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Current situation of donation after circulatory death in European countries

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Summary

The aim of the present study was to describe the current situation of donation after circulatory death (DCD) in the Council of Europe, through a dedicated survey. Of 27 participating countries, only 10 confirmed any DCD activity, the highest one being described in Belgium, the Netherlands and the United Kingdom (mainly controlled) and France and Spain (mainly uncontrolled). During 2000–2009, as DCD increased, donation after brain death (DBD) decreased about 20% in the three countries with a predominant controlled DCD activity, while DBD had increased in the majority of European countries. The number of organs recovered and transplanted per DCD increased along time, although it remained substantially lower compared with DBD. During 2000–2008, 5004 organs were transplanted from DCD (4261 kidneys, 505 livers, 157 lungs and 81 pancreas). Short-term outcomes of 2343 kidney recipients from controlled versus 649 from uncontrolled DCD were analyzed: primary non function occurred in 5% vs. 6.4% (P = NS) and delayed graft function in 50.2% vs. 75.7% ($P < 0.001$). In spite of this, 1 year graft survival was 85.9% vs. 88.9% ($P = 0.04$), respectively. DCD is increasingly accepted in Europe but still limited to a few countries. Controlled DCD might negatively impact DBD activity. The degree of utilization of DCD is lower compared with DBD. Short-term results of DCD are promising with differences between kidney recipients transplanted from controlled versus uncontrolled DCD, an observation to be further analyzed.

Introduction

In the early days of transplantation, the source of transplantable kidneys was either living donors or nonheart beating donors. Nonheart beating donors (those who have donated after death has been declared following irreversible cessation of circulatory and respiratory functions) are currently termed 'donors after cardiac death' or, more recently, 'donors after circulatory death' (DCD) [1,2]. Later on, the wide acceptance of the concept and

the criteria for the diagnosis of brain death made the use of organs from donors after brain death (DBD) largely replace DCD. At present, shortage of organs for transplantation and promising results with organs transplanted from these donors have renewed the interest in DCD. This interest has led to several consensus conferences and guidelines that tried to face the inherent ethical, legal, organizational, and technical issues that did arise [3–8].

The *First International Workshop on DCD*, held in Maastricht in 1995, identified four categories of DCD, depending on the context in which the irreversible cessation of respiratory and circulatory functions is determined [3]. Types I (dead on arrival) and II (unsuccessful resuscitation) Maastricht Categories have also been named 'uncontrolled DCD'. Type III (awaiting cardiac arrest) and type IV (cardiac arrest while brain dead) have been also referred to as 'controlled DCD'.

DCD has evolved in different ways between the countries. DCD type III has increased progressively in the US and now accounts for 10–11% of all the deceased donation activity in this country [9]. In Japan, DCD remains the main source of organs for transplantation from deceased donors, since the concept of brain death has been only recently adopted in the national legislation [10,11]. The aim of the present study was to describe the current situation of DCD in Member States of the Council of Europe. In particular, the study intended to describe the organizational features of DCD programs in place, the DCD activity, and the degree of utilization of DCD compared with DBD over time, and to evaluate the short-term results of transplants performed from DCD, comparing those performed with organs from controlled with uncontrolled DCD.

Materials and methods

The study was carried out by the *European Committee on Organ Transplantation within the Council of Europe* (CD-P-TO). A specific questionnaire was designed and agreed upon by the representatives of countries in this committee. Each representative collected the requested information from official sources, either the National Transplant Organization or the corresponding department of the Ministry of Health. The information was complemented with data from the annual *Newsletter Transplant*, the official publication of the CD-P-TO.

Post-transplant follow-up information was directly collected from centers performing DCD and/or transplanting organs from DCD or from national registries, when available.

The collected information was returned to the *Spanish National Transplant Organization* and the *Dutch Transplantation Foundation* for subsequent quality control of data and analysis.

Donation and transplantation activity

Information on donation and transplantation activity from DCD and DBD was collected for the years 2000–2009, based on the following definitions:

Actual donor (hereinafter, donor): A deceased person from whom at least one solid organ has been recovered for the purpose of transplantation.

Utilized donor: A deceased person from whom at least one solid organ has been transplanted.

Utilization rate: Percentage of donors who are converted into utilized donors.

Uncontrolled DCD: Includes Maastricht categories I and II DCD donors.

Controlled DCD: Includes Maastricht categories III and IV DCD donors.

Solid organ (hereinafter, organ): Differentiated and vital part of the human body, formed by different tissues that maintains its structure, vascularization and capacity to develop physiological functions with an important level of autonomy (*Directive 2004/23/EC*).

Organs recovered per donor (ORPD): Number of organs recovered for the purpose of solid organ transplantation from donors within the country divided by the number of actual donors. Organs recovered for the purpose of tissue or cell transplantation were not counted as organs recovered (i.e. pancreas recovered for the purpose of islet transplantation, hearts recovered for the purpose of heart valve transplantation). Organs were counted as individual organs regardless of the type of transplantation performed in the event organs were subsequently transplanted.

Organs transplanted per donor (OTPD): Number of organs transplanted as solid organs from donors within the country divided by the number of actual donors. Organs were counted as individual organs regardless of the type of transplantation performed.

Discard rate: The percentage of organs that were discarded once recovered was calculated as follows: $[(\text{ORPD} - \text{OTPD})/\text{ORPD})] \times 100$.

Short-term results of transplantation from DCD

Information on the follow-up of recipients transplanted from DCD was limited to those transplants performed from January 1st 2000 to December 31st 2007.

For survival figures, each country provided cumulative data stratified according to type of organ transplanted and type of DCD (controlled versus uncontrolled) as specified below:

A: Number of patients who received a transplant from a DCD during the period of study.
B: Number of patients with no evidence of graft loss and/or patient death, but lost to follow-up before 1 year (±1 month).
C: Number of patients who lost their graft during the 1st year and subsequently or simultaneously died.
D: Number of patients who lost their graft during the 1st year and who remained alive at 1 year (±1 month). Patients with no follow-up information after graft loss were considered to be alive.
E: Number of patients who died during the 1st year with a functioning graft.
F: Number of patients alive and with a functioning graft at 1 year (±1 month)

Survival figures per type of organ transplanted and per type of DCD (controlled versus uncontrolled) were constructed as follows:
1 year death-censored graft survival: $[(E + F)/(A - B)] \times 100$
1 year death noncensored graft survival: $[F/(A - B)] \times 100$
1 year patient survival: $[(D + F)/(A - B)] \times 100$

For kidney recipients, information was also collected on the number of patients developing delayed graft function (DGF), defined as the need for dialysis in the first week after kidney transplantation and the number of patients with primary non function (PNF) of the graft, defined as never functioning kidney transplants.

Data are represented as absolute numbers and percentages, when applicable. The incidence of DGF and PNF for kidney recipients of patients transplanted from controlled versus uncontrolled DCD was compared by the chi-square test. One-year graft and patient survival for recipients transplanted from controlled versus uncontrolled DCD was also compared by the chi-square test, and the Fisher's exact test, when applicable. When a statistically significant difference was found ($P < 0.05$), the odds ratio (OR) was calculated with its 95% confidence interval.

Results

General characteristics of DCD programs

The questionnaire was returned by 27 Member States of the Council of Europe (Fig. 1). Of the countries participating in the survey, 10 confirmed any DCD activity

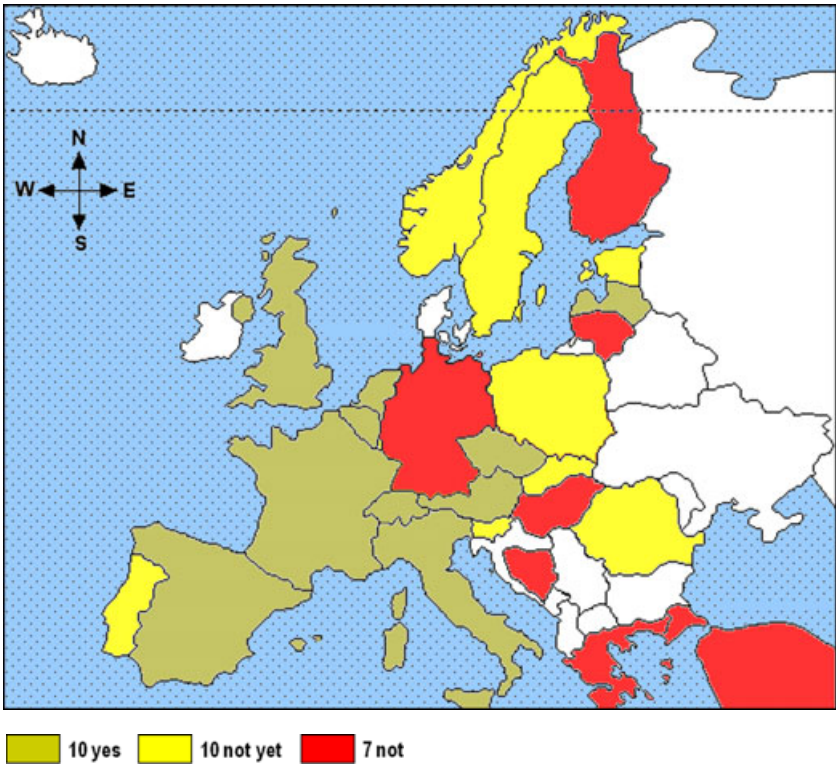

Figure 1 Member States of the Council of Europe participating in the survey (colored). Countries with donation after circulatory death (DCD) activity (green): Austria, Belgium, Czech Republic, France, Italy, Latvia, the Netherlands, Spain, Switzerland and United Kingdom. Countries planning to start a DCD program (yellow): Cyprus, Estonia, Luxembourg, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia and Sweden. Countries with no present or planned DCD activity (red): Bosnia-Herzegovina, Finland, Germany, Greece, Hungary, Lithuania and Turkey.

Table 1. General characteristics of donation after circulatory death (DCD) programs existing in Member States of the Council of Europe.

	No touch period (min)	Procurement protocol	Donation program	Allocation DCD organs
Austria	10	–	1 center	Local
Belgium	5	Super-rapid laparotomy and sternotomy with direct arterial cannulation	National	National
Czech Republic	10	DB	Centers	Special
France	5	ECMO, DB	Centers	Local
Italy	20	NECMO	National	Local
Latvia	15	DB	National	National
The Netherlands	5	Super-rapid laparotomy and sternotomy with direct arterial cannulation	National	National
Spain	5	ECMO, NECMO, DB	Centers	Local/special
Switzerland	10	–	Centers	Local
United Kingdom	5	Super-rapid laparotomy and sternotomy with direct arterial cannulation	National	Local

ECMO, extra corporeal membrane oxygenation; DB, double balloon; NECMO, normothermic extra corporeal membrane oxygenation; DCD, donation after circulatory death.

during the years 2000–2009, 10 were planning the initiation of a DCD program, but had no activity yet, and seven were not planning to start a program of this nature. In six countries, DCD was forbidden by law (Finland, Germany, Greece, Poland, Portugal, and Luxembourg). Other reasons that justified the lack of a DCD program were organizational difficulties in 10 countries and lack of technical expertise in two.

The general characteristics of DCD programs are shown in Table 1. The no-touch period, defined as the time between the cessation of circulation and respiration and the determination of death, ranged from 5 min in five countries to 20 min in Italy. The super-rapid laparotomy and sternotomy with direct arterial cannulation, along with the extra corporeal membrane oxygenation (ECMO) were procedures gaining predominance in countries with multi-organ recovery from DCD donors. In most countries, DCD was limited to specific experienced centers. Organs from these donors were mainly transplanted locally in those centers where recovery took place, or were subjected to special allocation criteria. Only Belgium, Latvia, and the Netherlands

Table 2. Donation and transplantation activities from donation after circulatory death (DCD) in Member States of the Council of Europe for the years 2000 and 2008 and year when the program started.

		DCD (*n*) 2008									
		Maastricht categories					Transplants from DCD (*n*) 2000–2008				
	Year the program started	I	II	III	IV	DCD (*n*) 2000–2008	Kidney	Liver	Lung	Pancreas	Total
Austria	1994	0	3	0	0	20	39	1	–	–	40
Belgium	1994	0	2	40	0	148	231	71	17	9	328
Czech Republic	1972	0	0	1	0	15 (since 2002)	13	–	–	–	13
France	2006	47		0	0	87 (since 2006)	99	–	–	–	99
Italy	2005	0	2	0	0	5 (since 2007)	3	–	–	–	3
Latvia	1992	0	0	11	0	58 (since 2004)	97	–	–	–	97
The Netherlands	1981	0	6	85	0	819	1319	113	46	5	1483
Spain	1994	77		0	0	537	700	64	54	–	818
Switzerland	1993	0	0	0	0	35	58	–	–	–	58
United Kingdom	1989	0	0	264	0	1005	1702	256	40	67	2065
Total		137		401		2729	4261	505	157	81	5004

DCD, donation after circulatory death.

allocated organs from DCD nationally, by applying general allocation criteria.

Donation and transplantation activities

General donation and transplantation activities from DCD for the years 2000–2008 are depicted in Table 2. DCD activity started first in Czech Republic and the Netherlands and most recently in Italy, (2005) and France (2006). The highest DCD activity, taking into account the years 2000–2008, was described in five out of the ten countries with any DCD activity: United Kingdom, the Netherlands, Spain, Belgium, and France. United Kingdom reported more than 1000 DCD during the period of study. DCD was based on type III category in most of the countries. Uncontrolled DCD was predominant in Spain and in France.

More than 5000 transplants were performed from DCD during 2000–2008 (Table 2). Kidney transplantation activity was prominent compared with liver transplantation (kidney/liver ratio: 8/1). Lung transplantation was quantitatively most important in Spain, relying on uncontrolled DCD; this program having started in the 2002. Pancreas transplantation from DCD was notable in the United Kingdom, with most of the 67 transplants having been performed between 2007 and 2008.

The evolution of DBD versus DCD in European countries with a predominant type III DCD activity is shown in Fig. 2 and Table 3. In Belgium (Fig. 2a), DCD activity was ≤1 per million population (pmp) until 2006, but rose to 21% of the overall deceased donation in 2009. As DCD increased, there was a progressive decrease in DBD so DBD was 19% lower in 2009, compared with 2000. In the Netherlands, DCD activity has been outstanding over the entire evaluated period. Figure 2b makes evident a progressive decline in DBD activity, while DCD was increasing (DBD was 22% lower in 2009, compared with 2000). Overall deceased donation activity showed slight variation over this period of time. The contribution of DCD to overall deceased donation activity ranged between 22% and 50% during the period studied. DCD in the United Kingdom became more marked from 2004 (Fig. 2c). In 2009, 34% of the deceased donation activity in the country was from DCD. As in Belgium and the Netherlands, there has also been a progressive decline in DBD (DBD was 19% lower in 2009, compared with 2000), while DCD was increasing. In contrast to what occurred in these three countries, DBD activity increased in most of the European countries between 2000 and 2009, including those with a predominant uncontrolled DCD program, such as France and Spain (Fig. 3).

The utilization rate of DCD in 2008 was 68% in France, 77% in Spain, 90% in Belgium and the Netherlands and

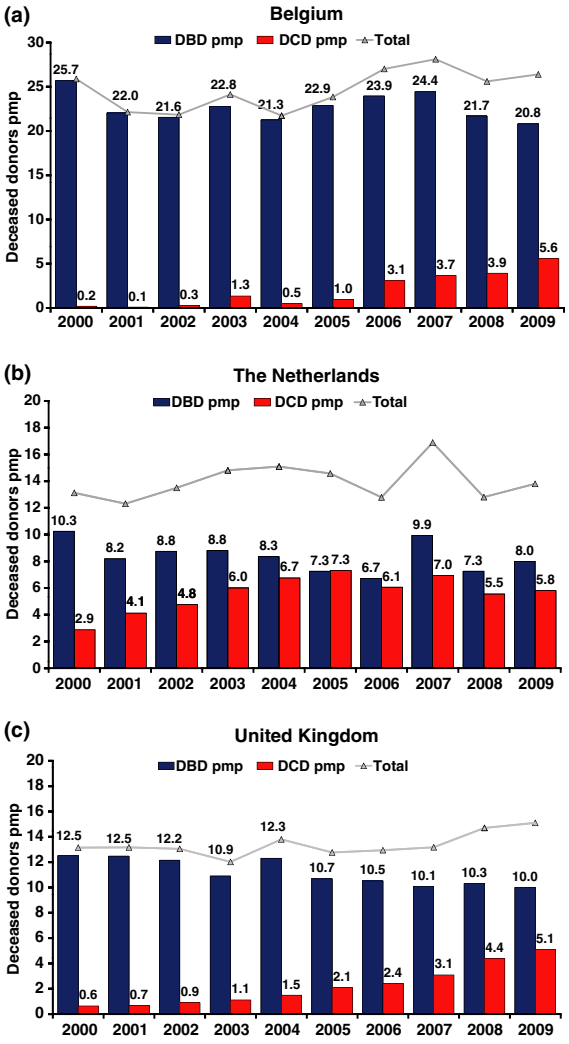

Figure 2 Evolution of donation after circulatory death (DCD, red bars) and donation after brain death (DBD, blue bars) per million population (pmp) in the three European countries with a predominant and outstanding type III DCD activity. Years 2000–2009. (a) Belgium; (b) the Netherlands; (c) United Kingdom.

93% in the United Kingdom. Thus, depending on the country, in 7 to 32% of the cases of DCD, no organ was finally transplanted. In general terms, and as depicted in Table 3, the number and type of organs recovered and transplanted per DCD has been progressively increasing over the years. The number of organs transplanted per DCD in 2008 was the highest in the United Kingdom (2.27). The ORPD and OTPD for DCD were always substantially lower than corresponding figures for DBD in the five countries, making quantitatively evident the different degree of utilization of DCD compared with DBD.

As shown in Table 3, discard rates for organs recovered from DCD were high: 16.7% in the United Kingdom, 21.9% in the Netherlands, 23.9% in Belgium, 36.5% in

Table 3. Donation and transplantation activities from donation after circulatory death (DCD) versus donation after brain death (DBD) in the four European countries with the highest DCD activity and degree of utilization of both types of donors. Years 2000–2008.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Belgium									
Population	10,2	10,3	10,3	10,4	10,4	10,4	10,5	10,6	10,7
Number of DBD	262	227	222	237	221	238	249	259	232
DBD pmp	25,7	22,0	21,6	22,8	21,3	22,9	23,7	24,4	21,7
Organs recovered per DBD									
Organs transplanted per DBD									
Number of DCD	2	1	3	14	5	10	32	39	42
DCD pmp	0,2	0,1	0,3	1,3	0,5	1,0	3,0	3,7	3,9
Number of kidneys recovered from DCD	4	2	5	27	10	20	62	77	70
Number of livers recovered from DCD	0	0	0	9	3	5	22	24	23
Number of lungs recovered from DCD	0	0	0	0	0	0	0	12	7
Number of pancreas recovered from DCD	0	0	0	3	0	1	4	8	9
Organs recovered per DCD	2,00	2,00	1,67	2,79	2,60	2,60	2,75	3,10	2,60
Number of kidneys transplanted from DCD	4	1	5	23	9	15	48	69	57
Number of livers transplanted from DCD	0	0	0	9	3	4	19	20	16
Number of lungs transplanted from DCD	0	0	0	0	0	0	0	10	7
Number of pancreas transplanted from DCD	0	0	0	3	0	1	0	2	3
Organs transplanted per DCD	2,00	1,00	1,67	2,50	2,40	2,00	2,09	2,59	1,98
France									
Population (million)							62,00	63,20	63,60
Number of DBD							1442	1561	1563
DBD pmp							23,3	24,7	24,6
Organs recovered per DBD							3,19	3,12	3,09
Organs transplanted per DBD							2,88	2,79	2,75
Number of DCD							1	39	47
DCD pmp							0,0	0,6	0,7
Number of kidneys recovered from DCD							2	78	94
Number of livers recovered from DCD							0	0	0
Number of lungs recovered from DCD							0	0	0
Number of pancreas recovered from DCD							0	0	0
Organs recovered per DCD							2,00	2,00	2,00
Number of kidneys transplanted from DCD							1	46	52
Number of livers transplanted from DCD							0	0	0
Number of lungs transplanted from DCD							0	0	0
Number of pancreas transplanted from DCD							0	0	0
Organs transplanted per DCD							1,00	1,18	1,11
The Netherlands									
Population	16,0	16,0	16,0	16,0	16,3	16,4	16,5	16,4	16,4
Number of DBD	164	131	140	141	136	119	111	163	119
DBD pmp	10,3	8,2	8,8	8,8	8,3	7,3	6,7	9,9	7,3
Organs recovered per DBD	3,74	3,93	3,82	3,85	4,10	4,51	4,53	4,58	4,24
Organs transplanted per DBD	3,45	3,60	3,48	3,55	3,71	4,07	4,00	4,01	3,65
Number of DCD	46	66	76	96	110	120	100	114	91
DCD pmp	2,9	4,1	4,8	6,0	6,7	7,3	6,1	7,0	5,5
Number of kidneys recovered from DCD	95	131	149	189	219	236	196	223	169
Number of livers recovered from DCD	0	2	6	14	13	24	16	16	30
Number of lungs recovered from DCD	0	0	0	0	0	8	8	10	22
Number of pancreas recovered from DCD	0	1	1	0	0	5	10	23	30
Organs recovered per DCD	2,07	2,03	2,05	2,11	2,11	2,28	2,30	2,39	2,76
Number of kidneys transplanted from DCD	80	108	123	158	180	191	168	170	141
Number of livers transplanted from DCD	0	2	6	13	10	22	14	16	30
Number of lungs transplanted from DCD	0	0	0	0	0	8	8	9	21
Number of pancreas transplanted from DCD	0	0	0	0	0	1	0	0	4
Organs transplanted per DCD	1,74	1,67	1,70	1,78	1,73	1,85	1,90	1,71	2,15

Table 3. continued

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Spain									
Population	40	41	42	43	43	44	45	45	46
Number of DBD	1313	1317	1360	1387	1424	1476	1433	1462	1500
DBD pmp	33,1	32,0	32,5	32,5	33,0	33,5	32,1	32,3	32,5
Organs recovered per DBD	3,23	3,33	3,32	3,31	3,26	3,29	3,29	3,20	3,26
Organs transplanted per DBD	2,59	2,66	2,65	2,62	2,54	2,55	2,55	2,47	2,47
Number of DCD	32	18	49	56	71	70	76	88	77
DCD pmp	0,8	0,4	1,2	1,3	1,6	1,6	1,7	1,9	1,7
Number of kidneys recovered from DCD	64	36	98	110	140	136	147	176	154
Number of livers recovered from DCD	4	6	6	6	11	13	20	29	37
Number of lungs recovered from DCD	0	0	2	8	27	21	14	6	12
Number of pancreas recovered from DCD	0	0	0	0	0	0	0	0	0
Organs recovered per DCD	2,13	2,33	2,16	2,20	2,49	2,43	2,38	2,40	2,64
Number of kidneys transplanted from DCD	42	24	71	83	93	76	100	106	105
Number of livers transplanted from DCD	3	2	3	3	5	6	11	17	14
Number of lungs transplanted from DCD	0	0	2	7	12	9	10	4	10
Number of pancreas transplanted from DCD	0	0	0	0	0	0	0	0	0
Organs transplanted per DCD	1,41	1,44	1,55	1,64	1,54	1,30	1,59	1,44	1,68
United Kingdom									
Population	59,1	59,1	59,0	59,0	59,0	59,0	60,2	60,2	60,2
Number of DBD	739	737	717	643	726	630	633	607	621
DBD pmp	12,5	12,5	12,2	10,9	12,3	10,7	10,5	10,1	10,3
Organs recovered per DBD	3,41	3,46	3,47	3,63	3,58	3,70	3,76	3,95	3,96
Organs transplanted per DBD	3,20	3,26	3,20	3,40	3,29	3,37	3,46	3,67	3,50
Number of DCD	38	41	53	66	88	123	146	186	264
DCD pmp	0,6	0,7	0,9	1,1	1,5	2,1	2,4	3,1	4,4
Number of kidneys recovered from DCD	73	77	99	125	163	233	283	360	504
Number of livers recovered from DCD	1	6	19	21	39	41	44	72	117
Number of lungs recovered from DCD	0	0	1	2	4	2	3	8	28
Number of pancreas recovered from DCD	0	0	0	0	1	1	4	37	70
Organs recovered per DCD	1,95	2,02	2,25	2,24	2,35	2,25	2,29	2,56	2,72
Number of kidneys transplanted from DCD	48	56	86	115	149	206	266	320	456
Number of livers transplanted from DCD	0	4	13	13	28	28	29	55	86
Number of lungs transplanted from DCD	0	0	1	2	4	2	3	6	22
Number of pancreas transplanted from DCD	0	0	0	0	0	1	3	28	35
Organs transplanted per DCD	1,26	1,46	1,89	1,97	2,06	1,93	2,06	2,20	2,27

DBD, donation after brain death; DCD, donation after circulatory death; pmp, per million population.

Spain, and 44.7% in France in 2008, and consistently higher for DCD compared with DBD in all countries.

Short-term results of transplantation from DCD (controlled versus uncontrolled)

Information was obtained on the short-term outcomes of 3329 patients receiving solid organ transplants from DCD during January 1st 2000 to December 31st 2007. Data were available from 86.8% of the transplants performed during the corresponding period.

Short-term results of transplantation were provided for 2992 recipients of kidneys transplanted from DCD (2343 from controlled versus 649 from uncontrolled DCD). Information is summarized in Fig. 4. The incidence of PNF was 6.4% vs. 5% for recipients transplanted from uncontrolled versus controlled DCD (P = NS). However, the incidence of DGF was significantly higher in kidney recipients transplanted from uncontrolled DCD (75.7% vs. 50.2%; $P < 0.001$), who had an estimated three times higher risk of developing DGF compared with those transplanted from controlled DCD (odds ratio = 3.09; $P < 0.001$). In spite of this difference, 1 year death-censored graft survival was significantly better for patients transplanted from uncontrolled DCD. No statistically significant differences were found in terms of 1 year not censored for death graft survival and 1 year patient survival between the groups.

Short-term results of liver transplantation from DCD were collected for 257 recipients of livers from controlled DCD versus 27 from uncontrolled DCD. No statistically significant differences were found between the two groups

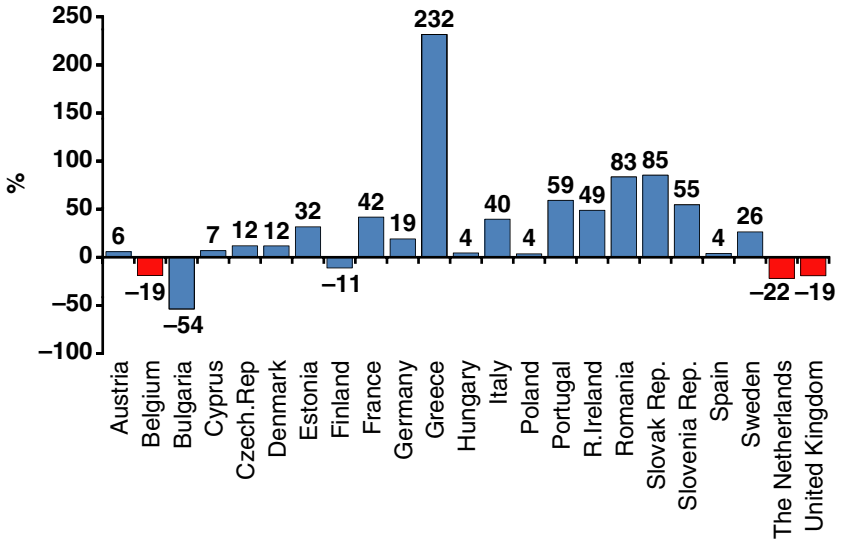

Figure 3 Change (as percentage) in donation after brain death (DBD) activity for 2009 compared with 2000 in Eutropean countries. Red columns highlight those countries with a predominant and outstanding type III donation after circulatory death (DCD) activity.

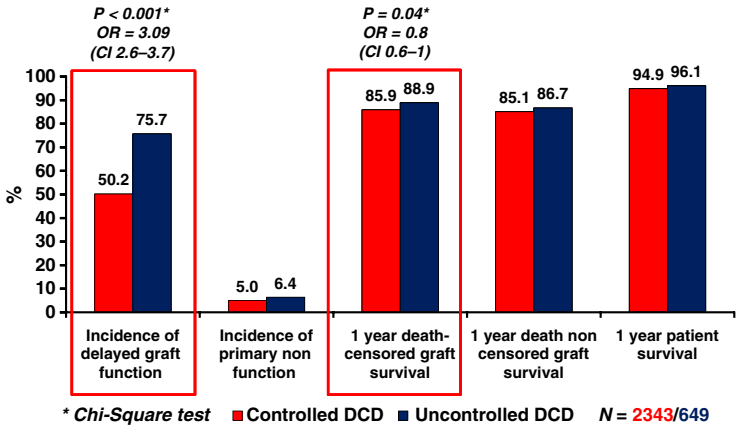

Figure 4 Short-term results with kidney transplantation from controlled versus uncontrolled donation after circulatory death (DCD).

in terms of 1 year death-censored graft survival (79.4% vs. 88.9%), 1 year not censored for death graft survival (76.4% vs. 74.1%) and 1 year patient survival (86.4% vs. 77.8%). Finally, no significant differences were observed in 1 year death censored graft survival (91.7% vs. 62.1%), 1 year non censored for death graft survival (79.2% vs. 62.1%) and 1 year patient survival (79.2% vs. 62.1%) for 24 lung recipients transplanted from controlled DCD versus 29 transplanted from uncontrolled DCD.

Discussion

DCD is now becoming an accepted medical practice in many countries following a period during which the procedure was practically abandoned because of poor results with organs transplanted from these donors. DCD has been progressively increasing in the US and now constitutes the main source of organs from deceased donors in some Asian countries, as Japan.The initiation of a DCD program is now being evaluated in different countries [12]. The present study makes evident the variable situation of DCD in the European setting.

Although increasingly accepted and used in Europe, DCD is still limited to a few countries. Out of the 10 countries with any reported DCD activity during the period of study, only five have a prominent DCD activity. Regarding the type of DCD, controlled DCD (type III of the Maastricht categories) is predominant in Europe. However, countries as France and Spain have embarked on uncontrolled DCD programs, which have been progressively consolidating. Variations in the type of DCD in place might be the result of differences in end of life practices between the countries [13], possibly resulting from the specific cultural, technical, and legal approaches to death and which determine different fears about the trust of the public in the donation system [14,15]. Of the 27 evaluated countries, seven are not planning to start a DCD program, and 10 are planning to start. In six cases,

starting such a program would require a modification of the law, since legal provisions in place do not allow organ recovery from persons determined death by circulatory and respiratory criteria. In these countries, only category IV would be therefore allowed. The limited activity of DCD in Europe makes evident the inherent difficulties in starting and consolidating a program of this nature. Legal obstacles have been already pointed out. Ethical issues are still under discussion in the international fora and evidently vary depending on the controlled or uncontrolled nature of DCD. Organizational issues and lack of technical expertise are also seen as the main obstacle in 12 countries with no DCD activity in our survey.

In our study, while DCD is increasing, DBD is progressively decreasing over time in Belgium, the Netherlands and the United Kingdom, those countries with a predominant and outstanding type III DCD activity. It has been suggested that a decline in DBD in these countries might reflect changes in patterns of neurocritical care determining a decrease in the potential of DBD [16,17]. However, DBD has increased in most of the European countries during the same period of time. This observation raises the possibility that, in some cases, the availability of a type III DCD program might influence end of life practices, in that persons with a devastating brain injury potentially evolving to a situation of brain death could be prematurely converted into DCD after the withdrawal of life-sustaining therapy, a theory still under debate [18,19]. However, uncontrolled DCD seems to be a clear additional source of organs for transplantation in France and Spain. If a negative impact of controlled DCD on DBD is a reality, subsequent implications are easy to deduce. As shown in our study, the degree of utilization of DCD, in terms of ORPD and OTPD, is lower than that for DBD and hence a negative impact on transplantation practices might result, especially for organs such as hearts. However, transplantation of hearts from DCD is now also being considered, but this requires a critical discussion and review of the conditions for determining death by means of circulatory and respiratory criteria [20,21]. Nevertheless, it is important to attain to the reality of many countries in which the limited availaiblity of intensive care resources might make DCD the only or the main possibility of transplantation practices from deceased donors to occur and the way of progressing to self-sufficiency in transplantation, a recent call from the *World Health Organization* and the *Istanbul Declaration on Organ Trafficking and Transplant Tourism* [22,23].

Therefore, DCD must progress in two different directions: recovery and transplantation of more and different types of organs and improvement of outomes. For the first, our study makes evident that most countries with DCD programs are progressively increasing the number and type of organs recovered and transplanted from these donors. However, the overall discard rate of organs once recovered is high, compared with DBD. Discard rates of DCD organs are higher in France and Spain compared with countries with a predominant type III DCD activity, which could suggest that uncontrolled DCD might be related to a higher discard rate of organs. This high discard rate has been described in center-based experiences [24]. Discard rates for DBD are also different between the evaluated countries. This indicator is not stratified per donor age, which might explain these differences referable to the current disparity in the use of organs from aged donors between European countries [25].

Regarding the post-transplant results, we have not found a statistically significant difference regarding the incidence of PNF between kidney recipients transplanted from controlled versus uncontrolled DCD, similar to what has been described elsewhere [26–29]. However, the incidence of DGF is significantly higher in recipients transplanted from uncontrolled DCD and similar to that reported in the literature for both types of DCD [26–33]. In spite of a higher incidence of DGF, 1 year graft survival is similar in both groups and even higher for recipients of uncontrolled DCD kidneys. This finding is consistent with studies demonstrating that DGF does not significantly impact graft survival in kidney recipients transplanted from DCD [27,29,30]. Reasons for the differences in graft survival between the two groups are a matter of future research, since we lacked the necessary information for a more indepth analysis, as clinical and demographic data of donors and recipients or specific details of protocols for organ recovery and preservation or immunosuppression therapies. We can conclude that this overall analysis provides evidence that results of kidney transplantation from DCD are appropriate and comparable to those described in the UNOS or the CTS registries [34,35].

Short-term outcomes of liver recipients from DCD seem encouraging in our experience. However, results are worser than those described for liver recipients in available registries [34] and as consistently reported in the literature [24,36–40]. Ischemic cholangiopathy and diminished graft survival compared with liver transplants from DBD need to be confronted and require further research. Although promising, results of lung transplantation from DCD still seem to be poorer than those described in currently available registries [41]. However, our results in terms of liver and lung transplantation should be interpreted with caution because of the limited number of cases, especially for recipients transplanted from uncontrolled DCD, and the mixture of protocols and criteria applied. Results provided by highly experienced centers seem promising both for liver and lung

transplantation and their work is essential for progress in this field [42–45]. Notably, we did not find a statistically significant difference on the outcome of liver and lung transplantation between recipients transplanted from controlled versus uncontrolled DCD. However, the lack of statistical significance might be ascribable to the relatively small number of cases included in our series. Further research with an increased sample size would be needed to evaluate the relevance of the aforementioned differences.

In conclusion, DCD is increasingly accepted and used in Europe, but still limited to a few countries. Legal barriers to DCD should be overcome and multidisciplinary fora to discuss the ethical and technical obstacles to this type of donation should be fostered in a European common framework of understanding. Controlled DCD seems to run in parallel with a decline in DBD and it is essential to ensure that the availability of a DCD program does not result in DBD donors becoming DCD donors. The utilization of DCD needs to be expanded, because of organ shortage and the necessity to adapt donation and transplantation practices to advances in critical care and to local realities where DCD might appear as an essential element in striving to achieve self-sufficiency. Uncontrolled DCD, although requiring more complex organization, provides an opportunity of significantly expanding the pool of potential deceased organ donors. The expansion of DCD must occur under the guidance of highly experienced centers and countries. Results of transplantation from DCD are encouraging, although efforts to improve the results is needed. European countries should be ready to admit DCD as a reality for the immediate future.

Authorship

All authors have participated in the design of the study and in the data collection. BD-G, BH-K and RVL: in charge of the data analysis and preparation of the manuscript.

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