieux F, Losser MR, Boureois E, *et al.* Kidney retrieval after sudden out of hospital refractory cardiac arrest: a cohort of uncontrolled non heart beating donors. *Crit Care* 2009; **13**: R141.
8. Rampino T, Abelli M, Ticozzelli E, *et al.* Non-heart-beating-donor transplant: the first experience in Italy. *G Ital Nefrol* 2010; **27**: 56.
9. Casavilla A, Ramirez C, Shapiro R, *et al.* Experience with liver and kidney allografts from non-heart-beating donors. *Transplantation* 1995; **59**: 197.
10. Roberts K, Blethyn K, Foreman M, Bleetman A. Influence of air ambulance doctors on on-scene times, clinical interventions, decision-making and independent paramedic practice. *Emerg Med J* 2009; **26**: 128.
11. Tucker ON, Girlanda R, Rela M, Heaton ND, Muiesan P. Successful outcome following transplantation of an injured liver from a nonheart beating donor. *Transpl Int* 2005; **18**: 724.
12. NCEPOD. Trauma: who cares? NCEPOD 2007; http://www.ncepod.org.uk/2007report2/Downloads/SIP_report.pdf (last accessed 1 December, 2010).
13. Anderson ID, Woodford M, de Dombal FT, Irving M. Retrospective study of 1000 deaths from injury in England and Wales. *Br Med J* 1988; **296**: 1305.
14. Acosta JA, Yang JC, Winchell RJ, *et al.* Lethal injuries and time to death in a level I trauma center. *J Am Coll Surg* 1998; **186**: 528.