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Donation after circulatory death

A. R. Manara [1]*, P. G. Murphy [2] and G. O'Callaghan [3]

[1] The Intensive Care Unit, Frenchay Hospital, Frenchay Park Road, Bristol BS16 1LE, UK
[2] Leeds Teaching Hospitals NHS Trust, Leeds, UK
[3] Flinders Medical Centre, Adelaide, South Australia

* Corresponding author. E-mail: alex.manara@nbt.nhs.uk

Editor's key points

- Donation after circulatory death (DCD) has been re-introduced and contributes to donor numbers in many countries.
- DCD is increasing in response to a lack of organs available for transplant.
- DCD differs in many aspects from donation after brain death and poses specific challenges.
- Where DCD is practiced widely, organ donation is often considered a routine part of end-of-life care.

Summary. Donation after circulatory death (DCD) describes the retrieval of organs for the purposes of transplantation that follows death confirmed using circulatory criteria. The persisting shortfall in the availability of organs for transplantation has prompted many countries to re-introduce DCD schemes not only for kidney retrieval but increasingly for other organs with a lower tolerance for warm ischaemia such as the liver, pancreas, and lungs. DCD contrasts in many important respects to the current standard model for deceased donation, namely donation after brain death. The challenge in the practice of DCD includes how to identify patients as suitable potential DCD donors, how to support and maintain the trust of bereaved families, and how to manage the consequences of warm ischaemia in a fashion that is professionally, ethically, and legally acceptable. Many of the concerns about the practice of both controlled and uncontrolled DCD are being addressed by increasing professional consensus on the ethical and legal justification for many of the interventions necessary to facilitate DCD. In some countries, DCD after the withdrawal of active treatment accounts for a substantial proportion of deceased organ donors overall. Where this occurs, there is an increased acceptance that organ and tissue donation should be considered a routine part of end-of-life care in both intensive care unit and emergency department.

Keywords: brain death; death; directed organ donation; donation after cardiac death; end-of-life care; ethics; organ donation; organ transplantation

Organ transplantation improves the quality of life and increases the life expectancy of patients with end-stage organ failure. The demand for transplantation is likely to continue to increase, given an ageing population, an increase in the prevalence of renal failure, and advances in transplant technology, immunosuppression, and intensive care.[1] Donation after circulatory death (DCD) describes the retrieval of organs for the purposes of transplantation that follows death confirmed using circulatory criteria, and contrasts in many important respects within the modern-day standard model for deceased donation, namely donation after the confirmation of death using neurological criteria [i.e. donation after brain death (DBD)]. Although many of the original kidney transplant programmes started using organs retrieved from asystolic donors (indeed the first heart transplanted by Christiaan Barnard was retrieved from a DCD donor), many of these donors were in a state that would today be recognized as one of brain death. Consequently, the time taken for cessation of the circulation after withdrawal of cardiorespiratory support was predictable and short. Nevertheless, the professional acceptance of the concept of brain death that followed the declaration of the Ad Hoc Committee of Harvard Medical School in 1968[2] and publication of criteria for the diagnosis of brain death,[3][4] together with the better outcomes from using organs retrieved from cadavers with a heart beat, resulted in most of the early DCD programmes coming to an end.

The persisting shortfall in the availability of organs for transplants, and the repeated demonstration that kidneys retrieved from DCD donors have the same long-term outcome as those from DBD,[5–8] has prompted many countries to re-introduce DCD schemes. Furthermore, while these revived DCD programmes initially focused in the main on kidney retrieval, increasingly other organs with a lower tolerance for warm ischaemia such as the liver, pancreas, and lungs are being retrieved and successfully transplanted.[9] The challenges that face today's policy makers include how to identify patients as suitable potential DCD donors, how to support and maintain the trust of bereaved families, and how to manage and minimize the consequences of warm ischaemia in a fashion that is acceptable professionally, ethically, and at law. These challenges are quite different to those faced historically. They require solutions based not only on internationally applicable clinical research but also on national or even state-specific interpretation of the relevant ethical and legal frameworks. An important contemporary theme is that DCD not only benefits transplant recipients, but also allows more deceased patients and their families

to meet their wish to donate their organs after death, despite not fulfilling the criteria for neurological death. This is important both as a component of bereavement care to surviving family members and also as a basic principle for the ethical and legal justification for many of the interventions necessary to facilitate DCD.[10-13] It also meets the need of the small number of families who remain uncertain over the diagnosis of brain death, but who nevertheless give their permission for organ retrieval after asystole since it meets their need to witness an observable ending of life as represented by the cessation of the heart beat.[14]

Despite the endorsement of the practice of DCD by professional and regulatory bodies in many parts of the world,[15-20] concerns about the ethics and lawfulness of both controlled and uncontrolled DCD persist.[21-23] Healthcare staff may be particularly uncomfortable at the clinical interface between end-of-life care and organ donation.[24] These concerns include the perceived conflict of interest for clinicians involved in both the decision to withdraw treatments and any subsequent proposal for deceased donation, even though none may exist. Other concerns relate to the lawfulness and acceptability of interventions before or after death necessary to facilitate DCD (discussed elsewhere in this supplement)[25] and uncertainties around the time at which death can be confirmed using circulatory criteria. Such uncertainties include the possibility of spontaneous return of the circulation after asystole and lingering responsiveness of the nervous tissue to restoration of cerebral blood flow.

Classification and practice of DCD

The modified Maastricht classification[26] is widely used to categorize DCD (Table 1). Categories I, II, and V describe organ retrieval that follows unexpected and irreversible cardiac arrest (uncontrolled DCD), while categories III and IV refer to retrieval that follows death resulting from the planned withdrawal of life-sustaining cardiorespiratory support (controlled DCD). It follows that uncontrolled DCD can only occur in centres where facilities for organ perfusion and retrieval are at immediate hand (i.e. close to or within a transplantation centre), whereas almost any intensive care unit (ICU) or emergency department (ED) should be able to support controlled DCD.

Controlled DCD

The clinical pathway for controlled DCD is outlined in Figure 1 and highlights the differences from treatment withdrawal when DCD is not to take place.[27] While controlled DCD presents some challenging ethical and legal issues, the facility to coordinate treatment withdrawal with the availability of a surgical retrieval team means that multiple organs can be retrieved for transplantation. In controlled DCD, consent/authorization may be sought from the family or less commonly the patient, before the initiation of any intervention primarily focused on facilitating donation. The causes of death in controlled DCD donors in the UK are shown in Figure 2. Patients suitable for controlled DCD are generally those with catastrophic brain injuries who while not fulfilling the neurological criteria for death nevertheless have injuries of such severity as to justify withdrawal of life-sustaining cardiorespiratory treatments on the grounds of best interests. However, patients with other diagnoses, in whom treatment withdrawal is planned, may also be suitable. For instance, in the 15 month period from October 2009 to December 2010, in the UK, there were 20 DCD donors with a primary diagnosis of respiratory disease (data courtesy of NHSBT). Furthermore, although patients with hypoxic brain injury have previously been considered to have a low potential for DCD because of the presence of contraindications to transplantation (including age, medical history, and an excessive time to asystole after the withdrawal of treatment),[28] such patients accounted for 99 of a total of 397 donors over 15 months.

Uncontrolled DCD

Uncontrolled DCD presents a different set of challenges. By its very nature, warm ischaemic injury is already established at the time that the potential for donation is recognized, and measures to arrest its progression must be instituted in parallel to the assessment of donation potential, mobilization of a retrieval service, and approaching the family for permission to proceed. For logistical reasons, uncontrolled DCD is usually restricted to kidney-only retrieval within or close to transplant centres where a retrieval team is readily available.

The critical pathways for DCD and DBD have recently been published by the World Health Organization (Fig. 3) as part of an initiative to identify the common challenges faced by both developing and developed countries, and to make recommendations to governments, international organizations, and healthcare professionals on how to maximize deceased

Table 1 Modified Maastricht classification of DCD[26] and the locations where mainly practiced. ICU, intensive care unit; ED, emergency department

| Category	Description	Type of DCD	Locations practiced
I	Dead on arrival	Uncontrolled	ED in a transplant centre
II	Unsuccessful resuscitation	Uncontrolled	ED in a transplant centre
III	Anticipated cardiac arrest	Controlled	ICU and ED
IV	Cardiac arrest in a brain-dead donor	Controlled	ICU and ED
V	Unexpected arrest in ICU patient	Uncontrolled	ICU in a transplant centre
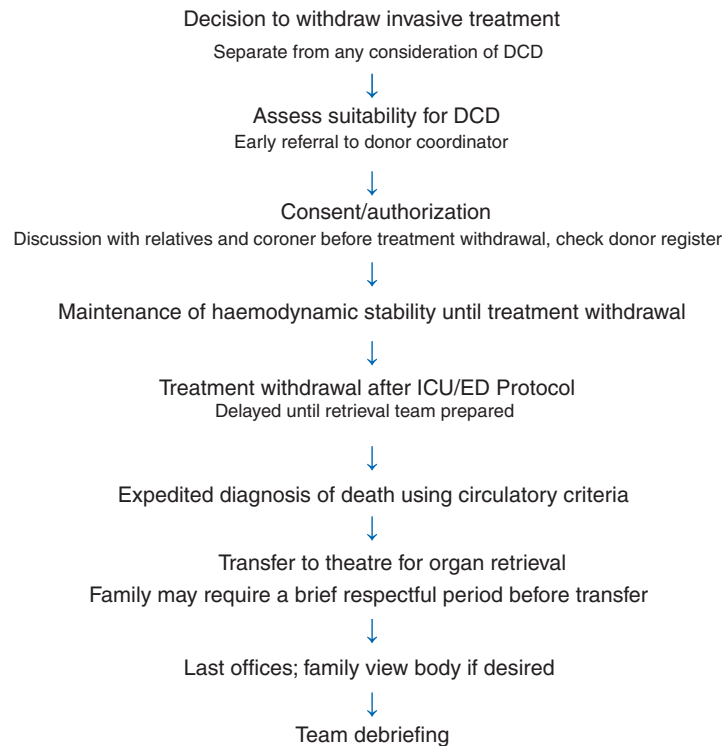
Fig 1 The clinical pathway for controlled DCD. Adapted from the Australian Guidelines on organ and tissue donation after death, for transplantation.[27]
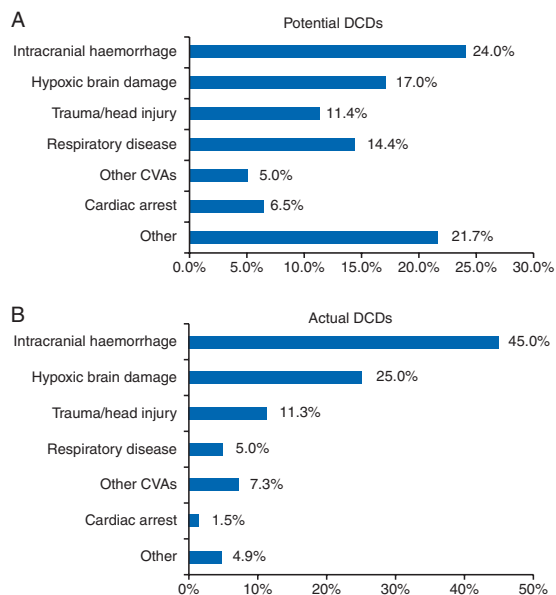
Fig 2 Diagnostic categories of (A) the 3825 patients referred as potential controlled DCDs and (B) the 397 patients who went on to became actual controlled DCDs in the UK between October 2009 and December 2010 (data courtesy of NHSBT).

donation.[29] The pathways provide clear definitions for potential, eligible, actual, and utilized donors, allowing better national and international comparisons to be made. It is also reaffirmed that the dead donor rule—the requirement that organ retrieval must not result in the death of the patient—must be respected at all times.

The contribution of DCD to overall deceased donor numbers varies internationally (Fig. 4A). Differences in medical practices, public attitudes, legislature, and resources will all influence the practice of DCD in other countries. Whereas in some countries (e.g. Netherlands, UK), DCD accounts for a substantial proportion of overall deceased organ donors, DCD is virtually non-existent in others (e.g. Germany, Portugal). In Australia and the UK, the numbers of controlled DCD donors have been increasing substantially over the last decade (Fig. 4B), and now represent more than one-third of all deceased organ donors.[30] This contrasts with Spain where DCD accounts for <10% of an overall annual rate of 34 donors per million population (pmp); furthermore, all DCD in Spain is uncontrolled. These differences possibly reflect fundamental differences in the approach to end-of-life care of critically ill patients and other factors as discussed by Clarkson and colleagues[31] in this supplement. In the UK, intensivists are comfortable with making decisions regarding the futility of continued interventions and support, with as many of 60% of deaths in the UK ICUs after a
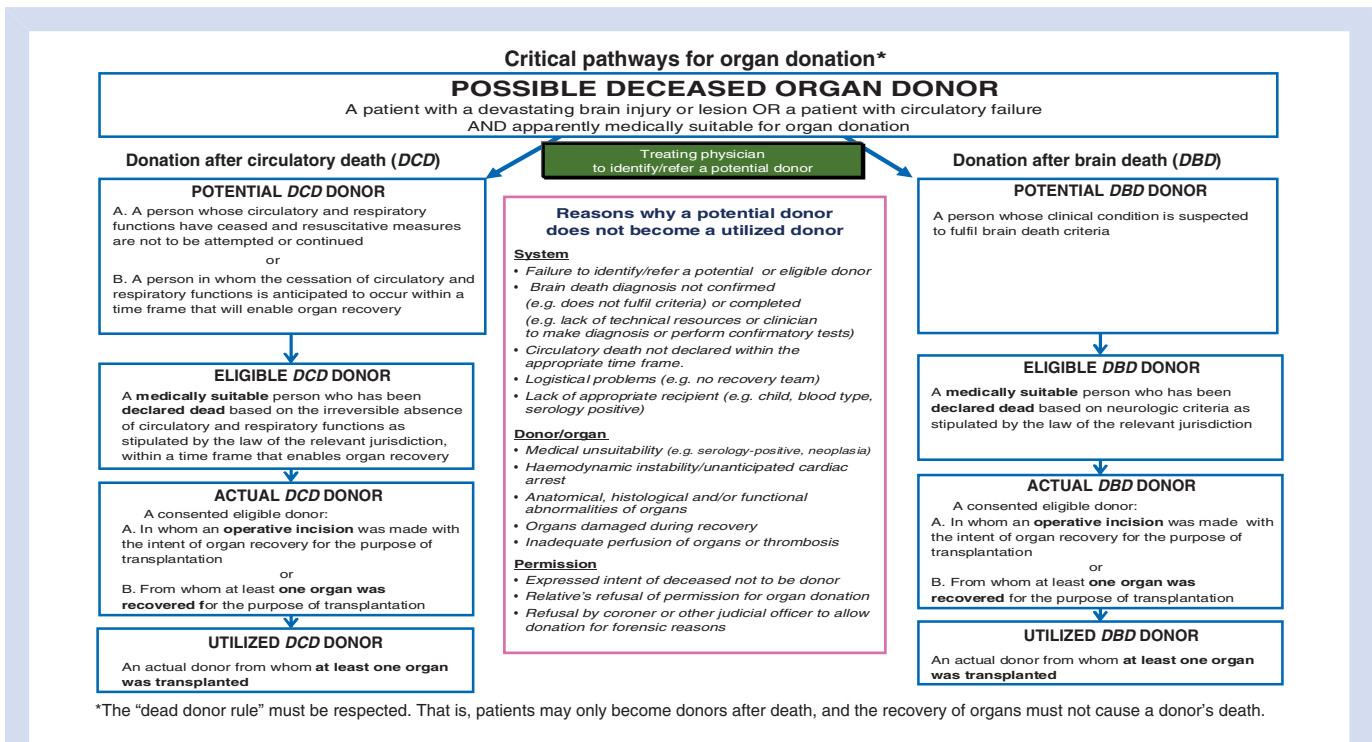
Critical pathways for organ donation*

POSSIBLE DECEASED ORGAN DONOR
A patient with a devastating brain injury or lesion OR a patient with circulatory failure
AND apparently medically suitable for organ donation

Donation after circulatory death (DCD)

Treating physician to identify/refer a potential donor

Donation after brain death (DBD)

POTENTIAL DCD DONOR
A. A person whose circulatory and respiratory functions have ceased and resuscitative measures are not to be attempted or continued
or
B. A person in whom the cessation of circulatory and respiratory functions is anticipated to occur within a time frame that will enable organ recovery

Reasons why a potential donor does not become a utilized donor

System
- Failure to identify/refer a potential or eligible donor
- Brain death diagnosis not confirmed (e.g. does not fulfil criteria) or completed (e.g. lack of technical resources or clinician to make diagnosis or perform confirmatory tests)
- Circulatory death not declared within the appropriate time frame.
- Logistical problems (e.g. no recovery team)
- Lack of appropriate recipient (e.g. child, blood type, serology positive)

Donor/organ
- Medical unsuitability (e.g. serology-positive, neoplasia)
- Haemodynamic instability/unanticipated cardiac arrest
- Anatomical, histological and/or functional abnormalities of organs
- Organs damaged during recovery
- Inadequate perfusion of organs or thrombosis

Permission
- Expressed intent of deceased not to be donor
- Relative's refusal of permission for organ donation
- Refusal by coroner or other judicial officer to allow donation for forensic reasons

POTENTIAL DBD DONOR
A person whose clinical condition is suspected to fulfil brain death criteria

ELIGIBLE DCD DONOR
A **medically suitable** person who has been **declared dead** based on the irreversible absence of circulatory and respiratory functions as stipulated by the law of the relevant jurisdiction, within a time frame that enables organ recovery

ELIGIBLE DBD DONOR
A **medically suitable** person who has been **declared dead** based on neurologic criteria as stipulated by the law of the relevant jurisdiction

ACTUAL DCD DONOR
A consented eligible donor:
A. In whom an **operative incision** was made with the intent of organ recovery for the purpose of transplantation
or
B. From whom at least **one organ was recovered f**or the purpose of transplantation

ACTUAL DBD DONOR
A consented eligible donor:
A. In whom an **operative incision** was made with the intent of organ recovery for the purpose of transplantation
or
B. From whom at least **one organ was recovered** for the purpose of transplantation

UTILIZED DCD DONOR
An actual donor from whom **at least one organ was transplanted**

UTILIZED DBD DONOR
An actual donor from whom **at least one organ was transplanted**

*The "dead donor rule" must be respected. That is, patients may only become donors after death, and the recovery of organs must not cause a donor's death.

Fig 3 The critical pathways for DBD and DCD as published by the World Health Organization.[29] Reproduced with permission from John Wiley and Sons.
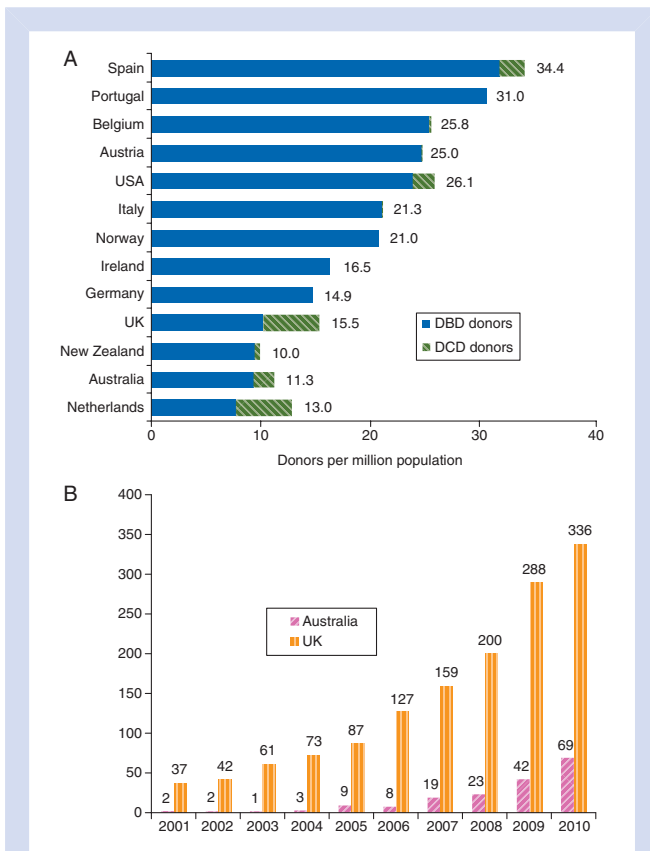

Fig 4 (A) International variation in the number and type of deceased organ donors; (B) development of controlled DCD in Australia and the UK 2001–2010.

decision to limit or withdraw treatments that are judged to be of no overall benefit to an individual.[32][33] This creates the potential for controlled DCD. In contrast, in countries such as Spain and other southern European countries where decisions to limit life-sustaining treatments (particularly with regard to admission to ICU) are less common, the potential for controlled DCD will be low. The origins of these differences are likely to be complex, although many point to the striking international variation in ICU bed capacity. For instance, there are 27 ICU beds pmp in the UK compared with 76 in Australia and 87.5 ICU beds pmp in Spain; it seems inevitable that intensivists in the UK may both avoid admitting patients to ICU with a hopeless prognosis (including those with acute catastrophic brain injury) and also consider withdrawing treatments that are no longer beneficial sooner than colleagues in countries with greater critical care capacity.

Warm ischaemic injury in controlled DCD

Organs from controlled DCD donors are exposed to a greater duration of warm ischaemia than those from comparable DBD donors. Furthermore, while this is at its most profound between the onset of asystole and establishing organ cold perfusion, it begins during the preceding phase of cardiorespiratory collapse. A better measure of ischaemic injury is therefore the so-called functional warm ischaemia time, which is considered to begin when the patient's systolic arterial pressure decreases below 50 mm Hg, the arterial oxygen saturation decreases below 70%, or both and which ends with cold perfusion.[34] Ischaemic injury increases the risks of

Table 2 UK functional warm ischaemia criteria for DCD organ retrieval[34]

Organ	Minimum functional warm ischaemia time (min)	Comments
Kidney	120	Plus a further 120 min in selected donors. DCD kidneys have a higher incidence of delayed graft function, but have similar long-term function to DBD grafts
Liver	30	May be limited to 20 min in sub-optimal donors. Outcomes from DCD liver transplantation are acceptable, but there is greater postoperative morbidity and a higher incidence of graft failure and biliary complications compared with DBD grafts
Lung	60	Time to re-inflation of the lungs rather than cold perfusion. DCD may represent an important source of additional lung grafts, particularly when combined with *ex vivo* perfusion techniques
Pancreas	30	

primary graft failure, delayed graft function, and other ischaemic complications (e.g. biliary structures), and is a considerable concern to retrieval and implantation teams. As a consequence, retrieval teams may be cautious in accepting organs from older potential DCD donors or those with co-morbidities such as diabetes mellitus, hypertension, and peripheral vascular disease that may amplify such ischaemic damage. Similarly, organ retrieval may not occur if the time interval from withdrawal of treatment (or onset of functional warm ischaemia) to asystole is prolonged, with the current UK criteria for DCD organ retrieval being given in Table 2.[34] Furthermore, retrieval and transplantation teams will continue to advocate a variety of interventions that might prevent or reverse ischaemic injury.[35] These include

(i) ante-mortem interventions (e.g. the administration of heparin, steroids, and vasodilators);
(ii) consistent application of published schedules for the prompt identification of death;
(iii) reducing the time interval between the diagnosis of death and organ retrieval (e.g. by withdrawing treatment in the operating theatre);
(iv) post-mortem reperfusion of particularly vulnerable organs such as the liver;
(v) early tissue typing to allow prompt identification and mobilization of suitable recipients.

It is elements of these strategies, together with issues around the withdrawal of life-sustaining treatment and identifying the potential for DCD, that give rise to many of the professional and ethical objections to the practice of DCD.

Difference in treatment withdrawal

Decision-making

All DCD guidelines recommend that the decision to withdraw cardiorespiratory support should always be independent, and made before any consideration of organ donation.[17 19 20 36 37] Most also advise separation of these discussions in time, and that they should be led by staff experienced in organ donation and with training in communication with grieving families. No member of the transplant or donor coordination team should be involved in decision-making around withdrawal of treatments, although donor transplant coordinators may be subsequently involved in supporting a family through the donation consent process.

Timing of treatment withdrawal

Treatment withdrawal is delayed until a retrieval team has travelled to the donating hospital and made their necessary preparations in theatre. It is vital that those responsible for organ allocation and retrieval do all they can to minimize these delays, recognizing the needs of the donor and their family at this time. This is particularly important in circumstances when it is proposed to delay withdrawal until the recipients of particularly vulnerable organs (e.g. liver, pancreas, and lung) have been identified and admitted to the transplant centre.

Manner of treatment withdrawal

There is significant variation in how treatment withdrawal is managed in adult critical care units,[34] particularly with regard to airway management and the use of pharmacological comfort cares. Although many guidelines have been published regarding the withdrawal of treatment,[27 38–40] these important documents define the principles for decision-making rather than providing a prescription for how end-of-life care should be managed. Nevertheless, all recommend that withdrawal of treatment should always be supervised by senior medical staff and specific clinical areas should develop operational policies that are based upon these guidelines. Many DCD guidelines recommend that treatment withdrawal in the context of DCD should follow the usual practice of that intensive care unit, to ensure that ICU practitioners are not perceived to have a conflict of interest in treatment-withdrawal decisions and practice. An alternative view would be that the interests of a patient as a donor might be better served by sedation and extubation (as appears routine in paediatric ICU practice), providing that this makes donation more likely and, importantly, represents no actual harm to the patient or their close family and friends. However, while it is widely held that terminal extubation promotes the possibility of DCD, evidence to support this view is limited[41] and not supported by

Table 3 Potential for DCD according to the method used to withdraw treatment in the UK from October 2009 to December 2010 (data from the Potential Donor Audit courtesy of NHS Blood and Transplant)

Treatment withdrawal type	Potential DCD (n)	Actual DCD (n)	Potential to actual DCD (%)	Consented to actual DCD (%)	% of total DCDs
Continuing current level of intervention with no further escalation	257	2	0.78	20.00	0.5
Reduction/withdrawing of ventilation, but not extubated	1319	53	4.02	47.75	13.4
Extubation	2249	342	15.21	52.94	86.1
Total	3825	397	10.38	51.76	100

data from the UK potential donor audit (Table 3). In any event, there is currently no consensus within adult ICU practice in the UK on how the airway should be managed during treatment withdrawal in the context of DCD, or on the use of adjuvant sedation, anxiolysis, and analgesia. It is therefore usually left for individual ICUs to formulate their own protocols. Although the need to develop and adhere to such protocols applies to all end-of-life care decisions, it is of particular importance that all units with DCD programmes have such protocols and that clinicians work within them in a consistent and transparent fashion.

Location of treatment withdrawal

Withdrawal of treatment within the operating theatre complex reduces ischaemic injury by avoiding the need to transfer a patient from a critical care area after the diagnosis of death. However, while the interests of the patient as an organ donor might be best served by treatment withdrawal within the theatre complex, there are concerns that this might compromise other aspects of end-of-life care.[42] Units planning for withdrawal in operating theatre must have systems in place to ensure that a patient's right to comfort, dignity, and privacy is guaranteed and that this care is delivered by appropriately trained and experienced healthcare professionals such as members of the ICU/ED team.[34] Specifically, transferring the care of a dying patient to theatre staff, who may be untrained and inexperienced in end-of-life management, is unacceptable.[42] Similarly, it is vital that unlimited access for close family, friends, and those meeting the religious or spiritual needs of the patient is ensured. It is also important that the medical professional responsible for confirming death is suitably experienced and readily available, and that a plan for the subsequent care of the patient should be available should donation not take place. In Australia, withdrawal of cardiorespiratory support is almost always undertaken in ICU as it is considered death in the operating theatre is a rare and difficult event for staff. Such an approach ensures that if cessation of the circulation does not occur in a time frame compatible with donation, further disruption to the family and patient is avoided and distress minimized. Members of the transplant team, including donor transplant coordinators, must not be involved

in any aspect of the end-of-life care of the potential DCD patient.

Predicting time to asystole and avoiding stand-down

Currently, in the UK, retrieval teams mobilized for potential DCD donations 'stand down' on 40% of occasions. An accurate and reliable scoring system relevant to local practice which helped predict the likelihood of death within a given time period would be welcome. Reducing the number of 'stood down' donations would avoid family distress,[43] reduce the burden on hard-pressed ICU staff, and also enable more efficient use of scarce retrieval capacity. Factors associated with early circulatory collapse after treatment withdrawal include a younger age, non-triggered modes of artificial ventilation, high F_{IO_2}, the use of inotropes, and a low arterial pH.[41] Two predictive tools, the University of Wisconsin[44] and the UNOS scoring systems,[45] are available from North America, but neither has been fully validated for UK or Australian practice. In the USA, more than 50% of patients meeting more than one of the UNOS criteria die within an hour of withdrawing life support treatment.[46]

The criteria used to justify the decision to stand-down organ retrieval, need to be robust, outcome-based, and subject to continual review in order to ensure that suitable donors are not lost. Although more than 90% of the patients who become DCD donors in the UK die within 2 h of withdrawal of treatment (Table 4), data from the UK Potential Donor Audit indicate that successful retrieval has occurred even after 4 h in circumstances where the functional warm ischaemic time has been acceptable. One centre has demonstrated that increasing the minimum waiting time from 1 to 4 h after withdrawal of treatment, the number of DCD kidney retrieved was increased by 30%, without compromising transplant outcome.[47] In contrast, in Australia, retrieval is not pursued if the patient does not die within 90 min of the withdrawal of cardiorespiratory support. It is vital that retrieval teams work consistently to agreed minimum standards if the confidence of referring units in the process is to be maintained and developed. It is similarly important that the reasons for standing a retrieval team down are clearly and promptly communicated to the referring team.

Table 4 Potential for DCD and actual DCD donations according to the time elapsed between treatment withdrawal and onset of asystole in the UK from October 2009 to December 2010 (data from the Potential Donor Audit courtesy of NHSBT)

Time to asystole	Potential DCD (n)	Potential DCD (%)	Actual donor (n)	Potential to actual (%)	% of total DCDs
0–2 h	2103	55.0	365	17.4	91.9
2–4 h	800	20.9	18	2.3	4.5
4+ h	571	14.9	9	1.6	2.3
Unknown	351	9.2	5	1.4	1.3
Total	3825	100.00	397	10.4	100

Pre-mortem interventions

Potential DCD donors usually lack capacity at the time of their final illness, although there are occasions where patients with motor neurone disease, high cervical cord injury, or end-stage respiratory failure have consented themselves for donation after irreversible asystole. This has happened on at least four occasions in Australia. In circumstances where patients lack capacity for decision-making, ICU clinicians in the UK have an overarching obligation to limit treatments to those which offer some overall benefit to their patients. In the past, such assessments have focused heavily upon what might be considered to be in the medical best interests of an individual, an approach that might appear to render interventions to promote deceased donation for the benefit of a third party transplant recipient unethical and even unlawful. However, it is now recognized that what is of 'overall benefit' to an individual within the context of their end-of-life care is much broader than this[12 13] and should include an assessment of factors such as their emotional, cultural, family, and religious interests and also the patient's medical condition. These interests, including those relating to organ donation, are usually determined by discussions with the patient's family and by consulting an organ donor register in countries that have one. This broader interpretation of best interests has been supported by the courts[48 49] and is enshrined in the UK Mental Capacity Act.[50] Once it is established that an individual wished to be an organ donor, then certain interventions can be considered to be in their best interests if they facilitate donation and do not cause the person distress or harm.[11] Examples of interventions that may or may not represent potential harm are included in Table 5, although it is stressed that such assessments should be made on an individual basis. What might be the correct course of action (and therefore lawful) for one individual might not be for another. Using this approach, obtaining blood samples, maintaining life-sustaining treatment, and altering the time and place of treatment withdrawal may all be considered to be in a patient's best interests if they wished to be an organ donor and they represent no harm, whereas interventions such as systemic heparinization (which might promote the expansion of an intracerebral haematoma), cardiopulmonary resuscitation (CPR), and femoral cannulation that might inflict pain or distress to a patient or their close family and friends or accelerate death are unlikely ever to be in the patient's best

interests.[11] The Australian ethical framework for organ donation makes a distinction between a decision made by an individual and the one made by surrogate decision makers, and gives greater weight to an expression of individual autonomy.[27] This is of particularly relevance to end-of-life care, when the assessment of an individual's best interests extends beyond their wellbeing to attainment of their aspirations and the fulfilment of other desires and wishes.

Absence of circulation before the diagnosis of death

One of the most debated areas worldwide in the practice of DCD is at what point death can be declared after loss of the circulation and respiration. DCD requires that death is declared at the earliest possible time after circulatory arrest that is scientifically, ethically, and professionally acceptable to minimize warm ischaemic time while ensuring that the dead donor rule is not breached, that is, the patient is not unintentionally killed as a result of donating their organs. Perhaps surprisingly, there has until recently been very little professional guidance on how and when to declare death after loss of the circulation and respiration. This is despite the fact that globally, circulatory criteria are the most commonly used and accepted criteria for determination of death. However, the introduction of DCD programmes and reports of autoresuscitation (spontaneous return of the circulation after circulatory arrest) have brought these criteria into sharp focus and resulted in the publication of many, and not always consistent, national guidelines.[17–19 35 51 52] Much controversy surrounds the precise time that needs to elapse after the onset of circulatory arrest before death can be declared. This varies around the world, with some commentators believing that the criteria for the determination of death are being manipulated to facilitate transplantation[53] while apparently not breeching the dead donor rule. Indeed, others have suggested that the dead donor rule has resulted in the definition of death being revised inappropriately and should therefore be abandoned, permitting the removal of vital organs while a donor was still alive. They argue that with proper safeguards no patient will die from organ donation who would not otherwise die as a result of the withdrawal of life support.[54–57]

Many criteria allow death to be confirmed (and therefore organ retrieval to begin) after 5 min of continuous

Table 5 Pre-mortem interventions to facilitate controlled DCD that may be considered acceptable and unacceptable[11 34]

Acceptable interventions	Unacceptable interventions
Discussing a potential donor with the donor transplant coordinator before the patient's death and checking the organ donor register	Anything that causes or places the person at risk of serious harm or distress
Approaching the relatives about donation before the patient's death	Donor transplant coordinator caring for the potential donor while they are still alive
Seeking details of the patient's medical history relevant to donation	Systemic heparinization in circumstances where this might accelerate death (e.g. recent intracranial bleed)
Taking blood and testing blood or serum samples	Femoral cannulation
Maintenance of life-sustaining treatment	CPR
Delaying the withdrawal of treatment	Involvement of the retrieval team and the recipient's clinical team in the care of the potential donor
Changing a patient's location for treatment withdrawal	

cardiorespiratory arrest. Five minutes of continuous asystole is sufficient to ensure that both consciousness and respiration have ceased and also that the possibility for spontaneous resumption of the circulation has passed. However, the brain may at this time remain to some degree responsive to the artificial restoration of its blood supply, be this as a result of continued CPR,[58] the introduction of extra-corporeal circulatory support or as a result of post-mortem interventions that inadvertently provoke the return of ventricular function. It follows that at this time, that is, after 5 min of continuous asystole, irreversibility depends in part upon prohibiting restoration of the cerebral circulation rather than an absolute inability to restore cerebral function. This contrasts with circumstances in which neurological criteria for the determination of death are applied. In these circumstances, the pathology leading to the irreversible loss of consciousness and respiration has been established for several hours before the diagnosis is made.

The challenges in this area are considerable. Irreversibility in such circumstances might be considered to be weaker than when death is confirmed by neurological criteria because here it depends upon intent and pathophysiology.[59] Others suggest that the loss of circulation should be described as permanent rather than irreversible,[60] and propose that for the purposes of DCD, death should only be recognized when the risk of autoresuscitation has passed, when CPR will not be attempted and when there is an absolute prohibition on interventions that may restore the cerebral circulation being undertaken after the declaration of death. A recent systematic review of autoresuscitation showed that this has only been reported in the context of abandoned CPR and not when invasive treatment is withdrawn.[61] There seems to be growing global consensus that a minimum of 5 min of continuously observed and appropriately monitored absence of the circulation, apnoea, and coma will define the point at which death can be diagnosed. The development of such consensus will increase confidence in the way we determine death and prevent a repetition of practices in DCD that have previously aroused much concern and criticism, such as retrieval of a heart from a neonatal DCD donor after only 75 s of loss of the circulation.[62]

The diagnosis of death is reviewed in detail elsewhere in this issue.[63]

Interventions after death

As noted above, warm ischaemic injury limits the potential for DCD, and it is legitimate for retrieval teams to consider the benefits of reversal of such processes before cold perfusion and how this might be achieved. It is similarly legitimate, and indeed mandatory, for critical care teams to evaluate such proposals within the pathophysiological context of the criteria used to diagnose death. For instance, uncontrolled DCD protocols that allow CPR to continue or being re-instated after the declaration of death in order 'to decrease warm ischaemia of the kidneys…and to re-establish heart activity before organs were removed'[64] might carry some considerable risk. Further to this, a recent study has revealed that three patients in a series of 48 had a return of spontaneous circulation when a mechanical device was used during transfer of potential DCD donors from the community to the transplant centre, one of whom went on to make a good neurological recovery.[58]

There is now growing consensus that no intervention that might potentially restore cerebral circulation at a time when nervous tissue might be responsive to such restoration should be allowed under any circumstances, given the time-sensitive way in which death is diagnosed in the setting of DCD.[34 60] These include both those that might inevitably or inadvertently restore cerebral blood flow (Table 6). Protocols for uncontrolled DCD raise further specific ethical issues regarding post-mortem interventions, including how much information families receive and the acceptability of applying invasive measures to preserve organs before obtaining consent from the family or establishing the patient's wishes. The legal framework for donation in Spain, which is one of presumed consent, is interpreted in practice to support such interventions,[65] while in the UK, both the Human Tissue Act[66] and the Human Tissue (Scotland) Act[67] specifically allow the placement of femoral perfusion cannulae ahead of the family approach.

Table 6 Interventions that risk restoration of cerebral blood flow after the confirmation of death using circulatory criteria[34 43 60]

Procedures that inevitably restore cerebral blood flow	Recommendation
Cardiopulmonary resuscitation (internal or external cardiac massage)	Any steps that can restore the circulation or the heart beat *in situ* are forbidden without prior isolation of the cerebral circulation
Full cardiopulmonary bypass	
Procedures that might inadvertently restore cerebral blood flow	
Perfusion of the body either regionally or systemically with blood containing fluids (e.g. ECMO)	Complete exclusion of the cerebral circulation must be achieved by clamping of appropriate vessels before perfusion is commenced. Balloon occlusion of the thoracic aorta does not reliably exclude the cerebral circulation and should only be used when perfusion is achieved using non-blood fluid
Mechanical ventilation with O_2 for the purposes of DCD lung retrieval	The trachea can be re-intubated after the confirmation of death. The lungs can be insufflated with a single recruitment manoeuvre 10 min after the onset of circulatory arrest, and held open with CPAP. *In vivo* cyclic positive pressure ventilation must not occur until the cerebral circulation has been isolated
Patient movement during transfer to the operating theatre and onto the operating table	Not been reported as cause of autoresuscitation but all transplant surgeons should have guidance on what to do should this exceptional circumstance ever occur
	Continued cardiac standstill should be re-confirmed if necessary by an appropriately trained member of staff before the retrieval operation commences

Practical guide to the introduction of a DCD programme

A DCD programme should only be introduced into a hospital's ICU, ED, or both in a planned fashion and after extensive consultation with all interested parties. The following steps have been suggested as helpful in the implementation.[7 8 16 68 69]

Establish a DCD implementation team

This should include opinion leaders from the ICU, ED, and transplant teams to influence attitudes and behaviours, ideally those with experience in implementing change or healthcare improvement. They should identify and engage all the key stakeholders that need to be involved in the development of a local protocol and its implementation. They should also identify the potential local barriers and solutions to the development of a DCD programme.

Decide which patients will be potential DCDs

Hospitals will need to decide whether they plan to undertake controlled or uncontrolled DCD (Table 1). The choice will be influenced not only by logistical issues but also by the ethical, moral, and legal codes of the jurisdiction in which the programme is being implemented. Irrespective of whether controlled or uncontrolled DCD is undertaken, the impact of introducing the scheme will primarily be on the ICU, ED, and operating theatre staff, and this is where training and education should be directed.

Audit the potential for DCD

An audit of all deaths in the ICU and ED over a period of time will allow an estimation of the total number of patients who would be suitable for DCD. The criteria for suitability will depend on whether controlled or uncontrolled DCD is to be practiced. The audit is helpful in assessing the workload implications and resources requirements for both the ICU and ED and also the local retrieval teams.

Discuss the practical, moral, and ethical issues

DCD raises significant ethical, moral, professional, and legal issues[21 22] that need to be discussed with all staff likely to be involved in DCD. These include staff in ICU, ED, operating theatres, and medical specialities with primary responsibility for patients likely to become DCDs. In particular, the perceived conflict of interest when acting for the benefit of multiple third parties, the process of withdrawing treatment in the context of DCD and the confirmation of death using circulatory criteria should be addressed. The discussions allow concerns about practical, legal, and ethical issues surrounding DCD to be raised, and provide an opportunity to outline the expected impact on resources and workload. These discussions can form the basis of the development of an ongoing education programme for the healthcare teams involved in the DCD programme.

Design a protocol for local implementation

Once these issues are resolved, a local protocol can be developed, taking into account local factors and opinions, and should be approved by the Hospital Management Board. The focus should always remain on the provision of high-quality end-of-life care. The protocol should include guidance on the following key steps:

- How the decision to withdraw active treatment is reached, and by whom.
- The criteria for and the timing of notification to the donor co-ordinator and checking of donor registers.
- Involvement of the coroner.
- When the family are approached for authorization, and by whom.
- Information given to relatives.

- Pre-mortem interventions.
- Process of withdrawal of treatment, including airway management and the use of sedative drugs.
- Timing and location of treatment withdrawal.
- Organization of operating theatre.
- Diagnosis of death (who and where).
- Arrangements if patient does not die in a time frame compatible with organ donation.
- Post-mortem interventions (including tracheal intubation to facilitate lung retrieval).
- Criteria and management of standing down retrieval team.
- Arrangements for family after organ retrieval.
- Offering eye and tissue donation.

Regular review of cases

Review of the first few cases allows an opportunity to learn lessons and further improve the DCD programme. Any issues arising can be discussed and resolved locally. This may involve updating the local protocols when necessary to address issues such as management of stand-downs, coroner problems, lack of senior medical support, interventions to maintain cardiorespiratory stability while awaiting the arrival of a retrieval team, and the conflicting demands upon limited theatre capacity.

Outcomes from DCD

Kidneys

The long-term outcome of transplanted kidneys retrieved from DCDs has been shown previously to be comparable with that of kidneys retrieved from DBD donors.[5–8] Kidneys retrieved from uncontrolled DCD donors can be assessed using machine kidney perfusion to discriminate suitable from unsuitable organs. The technique also reduces the incidence of delayed graft function.[70]

Livers

Single centre and data from the United Network for Organ Sharing (UNOS) report good long-term patient survival and graft survival with DCD liver allografts, and these outcomes have been considered equivalent to those obtained from DBD allografts.[71–73] In Spain, good results have been achieved when using cardiopulmonary bypass to reverse ischaemia ahead of cold perfusion.[74] The 3 yr survival of recipients of livers from DCDs and DBDs is comparable at 63% and 72%, respectively. However, the incidence of primary graft failure is increased (from 6% to 12%) in recipients of a liver from a DCD; there is also a higher incidence of bile duct complications, which is related to the length of the warm ischaemic time.[9 73 75] For these reasons, livers from DBDs remain preferable and very strict criteria for selection of DCD liver donors are used to reduce these complications. Encouraging results have been reported using an experimental model of *ex vivo* normothermic perfusion of the liver using a modified cardiopulmonary bypass circuit,[76] which may further improve outcomes in the future.

Lungs

Current UK experience with DCD lung transplants is limited, although initial results are promising, particularly if used in combination with *ex vivo* lung perfusion techniques. Indeed, theoretically at least, there may be advantages to lungs retrieved from controlled DCD donors, since they may not have been exposed to cardiopulmonary consequences of the autonomic storm that occurs in many potential DBD donors. Furthermore, although the lungs appear to be more tolerant of warm ischaemia than other organs as long as they are kept inflated with oxygen,[77] their cold ischaemic tolerance is limited, and thoracic transplantation units may therefore request that treatment withdrawal is delayed until a suitable recipient has been identified and admitted to hospital. While inferior early outcomes have been reported in recipients of DCD lungs by an individual transplant centre,[78] data from the UNOS in the USA showed that survival was better for DCD recipients than for DBD recipients (87% *vs* 69% 2 yr survival).[79] While variation in donor and recipient selection criteria and surgical technique may make outcomes comparison difficult,[75] most experience indicates that DCD donors represent a significant and largely untapped opportunity to increase cadaveric lung transplantation.

Hearts

As noted above, the world's first human heart allograft was retrieved from an asystolic donor. More recently, and somewhat controversially because of the very short interval from asystole to retrieval,[80] a small number of successful paediatric heart transplants have resulted from retrieval from neonatal DCD donors.[62] A number of teams around the world continue to explore the possibility of successful adult and paediatric heart transplantation using grafts retrieved from DCD donors,[81] mindful of both the apparent contradiction in using a heart graft from a patient whose death has been confirmed on 'cardiac' grounds[82 83] and perhaps more importantly aware of the genuine risks to the donor should retrieval require restoration of ventricular function and the systemic circulation *in vivo* before isolation of the cerebral circulation.[84] The diagnosis of death applies to that person as a whole, not to their individual organs. There is therefore no ethical inconsistency if the heart is re-started *ex vivo* and transplanted to a recipient.[43]

Avoiding a shift from DBD to DCD

In the UK, currently an average of 3.6 organs are transplanted per DBD donor compared with 2.1 organs after DCD. While the number of organs transplanted from DCD donors may increase in the future, they are unlikely to fully match those transplanted after DBD, either in terms of the number of organs transplanted or their quality. Therefore, the focus of DCD programmes should be to provide the option of deceased donation for patients who will never meet the neurological criteria for the diagnosis of death, rather than an option for clinical staff and families to support donation without the need for lengthy neurological
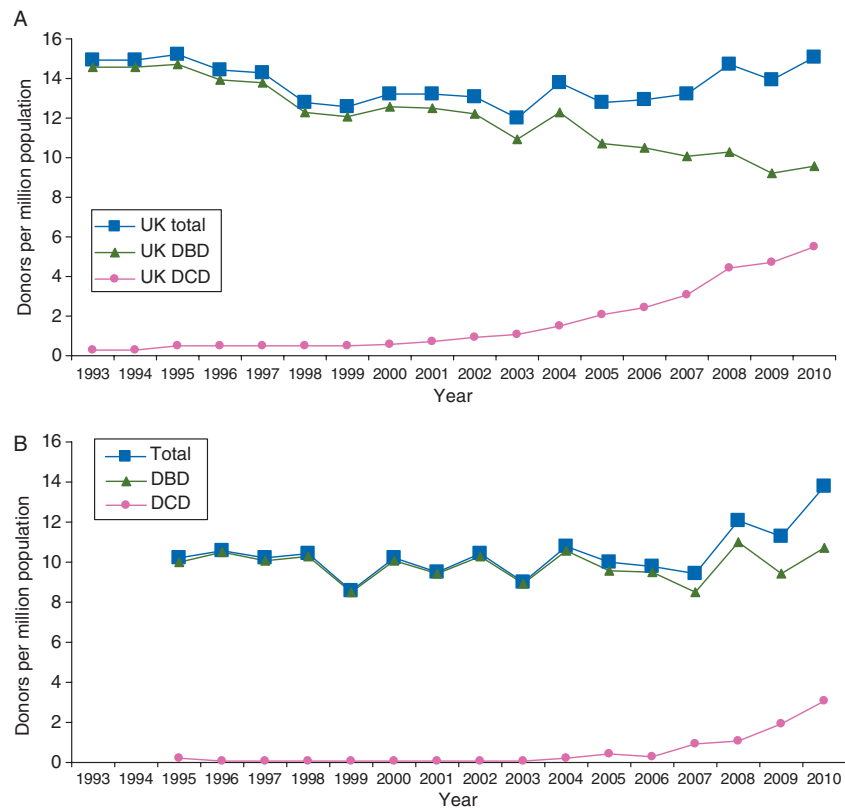
Fig 5 Incidence of DBD and DCD in (A) the UK and (B) Australia, expressed in terms of donors per million population. Note that the DCD donors in the UK from 1993 to 1999 were exclusively uncontrolled donors (Maastricht categories I/II), while the increases beyond this time in both countries were controlled DCD (Maastricht categories III/IV).

evaluations and subsequent donor optimization. However, many involved in transplantation express the view that DCD programmes do indeed detract from DBD and thereby jeopardize cardiothoracic, and to a lesser extent liver transplant programmes, and point to the falling number of DBD donors in countries with active controlled DCD programmes.

Detailed analysis in the UK does not support this view,[85] and indeed registry data indicate that the incidence of DBD was declining in the UK for several years before expansion of the DCD programme (Fig. 5A). Furthermore, a more recent promotion of DCD in Australia has not been associated with a decrease in DBD (Fig. 5B). The decrease in the incidence of death diagnosed by neurological criteria, and therefore the potential for DBD, over the last 6 yr,[35] is primarily a consequence of improved road safety[86] and improvements in the neurocritical care management and outcomes of acute traumatic brain injury[87 88] and intracranial haemorrhage.[89] It is therefore even more essential to ensure that the diminishing numbers of DBDs are identified and their potential for DBD maximized, and it is concerning that 9% of DCD donors in the UK appeared to fulfil the pre-conditions for brain-stem death testing but were not tested.[32] It is essential that professional training and education programmes reinforce the importance of testing potentially brain-dead patients irrespective of whether they are to become donors, particularly

because it allows clinicians to give the patient's family a definitive diagnosis (of death) rather than a prognosis that death will follow the withdrawal of treatment.

Conclusion

It is increasingly accepted that consideration of organ and tissue donation should be a routine part of end-of-life care in both ICU and ED, with DBD considered in patients meeting the neurological criteria for death and DCD considered in patients after the withdrawal of active treatment. DCD allows families the option to meet the wishes of a dying relative who had previously expressed a wish to become an organ donor but who does not meet the neurological criteria for confirming death. Expansion of DCD schemes has the potential to increase the number of transplantable organs donated by patients dying in ICUs and EDs.

Declaration of interests

A.R.M. is a Regional Clinical Lead in Organ Donation in the UK, and P.G.M. is the UK National Clinical Lead for Organ Donation. Both receive funding from NHS Blood and Transplant. G.O. is the Australian National Medical Director of Organ and Tissue Donation and Transplantation Authority.

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