REVIEW

Uncontrolled donation after circulatory death: European practices and recommendations for the development and optimization of an effective programme

Beatriz Domínguez-Gil[1] , Jacques Duranteau[2] , Alonso Mateos[3] , Jose R. Núñez[4] , Gaelle Cheisson[2] , Ervigio Corral[5] , Wim De Jongh[6] , Francisco Del Río[4] , Ricard Valero[7] , Elisabeth Coll[1] , Marie Thuong[8] , Mohammed Z. Akhtar[9] & Rafael Matesanz[1]

1 Organización Nacional de Trasplantes, Madrid, Spain
2 Department of Anesthesia and Intensive Care, Bicêtre Hospital, Hôpitaux Universitaires Paris-Sud, Université Paris-Sud, Assistance Publique des Hôpitaux de Paris, Paris, France
3 Summa 112 and Francisco de Vitoria University, Madrid, Spain
4 Transplant Coordination Unit, Hospital Clínico San Carlos, Madrid, Spain
5 SAMUR-Protección Civil, Madrid, Spain
6 Transplant Coordination Unit, University Hospital Maastricht, Maastricht, The Netherlands
7 Department of Anesthesia, Hospital Clínic de Barcelona, Barcelona, Spain
8 Agence de la Biomedecine, París, France
9 Oxford Transplant Centre, Oxford, United Kingdom

Correspondence
Beatriz Domínguez-Gil, MD, PhD, Organización Nacional de Trasplantes, C/ Sinesio Delgado 6, pabellón 3, Madrid 28029, Spain.
Tel.: +34 902 300 224;
fax: +34 902 300 226;
e-mail: bdominguez@msssi.es

SUMMARY

The shortage of organs remains one of the biggest challenges in transplantation. To address this, we are increasingly turning to donation after circulatory death (DCD) donors and now in some countries to uncontrolled DCD donors. We consolidate the knowledge on uncontrolled DCD in Europe and provide recommendations and guidance for the development and optimization of effective uncontrolled DCD programmes.

Transplant International 2016; 29: 842–859

Key words
Donation after Cardiac Death, donation after circulatory death, guidelines, kidney, nonheart-beating donation, review, uncontrolled

Received: 13 May 2015; Revision requested: 19 June 2015; Accepted: 16 December 2015; Published online: 17 February 2016

doi:10.1111/tri.12734

Introduction/Background

The major barrier to transplantation globally is the availability of good-quality organs. This has resulted in an increased utilization of organs previously considered unsuitable for transplantation, including organs from donation after circulatory death (DCD) donors. DCD donors can be considered as either uncontrolled (uDCD) or controlled (cDCD) donors.

While cDCD rates have been progressively increasing throughout Europe, uDCD programmes have only been developed in a minority of European countries [1]. In France and Spain, uDCD donors account for a significant number of deceased donor transplants. Other countries such as Austria, Belgium, Italy, the Netherlands, and recently Russia, have also developed uDCD programmes, but the activity rate is still low [2,3].

The potential of utilizing uDCD donors globally is substantial. In the United States, for example, it has been estimated that uDCD could result in an additional 22 000 potential donors a year [4]. In England and Wales, based on the availability of air ambulance teams and cases of witnessed Cardiac Arrests (CA) transferred to the hospital during a 75-month period, the potential of uDCD was estimated to yield an extra 300 potential donors per year [5]. However, uDCD has remained confined within a few countries. Besides the considerable technical and organizational challenges, ethical and legal constraints have been the other main difficulties encountered when trying to establish an uDCD programme [2,6–8].

uDCD relates to excellent long-term kidney graft survival, despite an increased incidence of primary nonfunction (PNF) and delayed graft function (DGF) [9–21]. The results of liver transplantation from uDCD donors are mixed and do not consistently provide similar outcomes compared with livers from donation after brain death (DBD) donors, mainly because of a higher incidence of primary graft dysfunction, graft nonfunction and biliary complications [22–27]. There remains limited experience in lung transplantation; however, the preliminary results are encouraging [28–30].

The development of a successful uDCD programme does not solely rely on technical knowledge and skills, but also on a well-developed logistical plan to allow for efficient activation of the uDCD pathway once the opportunity of donation is identified. Typical uDCD donors are patients who suffer an unexpected and witnessed CA and in whom advanced cardiopulmonary resuscitation (aCPR) has been exhausted and deemed unsuccessful. The identification of a potential uDCD donor is followed by the activation of protocols designed to minimize the duration and the impact of warm ischaemia. However, balancing the logistical and legal requirements with warm ischaemia time (WIT) is challenging and partly accounts for the low conversion rate of potential into utilized donors (approximately 65%) [21,23]. In addition, the actual number of organs transplanted is limited; for example, in France and Spain, the number of organs transplanted per donor is below 1.5 [2].

The objectives of this paper are:

1. To consolidate the experience of uDCD programmes in Europe, including information on the underlying regulatory and ethical frameworks and on organizational and technical aspects;
2. To provide recommendations for the development and optimization of uDCD.

Methods

A dedicated questionnaire was developed to collect information on the regulatory and ethical framework and the practice of uDCD in the European countries with the highest activity

1. France (*Agence de la Biomedecine)*
2. Spain (*Organización Nacional de Trasplantes)*
3. The Netherlands (*Dutch Transplant Foundation)*

Topics addressed were: (i) general information; (ii) donor selection and exclusion criteria; (iii) logistics of the protocol (out of hospital and in hospital); (iv) determination of death; (v) consent and authorization; and (vi) preservation techniques.

In addition, a review of the literature was conducted. An electronic search was performed in Medline and Pubmed, Cochrane library, ClinicalTrials.gov, and ControlledTrials.com. Keywords used: ['Cardiac arrest' or 'Uncontrolled'] and ['Non Heart Beating Donation' or 'Donation after Circulatory Death' or 'Donation after Cardiac Death']. Articles written in English, French and Spanish were selected. Abstracts were first reviewed. If the article was identified as discussing key regulatory–ethical issues or describing logistic aspects of uDCD, then the manuscript was further reviewed and information was used for the preparation of this paper.

An expert panel built recommendations based on the available evidence. Where possible, articles were ranked and recommendations graded as specified by the Oxford Centre for Evidence-based-Medicine (www.cebm.net/). Recommendations also resulted from a deliberative approach and consensus among members of the panel.

Draft recommendations were then presented at the 6th International Conference on DCD, held in Paris (France) in February 2013. Concept recommendations were discussed with and then adopted by the various expert panels of the initiative 'European recommendations on DCD' and congress participants.

Ethical–regulatory frameworks, practices and evidence

General information

uDCD first started in Maastricht, the Netherlands, in 1981. The first procedures in Spain were described in the 1980s. The programme started in France in 2006. The number of active programmes in 2014 was 9 in France, 11 in Spain and 4 in the Netherlands. During 2000–2014, the number of actual uDCD donors was 414, 1247 and 159 respectively. Of note, more than 90% of these donors had suffered an out of hospital CA.

The three countries have specific legislation providing the framework for the practice of uDCD. The legal texts include provisions related to criteria for the determination of death, limitations to preservation – if any – and the consent to organ preservation–recovery, among others. National protocols/recommendations/guidelines have also been issued, that deal with the ethical, technical and organizational aspects of uDCD [31–34]. Dedicated action protocols defining roles and responsibilities in the process are in place at every Emergency Medical Service (EMS) and hospital embarked on this type of donation. These protocols are adapted to the available resources, manpower and the internal organization of each service.

The process of uDCD includes a number of phases, not necessarily sequential, graphically represented in Fig. 1. In summary, the identification of a potential uDCD donor is continued with donor transfer in the case of an out of hospital CA. Death is determined in the hospital and preservation strategies are then commenced. For abdominal organs, these may consist of *in situ* preservation/cooling (ISP) or the establishment of a femoro–femoral bypass extracorporeal circulation with membrane oxygenation, either in hypothermia or normothermia – Hypothermic (hRP) or Normothermic Regional Perfusion (nRP). Consent and authorization need to be obtained before organ recovery, but conversation with relatives can be maintained at

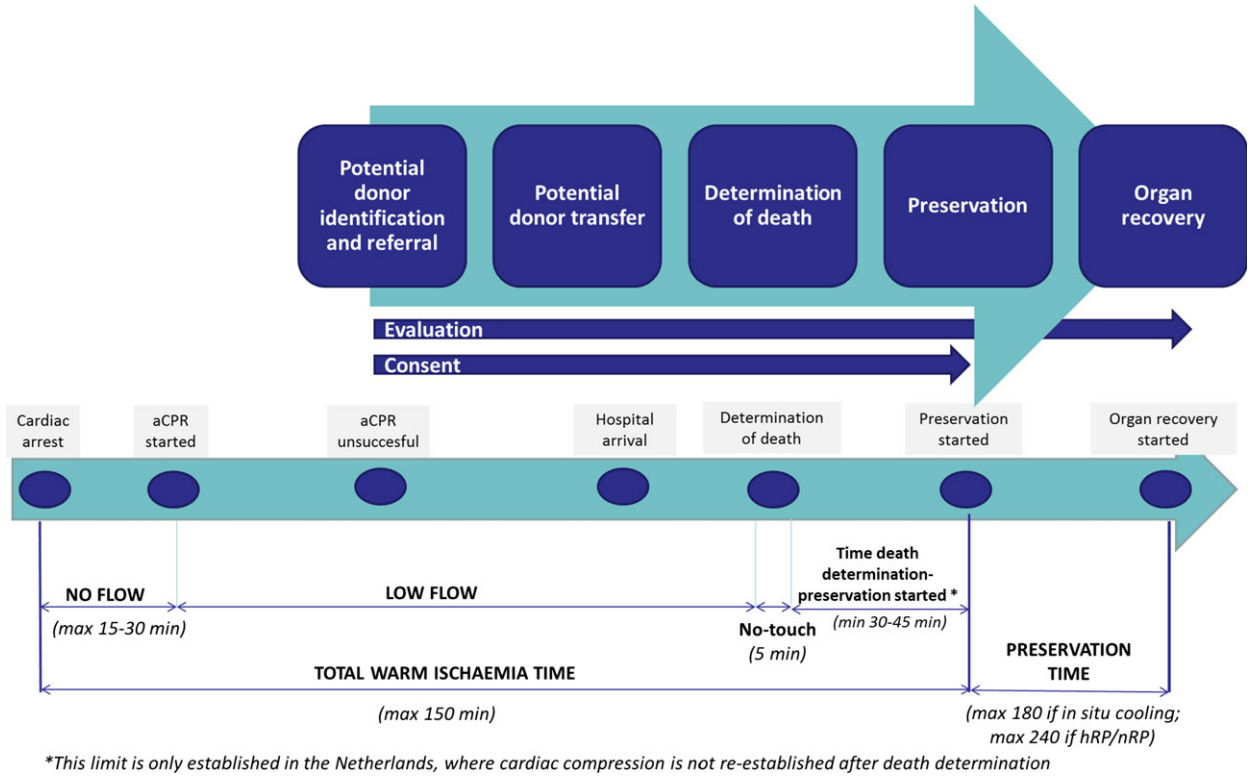

Figure 1 The process of uncontrolled donation after circulatory death, as developed in France, the Netherlands and Spain. The figure also specifies warm ischaemia time and preservation time limits established at these programmes. aCPR: advanced cardiopulmonary resuscitation.

Transplant International 2016; 29: 842–859

different time points along the pathway. Donor evaluation is a continuum, starting at the moment of donor identification.

The practice of uDCD in the three studied countries, along with the available evidence, and their position with regard to some of the dilemmas that may arise at each of the phases are detailed below. Reducing WIT and its potential impact to ensure organ viability and optimal post-transplant results is vital, whilst ensuring the quality and safety of the procedure.

Donor identification and referral

The uDCD process is activated when a potential donor is identified, that is a patient who fulfils the following criteria:

1. has suffered a witnessed CA, out of hospital or in the hospital setting;
2. aCPR has been exhausted, according to national protocols, aligned with international professional standards [35,36];
3. aCPR has been deemed unsuccessful by the attending team;
4. a set of criteria is met, in terms of age, comorbidities, circumstances of CA and WIT. A summary of the donor selection and exclusion criteria applied in the evaluated programmes is shown in Table 1.

When CA has occurred in the out of hospital setting, only persons transferred to the hospital with a therapeutic purpose and in whom aCPR is considered unsuccessful once in the hospital are considered potential uDCD donors in the Netherlands. In France and Spain, also persons in whom aCPR is deemed unsuccessful in the prehospital setting by physician-based EMS can be considered potential uDCD donors and transferred to the hospital with that purpose.

Table 1. Donor selection and exclusion criteria for uncontrolled donation after circulatory death in France, the Netherlands and Spain.

	France	The Netherlands	Spain
Selection criteria			
Age (min–max), years	18–55	12–65	Min: 1 –18; Max: 55–65
No-flow period (time between witnessed cardiac arrest and aCPR started)	<30 min for kidney/<15 min for liver	<20 min	<15–20 min (depends on the programme)
Time goal until arrival in the hospital	120 min	90 min	90 min (120 min in one programme)
WIT	≤150 min	Maximum mechanical CPR (besides 20 min of basic life support) of 70 min if <55 years and 45 min if 55–65 years Time between determination of death and preservation <30–45 min	≤150 min
Exclusion criteria			
External physical appearance	Signs of intravenous drug addiction	Signs of intravenous drug addiction	Signs of intravenous drug addiction
Trauma	Multiple trauma with haemorrhagic shock, kidney and liver injuries and aortic dissection	Haemorrhagic shock or aorta dissection	Exsanguinating lesions in thorax or abdomen
Cause of Cardiac Arrest	Cardiac arrest because of hypothermia or cardiotropes (aCPR needs to be prolonged) and violent death (eventual legal problems)	–	Violent death (in some programmes)
Other (Please, specify)	For kidney, renal disease, arterial hypertension or diabetes, all cancer types, severe sepsis, violent polytraumatism, and homicide For Liver, liver disease, all cancer types, severe sepsis, violent polytraumatism, and homicide	Unknown cause of death, unknown identity, untreated sepsis, malignancy, active viral infections, active tuberculosis. Kidney: primary kidney disease	Tumour or systemic disease

aCPR: advanced cardiopulmonary resuscitation.

Donor selection and exclusion criteria

Unsuccessful CPR. Potential donors are persons with an unsuccessfully resuscitated CA. CA is considered irreversible based on international standards if, despite aCPR being carried out correctly and without interruption for at least 30 min, return of spontaneous circulation is not achieved and the patient shows clinical signs of death – lack of consciousness and spontaneous movements, absence of spontaneous breathing, no detectable blood pressure, pulse or cardiac sounds [35,36]. In some circumstances, such as prearrest hypothermia, suspected poisoning or metabolic derangement, aCPR has to be prolonged and additional therapeutic options have to be considered, based on the mentioned standards.

Donor age. Most of the existing uDCD programmes have restriction criteria on age, but there is no strong evidence for age cut-offs. In a series of 242 kidney transplants, Mizutani *et al.* [10] reported lower graft survival for recipients of kidneys aged >60 years compared with the younger uDCD donor group. These results were confirmed in a retrospective study of 706 kidney transplants from uDCD donors, where donor age >55 years had a negative impact on long-term graft survival [11]. In one of the largest series published, Sánchez-Fructuoso *et al.* [13] described that 1- and 5-year graft survival for kidneys from uDCD donors with a maximum age of 60 years was similar to that of kidneys from DBD donors <60 and significantly better than that of kidneys from DBD donors ≥60 years. More recently, a donor age ≥54 years was identified as a risk factor for PNF and decreased graft survival in a series of 135 kidneys from uDCD donors [20]. Based on these limited data, it appears appropriate to include patients ≤55–60 years into uDCD protocols, although some of the existing programmes are transplanting kidneys beyond this age cut-off value and further data are required to determine age-related outcomes (Table 2).

Comorbidities. Some programmes exclude patients with a history of arterial hypertension or diabetes even if these diseases are controlled. Kidney/liver diseases, some brain tumours or cancer, sepsis, viral infection (HIV, HBV, HCV) and intravenous drug abuse are also contraindications for uDCD.

Circumstances of death. Suicide and homicide are contraindications for uDCD in some of the existing programmes, because of potential judicial obstacles. Major trauma is also a contraindication because of the risk of organ damage and hypoxia in case of haemorrhage. However, abdominal trauma does not preclude lung donation.

Warm ischaemia time. Minimization of WIT is a critical factor. uDCD programmes in France and Spain recommend that (i) the no-flow period is <15–30 min for kidney and <15 min for liver; (ii) total WIT is <150 min (Table 1, Fig. 1) [31,34]. However, these recommendations are based on empirical grounds and require further research and validation.

Donor referral

The team leading aCPR is primarily responsible for identifying and referring the potential uDCD donor to a prespecified hospital. The team needs to communicate a minimum set of information to ensure selection criteria are met, and to activate and facilitate the transfer to the corresponding hospital or ward (Table 3). Different procedures are used for the communication, either through an intermediate and/or directly through radio or phone.

The availability of a donor transplant coordinator (DTC) at the hospital is required for effective referral of the potential donor, this being the case at the three studied countries. The DTC in these centres is available 24/7, either at the hospital or close by on call. The DTC is in charge of: (i) evaluating the referred potential donor, ensuring that selection criteria are met; (ii) authorizing the transfer to the hospital; (iii) alerting a first rapid team of professionals in charge of completing the evaluation, obtaining consent/authorization and initiating the preservation measures, and a second team in charge of organ recovery, arriving at a later stage; (iv) locating relatives, if not present at the scene of the CA, in cooperation with the relevant agencies.

Donor transfer

The transfer of a potential donor to the corresponding hospital/ward implies maintaining cardiac compression and mechanical ventilation as per CPR standards [35,36], but for the purpose of preserving organ viability, as aCPR has already been deemed unsuccessful and hence further care is considered futile.

The majority of the existing programmes use mechanical cardiac compression devices for donor transfer, although there is limited evidence on its superiority versus manual cardiac compression in terms of

Transplant International 2016; 29: 842–859

Table 2. Selected studies addressing donor age in uncontrolled donation after circulatory death.

Kidney transplantation from uncontrolled DCD donors: recommended maximum potential donor age 55–60 years (grade B–C)											
Reference	Grade	Level	Study design	Trial	*N*	Times	Preservation	PNF	DGF	Graft survival	Patient survival
Hoogland *et al.* (2013), the Netherlands [20]	B	2b	Cohort study	Identification of risk factors for PNF and graft failure in KTx from uDCD	135	<45 min WIT	ISP	22% 35% if donors ≥54 yr vs. 16% if <54 yr** Donor age ≥54 yr independently associated with PNF**	62%	63% (5 yr) Lower if donors ≥54 yr. Donor age independent risk factor for graft failure**	–
Sánchez-Fructuoso *et al.* (2006), Spain [13]	B	2b	Cohort study	Comparison of results of KTx from uDCD (maximum 60 yr) vs. DBD <60 yr vs. DBD ≥60 yr	320 vs. 458 vs. 126	<15 min no-flow; <120 min WIT (CA-hRP)	Cardiac compression* + hRP	4.4% vs. 1.1% vs. 4%**	60.9% vs. 20.4% vs. 27.4%**	82.1% (5 yr) vs. 85.5% vs. 73.3%**	90% (5 yr) vs. 85.5% vs. 73.3% **
Hattori *et al.* (2003), Japan [11]	C	4	Poor case series	Identification of risk factors for graft failure in KTx from uDCD- donor age <55 vs. ≥55 yr (univariate analysis)	706 411 (<55 yr) vs. 192 (≥55 yr)	–	ISP	–	–	53% (10 yr) 62% vs. 29%**	82% (10 yr)
Mizutani *et al.* (2001), Japan [10]	B	2b	Cohort study	KTx from uDCD comparing donors <60 yr vs. ≥60 yr	252 200 vs. 52	WIT (does not specify calculation) 9.5 min vs. 7.9 min	ISP	1% vs. 6%**	73.8% 74% vs. 73%	43% (10 yr) 47% vs. 30%**	87% (10 yr) 88% vs. 83%

CA, cardiac arrest; DBD, Donors after Brain Death; DGF, delayed graft function; hRP, Hypothermic Regional Perfusion; ISP, *In situ* preservation; KTx, Kidney Transplant; PNF, primary nonfunction; uDCD, Uncontrolled donors after circulatory death; WIT, warm ischaemia time; yr, years.

*Not specified in the paper, but per protocol.

**$P < 0.05$.

Table 3. List of items to communicate during the referral of a potential uDCD donor as reflected in the 2012 Spanish National Consensus Document [34].

Name
Age
Gender
Close relatives, availability and information provided
Timing:
1. Exact time of the cardiac arrest
2. Time aCPR was started
3. Time of transfer to the hospital
Past and present medical history (if known)
Cause of the cardiac arrest
Possible haemorrhagic lesions
Venous accesses
Status of the endotracheal tube (blood, remains)
Blood gas analysis
Drug tests, rapid strip HIV test (if tests available)
ECO Fast (if test available)
Use of mechanical cardiac compressor devices

aCPR, advanced cardiopulmonary resuscitation.

organ viability and post-transplant outcomes. Preliminary results of the CIRC Trial show that return of spontaneous circulation and survival at hospital discharge for patients with a prehospital CA is similar with the use of Autopulse® compared with high-quality manual CPR [37]. A similar randomized controlled trial is being conducted with LUCAS2® [38]. Mechanical devices also facilitate long-distance transportation with good-quality cardiac compression [39,40]. The evidence cited above might suggest that organ viability would be superior with the use of mechanical CPR devices; however, published results have not borne out these theoretical benefits. In a cohort study comparing the results of an uDCD programme with donor transfer performed with the LUCAS® device ($n = 91$) versus manual cardiac compression ($n = 112$), the former was associated with a significant decrease in the number of kidneys discarded because of inappropriate organ perfusion (32.9% vs. 56.6%; $P = 0.026$) (Level 3b–4) [41]. Nonetheless, in another observational study assessing the outcome of kidney transplants ($n = 39$) from uDCD donors under mechanical versus manual chest compression, the incidence of PNF was similar (5.1% vs. 9.1%; $P = 0.5$) (Level 3b–4) [42]. Data from a cohort of 50 uDCD donors also showed similar renal function at 6 and 12 months in kidney transplants from donors transferred with mechanical versus manual chest compression (Level 3b–4) [43].

Mechanical devices do not seem to cause lung injuries that make lungs unsuitable for transplantation. This has been confirmed in dedicated studies comparing the LUCAS® device with manual CPR [44,45]. Moreover, a recent series of 33 potential uDCD donors under mechanical cardiac compression showed a limited number of mild and no severe thoracic and lung injuries, assessed by chest X-ray, tracheal and nasogastric tube examination and bronchoscopy (Level 4) [46].

To ensure the appropriate quality of cardiac compression and adequate organ perfusion, the team in charge of the transfer of a potential uDCD donor needs to guarantee a careful transportation, avoiding haemodynamic changes secondary to breaking and acceleration. The transfer is usually facilitated by the police or other agencies who are familiar with the uDCD protocol.

Determination of death

Determination of death in the evaluated uDCD programmes takes place systematically in the in hospital setting and is based on the criteria below:

1. aCPR exhausted according to national protocols, aligned with international standards, and deemed unsuccessful is a prerequisite. aCPR is identically applied, regardless of whether the person could be considered a potential donor or not.
2. Cessation of circulation and respiration is assessed based on the absence of electrical activity by electrocardiography or the appropriate means (as echocardiography or invasive blood pressure measurement) in case of electro-mechanical dissociation – if all its reversible causes have been discarded and treated.
3. Minimum observation (no-touch) period of 5 min.

In France and Spain, criteria to determine death preceding uDCD are based on the actual and demonstrated irreversibility of the CA, because aCPR has been exhausted and deemed unsuccessful as per international standards and end-of-resuscitation rules [35,36,47]. The possibility of an unperceived auto-resuscitation during donor transfer (after aCPR has been considered unsuccessful, but before determining death) is not possible the way the protocols are conceived – potential donors remain monitored electrocardiographically during transfer, while cardiac compression and mechanical ventilation are extended beyond the point of irreversibility of the CA, for the purpose of organ preservation. Both countries, however, use a 5-min no-touch period. Of note, potential uDCD donors have been exposed to prolonged low-flow periods and at least two periods of complete absence of circulation, with an

anticipated profound ischaemic injury to the brain [48]. In this context, the re-establishment of circulation after the determination of death with the aim of organ perfusion is considered ethically appropriate and is legally permitted and performed at these two countries [49].

These criteria for the determination of death are in contrast with standards developed in countries primarily focused on cDCD (including the Netherlands), where the permanent cessation of circulation ('will not return') is used as a surrogate of the irreversible cessation of circulation ('cannot return') for the diagnosis of death [50–53]. These different approaches are, however, a matter of controversy and international debate [8,49,54–56].

Death by circulatory criteria in the three described programmes is systematically certified in the hospital by a professional(s) independent of the donation and transplantation activity. This is usually done by the team taking over the aCPR manoeuvres in the hospital and hence by professionals independent from those who attended the CA in the street. This provides the programme further reassurance of the irreversibility of the CA prior to the determination and certification of death.

Preservation

After death is determined and certified, cardiac compression and mechanical ventilation are re-established routinely in France and Spain, with the purpose of organ preservation, this not being the case in the Netherlands. No dedicated studies have compared the results of re-establishing versus not re-establishing cardiac compression until further preservation measures are initiated. However, the most consolidated uDCD programmes in terms of number of actual and utilized donors, and organs recovered and transplanted apply cardiac compression systematically after death. These programmes also offer the most promising results with regard to post-transplant outcomes, not only in kidney, but also in liver transplantation (Tables 4 and 5).

Preservation of abdominal organs

Preservation of abdominal organs is usually performed through hRP or nRP in France and Spain, although ISP is also applied in some programmes exclusively for kidney preservation. Of note, preservation with nRP in uDCD is a legal requirement for further proceeding with liver transplantation in France. Table 6 summarizes the main aspects of the different techniques.

The maximum WIT allowed is usually 150 min. In the Netherlands, where cardiac compression is not restored after death, there is an additional no-flow period following death, allowed to be of a maximum duration of 30–45 min [16,33]. There are variations in the maximum time allowed under preservation measures, before proceeding with organ recovery, but most of the programmes establish the limit of 240 min in case of hRP/nRP, with more restrictive times for ISP (180 min). Maximum WIT and preservation times allowed in the three programmes are graphically represented in Fig. 1. These times are, however, based on empirical grounds.

Tables 4 and 5 show the results of kidney and liver transplantation in uDCD with different preservation strategies. In the setting of kidney transplantation, there is only one study directly comparing the three different techniques. Valero *et al.* [9] observed that the incidence of DGF and PNF was significantly lower when preservation was based on nRP ($n = 8$) versus hRP($n = 8$) and ISP ($n = 44$) ($P < 0.01$). Also, duration of DGF was significantly shorter with the use of nRP compared with ISP ($P < 0.05$).

In the field of liver transplantation from uDCD donors, the early results published by the Pittsburgh group in 1995 were disappointing, with very poor graft and patient survival in a series of six cases [57]. In 2003, higher graft and recipient survivals were reported in a Spanish series of 20 liver recipients from uDCD donors, with a heterogeneous use of preservation methods (chest-abdominal compression–decompression versus hRP versus nRP) [25]. A subsequent description of 10 liver transplants whose donors had only been subjected to chest-abdominal compression–decompression raised survival to 90% after 57 months of follow-up [26]. Subsequently, experienced centres reported improved short-term results with nRP following chest compressions. Using this approach, in a prospective case–control study comparing liver transplantation in uDCD ($n = 20$) versus DBD ($n = 40$), 1-year graft and patient survival was 80% and 85.5% vs. 87.5% and 87.5% respectively. Although the incidence of PNF and ischaemic cholangiopathy was higher in the uDCD group, the difference was not statistically significant [27]. Combining chest compression with the LUCAS2® device after death determination with nRP, Fondevila *et al.* [23] reported the results of a series of 34 liver transplants from uDCD donors with 1-year graft and patient survival of 70% and 82% respectively.

Table 4. Studies addressing preservation strategies and results with kidney transplantation from uncontrolled DCD donors.

Kidney transplantation from uncontrolled DCD donors: nRP provides superior outcomes compared with hRP and hRP compared with ISP, particularly with regard to the incidence of primary nonfunction (grade C)												
Reference	Grade	Level	Study design	Trial	*N*	Times	Preservation	PNF	DGF	Graft survival	Patient survival	Comments
Miranda-Utrera *et al.* (2013), Spain [21]	C	4	Case series	Description of results of KTx from uDCD	156	–	Cardiac compression* + nRP	8.6%	85%	87% (mean follow-up 18 months)	98% (mean follow-up 18 months)	–
Abboud *et al.* (2012), France [17]	C	4	Case series	Description of results of KTx from uDCD	58	<30 min CA-CPR; <150 min total WIT; preservation time <180 min (ISP) or <240 min (nRP)	Cardiac compression + ISP or nRP	5%	95%	91.4% (1 yr)	98% (1 yr)	*Ex situ* kidney preservation with pulsatile preservation
de Gracia *et al.* (2012), Spain [18]	C	4	Case series	Description of results of KTx from uDCD	27	<120 min total WIT	Cardiac compression* + ISP or nRP	0%	85.2%	85% (2 yr)	100% (2 yr)	–
Hanf *et al.* (2012), France [19]	B	2b	Cohort study	Description of results of KTx from uDCD vs. ECD vs. SPK	27 vs. 30 vs. 24	<30 min CA-CPR	Cardiac compression* + ISP	0% vs. 0% vs. 0%	81.5% vs. 27.6% vs. 0%**	100% (3 yr) vs. 82% vs. 94%**	100% (3 yr) vs. 100% vs. 100%	Pulsatile preservation used for kidney selection in uDCD
Hoogland *et al.* (2011), the Netherlands [16]	B	2b	Cohort study	Comparison of results of KTx from uDCD vs. cDCD	128 vs. 208	<45 min of CPR; <45 min CPR-ISP	ISP	22% vs. 21%	61% vs. 56%	50% (10 yr) vs. 46%	61% (10 yr) vs. 60%	Pulsatile preservation used in 82% vs. 84%
Reznik *et al.* (2011), Russia [3]	C	4	Case series	Description of results of KTx from uDCD	20	45–92 min no flow after cessation of CPR	Leukoapheresis + fibrinolytics + nRP	0%	70%	100% (3 mo)	100% (3 mo)	–
Sánchez-Fructuoso (2006), Spain [13]	B	2b	Cohort study	Comparison of results of KTx from uDCD vs. DBD <60 yr vs. DBD ≥60 yr	320 vs. 458 vs. 126	<15 min CA-CPR; <120 min total WIT	Cardiac compression* + hRP	4.4% vs. 1.1% vs. 4%**	60.9% vs. 20.4% vs. 27.4%**	82.1% (5 yr) vs. 85.5% vs. 73.3%**	90% (5 yr) vs. 85.5% vs. 73.3%**	–
Gagandeep *et al.* (2006), United States [12]	B	2b	Cohort study	Comparison of results of KTx from uDCD vs. DBD vs. cDCD	216 vs. 75 865 vs. 1814	Mean: 23.7 min CA-Preservation	–	–	51% vs. 24% vs. 42%**	–	–	uDCD donors are persons with an unplanned CA who could not be resuscitated before brain death was determined

Table 4. Continued.

Kidney transplantation from uncontrolled DCD donors: nRP provides superior outcomes compared with hRP and hRP compared with ISP, particularly with regard to the incidence of primary nonfunction (grade C)												
Reference	Grade	Level	Study design	Trial	*N*	Times	Preservation	PNF	DGF	Graft survival	Patient survival	Comments
Hattori *et al.* (2003), Japan [11]	C	4	Poor case series	Identification of risk factors for graft failure in KTx from uDCD-donor age <55 vs. ≥55 yr (univariate analysis)	706 411 (<55) vs. 192 (≥55 yr)	–	ISP	–	–	53% (10 yr) 62% vs. 29%**	82% (10 yr)	–
Mizutani *et al.* (2001), Japan [10]	B	2b	Cohort study	Comparison of results of KTx from uDCD <60 yr vs. ≥60 yr	252 200 vs. 52	WIT (does not specify calculation) 9.5 min vs. 7.9 min	ISP	1% vs. 6%**	73.8% 74% vs. 73%	43% (10 yr) 47% vs. 30%**	87% (10 yr) 88% vs. 83%	–
Valero *et al.* (2000), Spain [9]	C	4	Poor cohort study	Comparison of KTx from uDCD with ISP vs. hRP vs. nRP	44 vs. 8 vs. 8	<30 min CA-CPR <150 min total WIT	Cardiac compression* + ISP vs. hRP vs. nRP	22.5% vs. 0% vs. 0%**	55% vs. 75% vs. 12.5%** (& significantly shorter duration with nRP)	56% (5 yr) No statistically significant differences between the groups	89.3% (5 yr) No statistically significant differences between the groups	–

CA, cardiac arrest; CPR, Cardiopulmonary resuscitation; cDCD, Controlled Donors after Circulatory Death; DBD, Donors after Brain Death; DGF, delayed graft function; hRP, Hypothermic Regional Perfusion; ECD, Expanded Criteria Donors; ISP, In situ preservation; KTx, Kidney Transplant; nRP, Normothermic Regional Perfusion; PNF, Primary nonfunction; SPK, Simultaneous Pancreas Kidney; uDCD, Uncontrolled donors after circulatory death; WIT, warm ischaemia time; yr, years.

*Not specified in the paper, but per protocol.

**$P < 0.05$.

Table 5. Studies addressing preservation strategies and results with liver transplantation from uncontrolled donors after circulatory death.

Liver transplantation from uncontrolled DCD donors: nRP (preceded by cardiac compression) is advisable for the preservation of livers from uDCD donors (grade C)												
	Grade	Level	Study design	Trial	*N*	Times	Preservation	Graft survival	Patient survival	Biliary complications	PNF	Comments
Fondevila *et al.* (2012), Spain [23]	C	4	Case series	Outcomes of LTx from uDCD. Comparison with cohort of LTx from DBD.	34 vs. 538	<15 min CA-CPR <150 min total WIT	Cardiac compression + nRP	70% (1 yr) vs. 87%**	82% (1 yr) vs. 90%	8% (IC)	–	–
Jiménez-Galanes *et al.* (2009), Spain [27]	C	3b	Case–control study	Outcomes of LTx from uDCD. Comparison with LTx from DBD before and after	20 vs. 40	<15 min CA-CPR; <150 min total WIT	Cardiac compression* + nRP	80% (1 yr) vs. 87.5%	85.5% (1 yr) vs. 87.5%	1 vs. 0	10% vs. 2.5%	–
Suárez *et al.* (2008), Spain [24]	C	4	Case series	Describe biliary complications with LTx from uDCD. Compares with a large population of LTx from DBD	27 vs. 471		Cardiac/abdominal compression and cardiac compression + hRP/nRP*	49% (5 yr) vs. 68%**	62% (5 yr) vs. 74%	41.7% vs. 16.8% NAS 25% vs. 2.3%**	–	–
Otero *et al.* (2003), Spain [25]	C	4	Poor case–control study	Outcomes of LTx from uDCD. Comparison with DBD before–after. Comparison Cardiac/abdominal compression vs. hRP/nRP	20 vs. 40 6 vs. 14 (7 + 7)		Cardiac/abdominal compression versus cardiac compression + hRP/nRP*	55% (2 yr) vs. 73% 83% vs. 43%	80% (2 yr) vs. 73% 100% vs. 71%	30% vs. 8%**	25% vs. 3%	Mixed preservation protocols. Livers on hRP/nRP sent from long-distance centre

CA, cardiac arrest; DBD, donation after brain death; IC, Ischaemia cholangiopathy; CPR, Cardiopulmonary resuscitation; hRP, Hypothermic Regional Perfusion; LTx, Liver transplant; NAS, Nonanastomotic strictures; nRP, Normothermic Regional Perfusion; uDCD, uncontrolled donation after circulatory death; WIT, warm ischaemia time; yr, years.

*Not specified in the paper, but per protocol.

**$P < 0.05$.

The promising results obtained with nRP can be explained by the fact that warm oxygenated reperfusion allows some repair from WIT to take place, which is supported by experimental studies [58–60] and allows for biochemical assessment of the liver – and hence a more appropriate selection of the liver donor. It is worth noting that technical difficulties inherent to preservation with hRP/nRP may result in potential donor losses. This has been reported by the Barcelona group – 72 of 400 (18%) potential uDCD donors placed under nRP were lost because of inadequate venous return, resulting from unrecognized vascular trauma or internal haemorrhage or supposedly from the collapse of the inferior cava vein [23].

Recently, a novel preservation approach for abdominal organs in uDCD has been described in St. Petersburg, Russia [3]. The protocol is applied to patients suffering an in hospital CA unsuccessfully resuscitated. After death is determined, heparin is administered and distributed through the application of a limited number of cardiac compressions. This is followed by a no-flow period of up to 90 min, when preservation of abdominal organs starts with nRP, combined with leucocyte depletion and fibrinolytics. Results with the transplantation of 20 kidneys from 10 uDCD donors show a 100% 3-month graft survival. These promising data may be guiding future preservation approaches in uDCD that allow longer acceptable WIT – something invaluable for overcoming key obstacles, as determination of death and consent.

Lung preservation

France and the Netherlands are in the process of establishing uDCD lung procurement programmes, a practice already established in Spain. Lungs are the only organs not requiring circulation to maintain the aerobic cellular metabolism, because of the mechanism of passive diffusion across the alveolar membrane. An adequate gas exchange has been shown after 2 h of WIT in the absence of lung circulation, which could be extended to 4 h in case of heparinization. The best method for the preservation of nonventilated lungs is topic cooling.

After mechanical ventilation is interrupted and the preservation of abdominal organs has been started, where appropriate, bilateral thoracic drains are placed via transthoracic insertion, through the second intercostal space, mid-clavicular line. Cold preservation solution (Perfadex®) is infused at 4°C (5–6 l per hemi thorax) to allow for a topic cooling and lung collapse. Oesophageal temperature is maintained at 20°C [28,29]. In case of abdominal preservation with nRP or to better ensure the cooling of the lungs, some groups place a system for the recirculation of the lung preservation solution, to keep this target temperature. For such purpose, two additional thoracic drains are placed in the sixth intercostal space, mid-axillary line [30]. However, the usefulness of this approach has not been shown yet. Before the procedure is started, approximately 300 ml of venous blood from the potential donor is recovered and preserved at 4°C for the subsequent functional evaluation of the lung. Recently, *ex situ* perfusion is being used to validate lungs from uDCD donors and results of this approach are awaited. The maximum preservation time varies according to the team; however, the usual criterion applied is 240 min.

Donor evaluation

Donor evaluation is a continuum that already starts in the phase of donor identification. In uDCD, inclusion and exclusion criteria are similar to those applied in DBD, with some peculiarities, as specified in Table 1.

As for a DBD procedure, donor and organ evaluation are based on the review of the past and present medical history and risk behaviours of the potential uDCD donor, a physical examination and complementary tests. Available medical records and charts must be carefully reviewed. A dedicated and guided interview with the relatives always should take place for the assessment of donor's suitability.

The EMS can facilitate donor evaluation in several ways. First, through the early recovery of blood samples when they activate the uDCD protocol, so non-haemodiluted samples are available. These early samples are also of value when potential donors have exsanguinating lesions, preserving the option of lung donation. On the other hand, the use of rapid screening tests for certain diseases (e.g. HIV) and drugs at the scene of the CA helps in an earlier selection of cases, thus avoiding the unnecessary activation of the protocol and the related use of resources.

Consent and authorization for organ donation

With an opt-in system, the practice in the Netherlands is to assess if the person has expressed his will about organ donation. A national registry must be consulted to assess the person′s wishes. Even in the case of an

Table 6. Technical aspects related to the preservation of abdominal organs in uDCD.

In situ preservation
1. Double-balloon triple-lumen catheter inserted via the femoral artery, one balloon placed at the aortoiliac bifurcation and the other balloon placed over the superior mesenteric artery.
2. Drain in femoral vein to allow the clearance of the haematic content.
3. Control of pressure of perfusion of preservation liquid (70–80 mmHg).
4. Variable preservation solutions used (HTK, Wisconsin, Celsior, IGL-1).

Hypothermic Regional Perfusion (hRP)
1. Use of an extracorporeal circuit: femoral vessels cannulated and connected with a module for temperature exchange and with a membrane oxygenation module. Blood is oxygenated and cooled at 4–15°C.
2. The contralateral femoral artery is cannulated with a unique balloon catheter. The balloon is advanced into the supraceliac aorta and is inflated with saline and X-ray contrast. Proper positioning on the balloon is confirmed by simple Rx.

Normothermic Regional Perfusion (nRP)
1. Similar to hRP, except for blood maintained at 32–37°C and kept until the macroscopic visualization of liver and kidneys in the surgical room and subsequent cold perfusion with preservation solution.
2. Pump flow is maintained at 1.7–2.5 l/min/m^2.
3. Blood is sampled at baseline and throughout nRP to determine biochemical and haematological parameters and acid–base status.
4. Additional heparin administered every 90 min (1.5 mg/kg i.v.).

Table 7. Levels in the participation of EMS in uDCD based on the availability of resources.

Application Procedure Basic Level
- a) Advanced Life Support Ambulances and/or helicopters, electromedical equipment, medication and equipment needed for resuscitation.
- b) Possibility of arrival at the receiving hospital within 120 min after the cardiac arrest.
- c) Communication system with the receiving hospital/donor transplant coordinator.
- d) Specific protocol for uDCD at the EMS.
- e) Training EMS staff in the uDCD protocol.
- f) Regular quality control of the implementation of the uDCD protocol.

Process Development Level: Donor selection and evaluation optimized and better results achieved.
- a) Support Basic Life Support units in each process.
- b) HIV test strips and drug detection kit.
- c) Mechanical cardiac compressors.
- d) Work procedures with nonhealthcare agencies (i.e. police) for locating family members and escorting ambulances during donor transfer.

Optimal Development Level: Optimal performance in donor selection/evaluation and better quality of preservation of donor's organs.
- a) Presence of a second doctor on the scene with a coordinating role with other agencies and with the receiving hospital and the Coordination Centre.
- b) Presence of a logistics support vehicle at the scene that facilitates the work of cardiac massage and provides the necessary material.
- c) Presence of an Emergency Psychologist at the scene, to facilitate the communication with the relatives and for the purpose of family care.
- d) Analytical stage, to evaluate and correct electrolyte imbalances and consider time of cardiac arrest.
- e) Medical helicopter for long-distance potential uDCD donors.

EMS, Emergency medical Service; uDCD, uncontrolled donation after circulatory death.

expressed positive consent, a dedicated interview is held with the relatives before organ recovery. In uDCD, the DTC consults the registry when the EMS announces that a potential donor is being transferred to the hospital. In case of registered opposition, organ recovery is not pursued. If no opposition or positive consent is identified, a family approach will be held, but the system allows cannulation of vessels and initiation of preservation measures before the family interview is held. However, organ recovery is not continued with if the family finally oppose or if the family interview cannot be held within the first 2 h following the initiation of preservation measures.

France and Spain hold an opting-out policy – obtaining consent is focused on checking any expressed opposition towards donation. There is a specific donor registry in France, and an advanced directives registry in Spain. Both countries also employ interviews with relatives. In uDCD, the family interview may be held at different time points along the process: as soon as when the irreversibility of the CA is established by the EMS, or until after preservation measures have started. This depends on the availability of relatives and their emotional status. As described for the Dutch system, preservation measures (and hence cannulation of blood vessels or placement of thoracic drains) can start after checking positive consent or no opposition to organ donation in the mentioned registries, even if the family has not been approached yet. Organ recovery will never proceed before the family has been informed and authorization obtained.

Principles guiding the information to relatives in uDCD have been a matter of debate. Providing relatives with information in a transparent manner about the process is a paramount principle. Messages are provided progressively and adapted to the emotional situation of the relatives and their understanding of the situation. Particular emphasis must be placed on cases transferred to the hospital for the purpose of organ donation.

With regard to the judicial authorization procedure, specific protocols are in place in Spain to facilitate a rapid communication with the coroner and a rapid authorization, first for preservation and later on for organ recovery [34]. Although this is largely limited to judicial cases, in practice these protocols are applied to most of the cases with a prehospital CA. The reason is that frequently professionals in charge of determining death lack the necessary information to specify the cause of the CA, requiring further information through a judicial autopsy.

Resources of EMS and uncontrolled DCD

In the experience of existing programmes, the implementation of uDCD does not necessarily increase material or human resource use on the EMS side. As for any time-dependent process, the essentials are a dedicated action protocol that reduces variability and ensures quality in practice, the smooth coordination and communication with the receiving hospital and the fast transfer of the potential donor. Table 7 summarizes three levels of participation of an EMS in uDCD based on the availability of resources [34].

For a basic implementation of the programme, additional means to those already available at any EMS are not necessary, as all are equipped with material for advanced life support. Additional resources may, however, facilitate the selection and evaluation of potential donors, avoiding unnecessary activations of the protocol if contraindications to donation are already identified at the scene.

As previously specified, the use of mechanical cardiac compressors can facilitate the transfer of potential uDCD donors and the safety of those in charge of cardiac compression, but it is not an essential.

If possible within the organization of the EMS, the presence of another vehicle can be very useful for enabling logistic support and helping with the cardiac compression and mechanical ventilation measures. When it is not feasible to transfer potential uDCD donors by road, the use of helicopters is a possible solution [61]. This allows expanding the pool of potential donors, by including those from areas with a complicated orography or at long distances from the receiving hospital.

With regard to additional human resources at the scene, the presence of a senior professional who coordinates all external and internal participants and guarantees the adequate compliance with the operating procedure may be considered. Some programmes also count on a psychologist at the scene to assist and accompany the family to the hospital.

Finally, the composition of the EMS teams may be critical. The presence of physicians at the scene of the CA does not only improve the quality of assistance, but also facilitates this particular donation process – the physician-based EMS model in France or Spain may be one of the underlying reasons for the important expansion of uDCD in these countries [62,63].

Recommendations	Grade	References
uDCD may be a helpful addition to alleviate organ donor shortage. Efforts must be undertaken to overcome the ethical, legal, technical & logistical barriers that avoid uDCD to be possible at the European level and at each Member State reality. This should include extensive public and professional debate, as well as vision, dedication and institutional support.	Expert opinion	[4,31–34]

Continued

Recommendations	Grade	References
An unambiguous national regulatory framework should exist to facilitate uDCD and its time- constrained related practice. Regulatory aspects should cover, at a minimum, issues related to: 1. Determination of Death – criteria to define the cessation of the cardiac–circulatory (and respiratory) functions and when such cessation is to be considered irreversible, along with the preconditions for the determination of death (aCPR applied and optimized as specified in national CPR protocols, aligned with international professional standards). 2. Preservation measures – establishing any limitations to its practice, if deemed appropriate within a given jurisdiction. 3. Consent and authorization criteria to proceed with organ preservation and recovery, adapted to the corresponding general consent framework of a given jurisdiction.	Expert opinion	[4,31–34]
Aligned with the national regulatory framework, a specific action protocol should be established at every EMS and hospital engaged in an uDCD programme, where roles and responsibilities are clearly defined, and which is adapted to the available resources and to the internal organization of the corresponding service. A dedicated protocol sets the basis for consistency in the development of the process, avoiding personal interpretations, and ensuring quality in practice. This protocol should be developed by a multidisciplinary team with the representation of all relevant professional groups engaged – in smooth cooperation with the EMS, where appropriate. The protocol should be continuously reviewed, updated and subjected to quality control. Continuous training and education, as well as information on the results of the implementation of the protocol, should be provided periodically to all relevant stakeholders and professional groups participating directly or indirectly in the development of the uDCD activity.	Expert opinión	[4,31–34]
Selection criteria for uDCD represent an important area for research in the future, particularly with regard to the limits in donor age and in WIT, which have been established based on empirical grounds. The following set of criteria describes the current practice in most of the existing programmes and may be proposed as the recommended profile: 1. Time of CA known 2. Age ≤55–60 years 3. Time between CA and aCPR initiation (no-flow period) <15–30 min for kidney transplants, <15 min for liver transplants. 4. Total WIT <150 min. 5. Exclusion criteria: a. Arterial hypertension – relative contraindication for kidney. b. Diabetes – relative contraindication for kidney c. Kidney disease d. Liver disease e. Malignancies f. Intravenous drug abuse g. Sepsis and viral infection (HIV, HBV, HCV) h. Major trauma – relative contraindication – abdominal trauma does not preclude lung donation. i. Homicide or suicide – relative contraindication.	C (donor age), Expert opinion	[9–34]
A mechanism for the activation of the uDCD protocol by the team in charge of the CPR should be enabled. Smooth communication between the attending team and the receiving hospital is paramount.	Expert opinion	[31–34]
A key donation person/DTC should be available 24/7, either in the hospital or close by on call In case of programmes that may be activated by the EMS, the DTC should be checking the selection criteria and authorizing the potential uDCD donor transfer, where appropriate, and should be always present at the arrival of the potential uDCD donor at the hospital. In every single case, the activation of a rapid alert team and the transplantation team should follow. In checking the selection criteria, special emphasis should be performed in the WIT (time since CA until the initiation of aCPR and estimated time of initiation of the preservation measures).	Expert opinion	[31–34]
As for the purpose of the transfer of the potential uDCD donor, mechanical cardiac compressors are not essential, although their use improves the quality of cardiac compression and the safety of participating professionals and may improve organ viability.	D	[37–43]
To ensure effective cardiac compression and adequate perfusion of organs, the team in charge of the transfer of a potential uDCD donor should ensure that the EMS vehicle travels at slow and constant speeds. An appropriate transfer may be facilitated by the coordination with other agencies.	Expert opinion	[31–34]

Transplant International 2016; 29: 842–859

Continued

Recommendations	Grade	References
Determination of death should always be the responsibility of a professional(s) independent of the donation and transplantation team. Determination of death preceding uDCD should be based on the following criteria: 1. aCPR exhausted according to international standards and local protocols (inclusive of at least 30 min of advanced CPR) with inability to restore spontaneous circulation 2. Cessation of spontaneous circulation based on the absence of electrical activity by ECG or the appropriate means (as echocardiography or invasive blood pressure measurement) in case of electromechanical dissociation, when reversible causes have been discarded and treated. 3. An observation period is recommended to be set down as a minimum of 5 min. There is no solid basis to recommend extending this period of observation beyond this time.There is an ongoing and unresolved controversy with regard to the validity of death determination after the re-establishment of circulation with oxygenated blood in the context of uDCD. For countries with large experience in this type of donation, this controversy is unfounded because of the particular clinical characteristics of potential uDCD donors. Firstly, these countries consider that the permanent cessation of circulation as a surrogate of the irreversible cessation of circulation is not applicable in this setting – because irreversibility of the CA has been already proven. Secondly, because potential uDCD donors have been exposed to prolonged low-flow periods (aCPR and cardiac compression during donor transfer) and to at least two periods of complete absence of circulation, the possibility of restoring brain function following the re-establishment of circulation is expected to be clinically negligible because of the profound ischaemic injury to the brain. Other countries, however, consider that the permanent cessation of circulation should be the criteria applied to determine death preceding uDCD and do not allow the re-establishment of circulation once death is determined.	Expert opinion	[35,36,47,49–56]
The effectiveness of the different preservation procedures for abdominal organs in the context of DCD, and in the context of uDCD in particular, is still to be compared in randomized controlled trials. However, preclinical and cohort studies suggest the superiority of nRP, compared with hRP, and that of hRP compared with ISP in kidney transplantation and make nRP (preceded by cardiac compression) the advisable preservation method for the liver. However, ISP may be considered as an option in kidney transplantation, as long as stricter criteria are used in donor selection, for example, age and WIT. Additionally, the nonrealization of the uDCD process when hRP/nRP is used is a matter of concern. The possibility of converting the preservation procedure to ISP in cases where the former fails may be seen as an option, for example, when the integrity of the vascular structure is not ensured. Research is needed for the objective establishment of the maximum times for abdominal preservation techniques, but current protocols establish the limit of 180 min for ISP and 240 min for hRP/nRP. The role of leukapheresis combined with nRP is to be determined. Each programme should select the preservation method that is better adapted to the local reality and resource availably, but the principles of reducing potential donor losses as much as possible, while ensuring organ viability and optimal post-transplant results, are paramount.	C	[3,9–21] (kidney) [23–27,57–60] (liver)
Preservation of the lungs should be based on topic cooling. The recirculation of the lung preservation solution allows for the simultaneous normothermia for abdominal organs. Further research should help establish the maximum times for preservation in terms of organ viability and post-transplant outcomes, but existing programmes set down the limit of 240 min	D	[28–30]
Donor evaluation is based on the same principles than the evaluation of any deceased organ donor. As for a DBD donor, evaluation should include a review of the past and present medical history and assessment of risk behaviours of the potential donor, a complete physical examination and corresponding complementary tests. Available medical records and charts should be carefully reviewed and a dedicated and guided interview with the relatives should always take place for the assessment of donor's suitability. For potential uDCD donors in whom CA takes place in the prehospital scenario, donor evaluation can be facilitated by the EMS in several ways, particularly through the collection of early blood samples (avoiding potential donor losses because of haemodilution or exsanguination – lung transplantation still possible) and rapid screening tests (e.g. HIV) at the scene of the CA.	Expert opinion	[31–34]
Information to the relatives and the procedure for obtaining consent to proceed with organ preservation and organ recovery should be in accordance with the consent system in place at a given jurisdiction. The principle of transparency should be preserved, while maintaining the spirit of an appropriate family care.	Expert opinion	[31–34]
A dedicated judicial procedure should be enabled for judicial cases because of the time constraints of the process.	Expert opinion	[31–34]
An EMS fully implemented in society does not need any additional equipment for the development of uDCD. The essentials are a clear protocol and a smooth communication system with the receiving hospital.	Expert opinion	[34]

Funding

The authors have declared no funding.

Conflicts of interest

The authors have declared no conflicts of interest.

REFERENCES

1. International figures on donation and transplantation-2014. Newsletter Transplant 2015. Available at: http://www.ont.es/publicaciones/Documents/NEWSLETTER%202015.pdf (accessed January 2016).
2. Domínguez-Gil B, Haase-Kromwijk B, Van Leiden H, *et al.* Current situation of donation after circulatory death in European countries. *Transpl Int* 2011; **24**: 676.
3. Reznik O, Skvortsov A, Loginov I, Ananyev A, Bagnenko S, Moysyuk Y. Kidney from uncontrolled donors after cardiac death with one hour warm ischemic time: resuscitation by extracorporal normothermic abdominal perfusion "in situ" by leukocytes-free oxygenated blood. *Clin Transplant* 2011; **25**: 511.
4. Institute of Medicine (U.S.). Committee on increasing rates of organ donation. In: Childress JF, Liverman CT, eds. *Organ Donation: Opportunities for Action*. Washington, DC: National Academies Press, 2006: p 183
5. Roberts KJ, Bramhall S, Mayer D, Muiesan P. Uncontrolled organ donation following prehospital cardiac arrest: a potential solution to the shortage of organ donors in the United Kingdom? *Transpl Int* 2011; **24**: 477.
6. Wall SP, Kaufman BJ, Gilbert AJ, *et al.* Derivation of the uncontrolled donation after circulatory determination of death protocol for New York City. *Am J Transplant* 2011; **11**: 1417.
7. Hanto DW, Veatch RM. Uncontrolled Donation after Circulatory Determination of Death (UDCDD) and the Definition of Death. *Am J Transplant* 2011; **11**: 1351.
8. Wall SP, Munjal KG, Dubler NN, Goldfrank LR; NYC uDCDD Study Group. Uncontrolled organ donation after circulatory determination of death: US policy failures and call to action. *Ann Emerg Med* 2014; **63**: 392.
9. Valero R, Cabrer C, Oppenheimer F, *et al.* Normothermic recirculation reduces primary graft dysfunction of kidneys obtained from non-heart-beating donors. *Transpl Int* 2000; **13**: 303.
10. Mizutani K, Ono Y, Kinukawa T, *et al.* Use of marginal organs from non-heart-beating cadaveric kidney donors. *Transplantation* 2001; **72**: 1376.
11. Hattori R, Ono Y, Yoshimura N, *et al.* Long-term outcome of kidney transplant using non-heart-beating donor: multicenter analysis of factors affecting graft survival. *Clin Transplant* 2003; **17**: 518.
12. Gagandeep S, Matsuoka L, Mateo R, *et al.* Expanding the donor kidney pool: utility of renal allografts procured in a setting of uncontrolled cardiac death. *Am J Transplant* 2006; **6**: 1682.
13. Sánchez-Fructuoso AI, Marques M, Prats D, Conesa J, Calvo N, Pérez-Contín MJ. Victims of cardiac arrest occurring outside the hospital: a source of transplantable kidneys. *Ann Intern Med* 2006; **145**: 157.
14. Fieux F, Losser M-R, Bourgeois 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.
15. Barlow AD, Metcalfe MS, Johari Y, Elwell R, Veitch PS, Nicholson ML. Case-matched comparison of long-term results of non-heart beating and heart-beating donor renal transplants. *Br J Surg* 2009; **96**: 685.
16. Hoogland ER, Snoeijs MG, Winkens B, Christaans MH, van Heurn LW. Kidney transplantation from donors after cardiac death: uncontrolled versus controlled donation. *Am J Transplant* 2011; **11**: 1427.
17. Abboud I, Viglietti D, Antoine C, *et al.* Preliminary results of transplantation with kidneys donated after cardiocirculatory determination of death: a French single-centre experience. *Nephrol Dial Transplant* 2012; **27**: 2583.
18. de Gracia MC, Osorio JM, Pérez-Villares JM, *et al.* A new program of kidney transplantation from donors after cardiac death in Spain. *Transplant Proc* 2012; **44**: 2518.
19. Hanf W, Codas R, Meas-Yedid V, *et al.* Kidney graft outcome and quality (after transplantation) from uncontrolled deceased donors after cardiac arrest. *Am J Transplant* 2012; **12**: 1541.
20. Hoogland ER, van Smaalen TC, Christiaans MH, van Heurn LW. Kidneys from uncontrolled donors after cardiac death: which kidneys do worse?. *Transpl Int* 2013; **26**: 477.
21. Miranda-Utrera N, Medina-Polo J, Pamplona M, *et al.* Donation after cardiac death: results of the SUMMA 112 – Hospital 12 de Octubre Program. *Clin Transplant* 2013; **27**: 283.
22. 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.
23. Fondevila C, Hessheimer AJ, Flores E, *et al.* Applicability and results of Maastricht type 2 donation after cardiac death liver transplantation. *Am J Transplant* 2012; **12**: 162.
24. Suárez F, Otero A, Solla M, *et al.* Biliary complications after liver transplantation from Maastricht category-2 non-heart-beating donors. *Transplantation* 2008; **85**: 9.
25. Otero A, Gómez-Gutiérrez M, Suárez F, Arnal F, Fernández-García A, Aguirrezabalaga J. Liver transplantation from Maastricht category 2 non-heart-beating donors. *Transplantation* 2003; **76**: 1068.
26. Quintela J, Gala B, Baamonde I, *et al.* Long-term results for liver transplantation from non-heart-beating donors maintained with chest and abdominal compression-decompression. *Transplant Proc* 2005; **37**: 3857.
27. Jiménez-Galanes S, Meneu-Diaz MJ, Elola-Olaso AM, *et al.* Liver transplantation using uncontrolled non–heart-beating donors under normothermic extracorporeal membrane oxygenation. *Liver Transpl* 2009; **15**: 1110.
28. de Antonio DG, Marcos R, Laporta R, *et al.* Results of clinical lung transplant from uncontrolled non-heart-beating donors. *J Heart Lung Transplant* 2007; **26**: 529.
29. Gómez-de-Antonio D, Campo-Cañaveral JL, Crowley S, *et al.* Clinical lung transplantation from uncontrolled non-heart-beating donors revisited. *J Heart Lung Transplant* 2012; **31**: 349.
30. Gámez P, Díaz-Hellín V, Marrón C, Meneses JC, de Pablo A, Martín de Nicolás JL. Development of a non-heart-beating lung donor program with "Bithermia Preservation", and results after one year of clinical experience. *Arch Bronconeumol* 2012; **48**: 338.
31. Conditions à respecter pour réaliser des prélèvements de reins sur des donneurs décédés aprés arrêt cardiaque dans un

établissement de santé autorisé aux prélèvements d'organes. Available at: www.agence-biomedecine.fr (accessed January 2016).
32. Conditions à respecter pour réaliser des prélèvements de foie sur des donneurs décédés aprés arrêt cardiaque dans un établissement de santé autorisé aux prélèvements d'organes. Available at: www.agence-biomedecine.fr (accessed January 2016).
33. Dutch National protocol. Model protocol organ-and tissue donation 2012. Available at: http://www.transplantatiestichting.nl/sites/default/files/product/downloads/modelprotocol_postmortale_orgaan-_en_weefseldonatie.pdf (accessed January 2016).
34. Donation after circulatory death: current situation and recommendations. Spanish National Consensus Document 2012. Available at: http://www.ont.es/infesp/DocumentosDeConsenso/DONACIÓN%20EN%20ASISTOLIA%20EN%20ESPAÑA.%20SITUACIÓN%20ACTUAL%20Y%20RECOMENDACIONES.pdf (accessed January 2016).
35. Nolan JP, Soar J, Zideman DA, Biarent D, Bossaert LL, Deakin C. European resuscitation council guidelines for resuscitation 2010. Section 1. Executive summary. *Resuscitation* 2010; **81**: 1219.
36. Field J, Hazinski MF, Sayre M, *et al.* American heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2010; **122**: S640.
37. CIRC Trial. European Resuscitation Council Congress. Vienna, 2012.
38. LINC Trial. Oral Communication. European Cardiology Congress. Amsterdam, 2013.
39. Steen S, Sjöberg T, Olsson P, Young M. Treatment of out-of-hospital cardiac arrest with LUCAS, a new device for automatic mechanical compression and active decompression resuscitation. *Resuscitation* 2005; **67**: 25.
40. Olasveengen TM, Wik L, Steen PA. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. *Resuscitation* 2008; **76**: 185.
41. Carmona Jiménez F, Ruiz Arránz A, Palma Padró P, Soto García A, Alberola Martín M, Saavedra Escobar S. Utilización de un compresor torácico mecánico (LUCAS®) en un programa de donación en asistolia: efecto sobre la perfusión de los órganos y la tasa de trasplante. *Emergencias* 2012; **24**: 366.
42. Mateos-Rodríguez A, Pardillos-Ferrer L, Navalpotro-Pascual JM, Barba-Alonso C, Martin-Maldonado ME, Andrés-Belmonte A. Kidney transplant function using organs from non-heart-beating donors maintained by mechanical chest compressions. *Resuscitation* 2010; **81**: 904.
43. Mateos-Rodríguez A, Navalpotro-Pascual JM, Andres-Belmonte A. Donor after cardiac death kidney graft under mechanical cardiac compression evolution. *Resuscitation* 2013; **84**: 117.
44. Smekal D, Johansson J, Huzavka T, Rubertsson S. No difference in autopsy detected injuries in cardiac arrest patients treated with manual compression compared with mechanical compressions with LUCAS device—a pilot study. *Resuscitation* 2009; **80**: 1104.
45. Xanthos T, Pantazopoulos I, Roumelioti H, *et al.* A comparison of autopsy detected injuries in a porcine model of cardiac arrest treated with either manual or mechanical chest compressions. *Eur J Emerg Med* 2011; **18**: 108.
46. Mateos Rodríguez AA, Pascual JM, Vallejo FP, García AP, Belmonte AA. Lung injuries secondary to mechanical chest compressions. *Resuscitation* 2012; **83**: E203.
47. Sasson C, Hegg AJ, Macy M, Park A, Kellermann A, McNally B; CARES Surveillance Group. Prehospital termination of resuscitation in cases of refractory out-of-hospital cardiac arrest. *JAMA* 2008; **300**: 1432.
48. Stiegler P, Sereinigg M, Puntschart A, *et al.* A 10 min "no-touch" time – is it enough in DCD? A DCD animal study. *Transpl Int* 2012; **25**: 481.
49. Matesanz R, Coll E, Domínguez-Gil B; Spanish Group for Donation after Circulatory Death. Response to circulatory death determination in uncontrolled organ donors: a panel viewpoint. *Ann Emerg Med* 2014; **63**: 87.
50. Bernat JL, Capron AM, Bleck TP, *et al.* The circulatory-respiratory determination of death in organ donation. *Crit Care Med* 2010; **38**: 963.
51. United Kingdom guidelines – transplantation from donors after deceased circulatory death. British Transplantation Society. Available at: http://www.bts.org.uk/Documents/2013-02-04%20DCD%20guidelines.pdf (accessed January 2016).
52. Shemie SD, Baker AJ, Knoll G, *et al.* National recommendations for donation after cardiocirculatory death in Canada: donation after cardiocirculatory death in Canada. *CMAJ* 2006; **175**: S1.
53. National Protocol for Donation after Cardiac Death. DonateLife. Available at: http://www.donatelife.gov.au/Media/-docs/DCD%20protocol%20020311-0e4e2c3d-2ef5-4dff-b7efaf63d0bf6a8a-1.PDF (accessed January 2016).
54. Munjal KG, Wall SP, Goldfrank LR, Gilbert A, Kaufman BJ, Dubler NN. A rationale in support of uncontrolled donation after circulatory determination of death. *Hastings Cent Rep* 2013; **43**: 19.
55. Bernat J. Determining death in uncontrolled DCDD organ donors. *Hastings Cent Rep* 2013; **43**: 30.
56. Bernat JL, Bleck TP, Blosser SA, *et al.* Circulatory death determination in uncontrolled organ donors: a panel viewpoint. *Ann Emerg Med* 2014; **63**: 384.
57. Casavilla A, Ramirez C, Shapiro R, *et al.* Experience with liver and kidney allografts from non-heart-beating donors. *Transplantation* 1995; **59**: 197.
58. Garcia-Valdecasas JC, Tabet J, Valero R, *et al.* Liver conditioning after cardiac arrest : the use of normothermic recirculation in an experimental animal model. *Transpl Int* 1998; **11**: 424.
59. Valero R, Garcia-Valdecasas JC, Tabet J, *et al.* Hepatic blood flow and oxygen extraction ratio during normothermic recirculation and total body cooling as viability predictors in non-heart-beating donor pigs. *Transplantation* 1998; **66**: 170.
60. Net M, Valero R, Almenara R, *et al.* The effect of normothermic recirculation is mediated by ischemic preconditioning in NHBD liver transplantation. *Am J Transplant* 2005; **5**: 2385.
61. Mateos Rodríguez A, Navalpotro JM, Ortega I, *et al.* Helicopter transport of cardiac death donors. *Emergencias* 2011; **23**: 372.
62. Fischer M, Kamp J, Garcia-Castrillo Riesgo L, *et al.* Comparing emergency medical service systems–a project of the European Emergency Data (EED) Project. *Resuscitation* 2011; **82**: 285.
63. Yasunaga H, Horiguchi H, Tanabe S, *et al.* Collaborative effects of bystander-initiated cardiopulmonary resuscitation and prehospital advanced cardiac life support by physicians on survival of out-of-hospital cardiac arrest: a nationwide population-based observational study. *Crit Care* 2010; **14**: R199.