ORIGINAL ARTICLE

Safely Expanding the Liver Donor Pool by Utilization of Organs from Donation after Circulatory Death with Comparable Results to Donation After Brain Death, a Large Single-Center Experience

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Abstract

Background Useof livers donated after circulatory death (DCD) is one way to expand the donor pool. Our center has aggressively incorporated use of DCD liver grafts into practice. We examined our center and national outcomes as well as national DCD liver utilization.

Methods Liver transplants performed at our center and nationally from 11/2016 through 9/2020 were compared. Primary outcomes were patient and graft survival, and national DCD liver utilization.

Results For our center, DCD and donation after brain death (DBD) donors were similar except DCD donors were younger (37 vs 40 years; $p < 0.05$). Recipient Na-MELD (20 vs 24; $p < 0.0001$) and cold ischemia time (4.63 vs 5.18 h; $p < 0.05$) were lower in DCD recipients. There were no significant differences in 1-year patient and graft survival between DCD and DBD liver recipients locally. Nationally, there was a difference in 1-year graft survival year (89.4% vs 92.4%, $p < 0.0001$) but patient survival was similar between groups. The proportion of DCD livers recovered and transplanted widely varied among organ procurement organizations (OPOs) and transplant centers.

Conclusions Similar outcomes for DCD and DBD liver recipients should encourage centers and OPOs nationwide to expand utilization of DCD livers.

Keywords DCD liver transplant · Liver donors · Liver transplant outcomes · Organ utilization

Introduction

Liver transplantation is the optimal treatment for end-stage liver disease. However, the critical limiting factor is supply of donor allografts resulting in death on the waitlist. These deaths reflect a shortage of donor organs that will only worsen over the coming years, with an aging population and an increased prevalence of liver disease requiring transplantation [1, 2]. Livers recovered from donation after brain death (DBD) have been long favored over livers recovered after circulatory death (DCD) due to their decreased warm ischemic time and biliary complications. One way to expand the donor pool is the use of DCD organs. To decrease waitlist mortality and keep up with the increasing demand for liver transplantation (LT), transplant centers must reevaluate how they select organ donors in order to expand their donor pools.

DCD livers historically have been considered marginal to DBD livers due to early reports of poor patient and graft outcomes secondary to primary non-function, ischemic cholangiopathy, and biliary complications compared to DBD donor livers [3, 4]. However, more recent data have shown improved graft and patient survival for DCD liver transplants, as well as fewer postoperative and biliary complications than initially reported [5–8]. A study of Organ

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Procurement and Transplantation Network (OPTN) data from 2013 to 2017 revealed that about half of all DCD liver transplants in the USA were performed at only 11 transplant centers, suggesting that many centers have yet to adopt DCD liver transplantation as a standard practice [9]. Utilization of DCD livers varies among centers due to a variety of factors including experience, potential increased costs, and most importantly concern for patient outcomes. In the past few years, our center has aggressively integrated DCD liver transplantation to augment the donor pool for our patients. We sought to compare our experience with the first 100 DCD liver transplants to DBD liver recipients and examine national trends and opportunities to expand the donor pool nationally.

Methods

This study was approved by The Ohio State University Institutional Review Board (#2019H0190); donor and recipient data were de-identified for data analysis. This retrospective study included 418 adult patients who underwent LT at our center from November 2016 until September 2020. One hundred patients received livers from DCD donors, and 318 from DBD donors that met criteria for this analysis. Exclusion criteria included pediatric patients, living donor liver recipients, re-transplanted patients, and multi-organ transplants. We analyzed demographic variables of donors and recipients, and outcomes during the 12 months following transplantation.

DCD livers in our study were obtained from controlled DCD (Maastricht type III) using the rapid technique for organ recovery. All donors received intravenous administration of heparin (30,000 units) prior to withdrawal of life support. The infrarenal aorta was rapidly accessed, cannulated, and flushed with pressurized preservation solution, followed by clamping of either supra-celiac or thoracic aorta, and venting of the vena cava. Following donor hepatectomy, the liver was flushed with preservation solution on the back-table through the portal vein prior to packaging and transport.

For DCD liver recovery, our center limits the functional warm ischemia time (WIT) to ≤ 30 min, starting from agonal phase (defined as systolic blood pressure (SBP) < 80 mmHg or SpO2 < 80%) until the start of cold ischemia time (CIT), including the mandatory "no touch" wait time ranging from 2 to 5 min implemented by the local organ procurement organization (OPO) to assure no autoresuscitation has occurred. Although our center permits CIT up to 12 h for DBD donors, we strive to limit CIT to less than 6 h for DCD donors. Efforts are made to avoid complicated recipients (i.e., re-transplants, vascular concerns, and multiple prior surgeries) for DCD liver allografts to minimize the

CIT. DCD allografts were avoided in recipients with portal venous thrombosis, extensive prior upper abdominal surgery, and those requiring re-transplantation. Our center does not perform any liver biopsies at the time of recovery to limit CIT.

The implantation did not vary between DCD and DBD recipients and involved side-to-side cavocavostomy and reconstruction of the portal vein, followed by a blood flush. Hepatic artery reconstruction was proceeded by an infusion of tissue plasminogen activator (tPA), 2 mg, through the hepatic artery for DCD livers. The biliary tract was reconstructed with either a duct-to-duct or Roux-en-Y anastomosis.

Postoperative immunosuppression was the same in both DCD and DBD recipients and included tacrolimus, mycophenolate mofetil, and corticosteroids, which were tapered off over 2 weeks. In some patients who were expected to have significant acute kidney injury after transplant, tacrolimus initiation was delayed and often basiliximab was given for a total of two doses.

We assessed national DCD utilization as a percent of total transplant performed at a center by year and for the entire time frame. This was also done for OPOs, counting DCD livers transplanted as a percent of total livers transplanted. There were 135 centers, 58 OPOs, and 24,415 total LTs during the time frame. The national mean for overall proportion for DCD use was calculated for transplant centers and OPOs. The 95% control limits were determined and centers and OPOs utilizing over or under the 95% control limits were considered super-performers or under performers, respectively. Only centers and OPOs performing 20 or more LTs within the time frame analyzed were included in the national center and OPO analysis.

Statistical Analysis

For analysis of our center data, DCD and DBD groups were compared using a two-sample *t*-test for continuous variables and Fisher's exact test for categorical variables. We compared 24 h liver enzymes, alkaline phosphatase, international normalized ratio (INR), lactate, and creatinine. We compared 72 h liver enzymes as the enzymes in a functioning liver decrease by 72 h. We also included 1 year alkaline phosphatase and bilirubin as a laboratory surrogate comparison for biliary issues. Continuous variables that were normally distributed mean and standard deviations were used and if not normally distributed medians and interquartile ranges were used. For continuous variables being significantly affected by a non-normal distribution, a Mann–Whitney *U* test was used. For both center and national data, biologic model of end-stage liver disease sodium (MELD-NA) scores was used not exception scores. The primary outcome measures were 1-year graft and patient survival determined

by the Kaplan–Meier method and compared using a log-rank test. Secondary outcomes included early graft dysfunction (EAD), primary non-function (PNF), hepatic artery thrombosis (HAT), re-transplantation, and biliary complications (either anastomotic or non-anastomotic strictures requiring an intervention). EAD was defined as post-transplant aspartate aminotransferase (AST) or alanine aminotransferase (ALT) greater than 2000 U/L in the first 7 days, day 7 total bilirubin greater than or equal to 10 mg/dL, or day 7 international normalized ratio (INR) greater than or equal to 1.6 [10].

For analysis of national data, Standard Transplant Analysis and Research (STAR) files were obtained through OPTN for all adult patients (greater than or equal to 18 years old) who received a primary deceased donor liver transplant alone from the same time period. Comprehensive data on EAD, primary non-function, HAT, re-transplantation, and biliary complications was not complete for analysis due to many missing values because they are not mandated fields for input. Patients were identified as having received DCD or DBD livers. Graft and patient survival was determined by the Kaplan–Meier method and compared using a log-rank test. Comparisons between our center and national means and proportions were based on z-tests. Centers and OPOs that performed or recovered at least 20 liver transplants during the study period were included in the national DCD utilization analysis. Center and OPO performance analysis was determined by 95% control limits based on the binomial distribution. Centers and OPOs performing above or below the 95% confidence limits were defined as super-performers or under-performers respectively. A p-value < 0.05 was considered to be significant for all statistical tests. All statistical analyses were generated using SAS (9.4 TS1M3, Cary, NC) on the 64-bit platform for Microsoft Windows.

Results

Donor and Recipient Characteristics

Our center performed 100 DCD liver transplants and 318 DBD liver transplants that met the criteria for inclusion. Nationally, 2,184 DCD and 22,231 DBD liver transplants were performed during the same time period and meeting the same inclusion criteria. Donor characteristics (Table 1) for our center showed that DCD donors were significantly younger than DBD donors (37 ± 11.4 vs 40 ± 14.5 years, $p < 0.05$) which was similar to national data (Table 2). Donor BMI and liver enzymes did not differ between the two groups. Donor characteristics were similar between our center and national data, except we used a higher proportion of hepatitis C virus (HCV) nucleic acid testing (NAT)–positive donors for both DBD and DCD. DCD and

DBD recipients were similar in age and BMI, but DCD recipients had a lower biologic MELD-NA score compared to DBD recipients (20 ± 5.7 vs 24 ± 9.1; $p < 0.0001$) and shorter CIT (4.63 ± 1.3 vs 5.18 ± 2.05 h; $p = 0.0018$), which was similar to national DCD MELD-NA score (19 ± 7.9 vs 24 ± 11.1; $p < 0.001$) and CIT (5.52 ± 1.6 vs 5.93 ± 2.1; $p < 0.0001$).

Outcomes After Liver Transplantation

One-year patient and graft survival was not statistically different between DCD and DBD liver recipients at our center (Fig. 1). Nationally, there was no difference in patient survival but graft survival was significantly different at 1 year (89.4% vs 92.4%, $p < 0.0001$; Fig. 1). Early allograft dysfunction for our center was more frequent in DCD recipients compared to DBD (45% vs 17%, $p < 0.01$). We were unable to compare EAD at the national level as the granularity of the OPTN data does not capture the necessary variables to determine EAD. The incidence of HAT, PNF, and re-transplantation were all similar at one year (Table 3). Alkaline phosphatase and bilirubin were also similar at one year (Table 3). Length of stay (LOS) at our center were similar ($p = 0.93$) for DCD (12 ± 12.6) and DBD recipients (11 ± 14.3).

Our center has a low threshold for endoscopic retrograde cholangiopancreatography (ERCP) as demonstrated by similar rates of intervention in the first year of transplant for both groups, 27% for DCD vs 33% for DBD ($p = 0.27$; Table 4). On review of the ERCPs and abdominal imaging, there were two cases of ischemic cholangiopathy in both groups, which was not statistically significant. One patient in the DBD group required re-transplant and was the only graft loss due to biliary issues in 1 year. The other three patients with ischemic cholangiopathy did not require re-transplant. Bile leak and bile strictures were also similar between groups.

National DCD Utilization

From September 1, 2017, through August 31, 2020, 9.3% (1814/19562) of LTs were performed from DCD donors nationally using the same exclusions as our local data set. Out of 134 liver transplant centers, 114 were included in analysis. There were 23 super-performers, 50 on-par performers, and 41 under-performers (Fig. 2). The distribution of center utilization is heterogeneous with the super-performers cohort having broad representation from small, medium, and large centers. A substantial number of centers (36%) fall into the underperforming category. Recovery of DCD livers that were transplanted from each OPO for the time frame is depicted in Fig. 3. Of the 58 OPOs, there were 13 super-performers, 33 on-par performers, and 12

Table 1 Ohio State University donor and recipient demographics

Participant	Parameter	DBD $N=318$		DCD $N=100$		p-value
		N	Mean (SD)	N	Mean (SD)	
Donor	Age	316	40 (14.5)	99	37 (11.4)	**0.0126**
	BMI	315	29.32 (7.769)	99	29.43 (8.154)	0.9035
	ALT*	316	48 (24–115)	99	46 (30–86)	0.7712
	AST*	316	43 (25–93)	99	54 (38–80)	0.0652
	Bilirubin	316	0.8 (0.77)	99	0.6 (0.47)	**0.0122**
	INR*	316	1.3 (1.1–1.4)	99	1.2 (1.1–1.4)	**0.0174**
	Serum creatinine	316	2.0 (1.93)	99	1.3 (1.58)	**0.0009**
		Count/total (%)		**Count/total (%)**		
	Ethnicity (White)	254/316 (80%)		92/99 (93%)		**0.0030**
	Sex (male)	190/316 (60%)		61/99 (62%)		0.8148
	HCV Ab serology	69/312 (22%)		17/98 (17%)		0.3934
	HCV NAT	47/316 (15%)		17/99 (17%)		0.6325
Recipient		*N*	**Mean (SD)**	*N*	**Mean (SD)**	
	Age	318	55 (11.0)	100	57 (10.2)	0.1477
	BMI	318	30.39 (6.720)	100	30.81 (6.478)	0.5741
	MELD-NA	317	24 (9.1)	98	20 (5.7)	**<.0001**
		Count/total (%)		**Count/total (%)**		
	Ethnicity (White)	283/318 (89%)		92/100 (92%)		0.4545
	Sex (male)	195/318 (61%)		62/100 (62%)		1.0000
	Prior abdominal surgery	177/318 (56%)		45/100 (45%)		0.0668
	Pre-transplant PVT	49/316 (16%)		11/99 (11%)		0.3278

*Due to skewness significantly affecting results, medians and interquartile range are reported

Abbreviations: *Ab*, antibody; *ALT*, alanine transaminase; *AST*, aspartate transaminase; *BMI*, body mass index; *DBD*, donation after brain death; *DCD*, donation after circulatory death; *HCV*, hepatitis C virus; *INR*, international normalized ratio; *MELD-NA*, model of end-stage liver disease sodium; *NAT*, nucleic acid test; *OSU*, Ohio State University; *PVT*, portal vein thrombosis; *SD*, standard deviation

under-performers. Thirty or 52% of the OPOs performed less than 9.3% of DCD liver recoveries.

Discussion

From November 2016 until September 2020, our center transplanted 100 DCD livers, which comprised 24% of our total deceased-donor liver transplants. Results from our experience suggest comparable graft and recipient outcomes from DCD and DBD grafts with appropriate donor-recipient matching. We have demonstrated excellent outcomes using DCD liver allografts in recipients with a median MELD of 20. However, DCD livers only accounted for 9% of deceased-donor grafts nationally with many transplant centers having yet to adopt standard usage of DCD grafts.

DCD liver transplantation has improved significantly since initial implementation in the USA. An analysis of the UNOS database from 1996 to 2003 revealed inferior graft survival of DCD grafts with 1- and 3-year survival 71% and 60% compared to 80% and 72% for DBD grafts [3]. Over the

past 10 years, many centers are now reporting similar graft and patient survival rates among DCD and DBD donors [8, 11, 12]. In our experience with 100 DCD liver grafts, we found no significant difference between patient and graft survival at 1 year compared to DBD grafts. Additionally, our analysis of the UNOS database from the same time period reports no significant difference in overall patient survival but graft survival for DCD livers was significantly lower at 1 year post-transplant. This is likely secondary to the biliary complications, specifically ischemic cholangiopathy that is often more frequently seen in DCD liver grafts. This could also be representative of center experience with DCD livers for transplant. There are a sizeable number of centers where DCD livers represent a small fraction of overall transplants thus limiting experience with appropriate donor and recipient selection.

Extensive data from multiple centers across the globe have described increased biliary complications and ischemic cholangiopathy in DCD recipients [13–16]. Ischemic cholangiopathy is often a devastating complication resulting in multiple readmissions, invasive biliary procedures, and

Table 2 Ohio State University vs national data

Participant	Parameter	DBD			DCD		
		OSU Mean (SD)	National Mean (SD)	*p*-value	OSU Mean (SD)	National Mean (SD)	*p*-value
Donor	Age	40 (14.5)	43 (16.2)	**0.0095**	37 (11.4)	37 (13.3)	0.7039
	BMI	29.32 (7.769)	28.5 (6.86)	**0.0249**	29.43 (7.769)	27.7 (6.42)	**0.0064**
		OSU %	**National %**		**OSU %**	**National %**	
	HCV NAT	15	6.1	**< .0001**	17	4.1	**< .0001**
	Race (White)	80	63	**< .0001**	93	76	**< .0001**
	Sex (male)	60	60	1.0000	62	67	0.2679
Recipient		**OSU Mean (SD)**	**National Mean (SD)**		**OSU Mean (SD)**	**National Mean (SD)**	
	Age	55 (11.0)	56 (11.3)	0.6197	57 (10.2)	58 (9.6)	0.6580
	MELD-NA	24 (9.1)	24 (11.1)	0.3254	20 (5.7)	19 (7.9)	0.0629
	LOS	11 (14.3)	15 (19.6)	**0.0042**	12 (12.6)	12 (15.1)	0.7337
	CIT	5.18 (2.053)	5.93 (2.120)	**< .0001**	4.63 (2.053)	5.52 (1.582)	**< .0001**
		OSU %	**National %**		**OSU %**	**National %**	
	Prior abdominal surgery	56	47	**0.0033**	45	48	0.5992
	Pre-transplant PVT	16	14	0.6096	11	15	0.3790
	Race (White)	89	71	**< .0001**	92	77	**0.0001**
	Sex (male)	61	65	0.1414	62	68	0.2249

Abbreviations: *BMI*, body mass index; *CIT*, cold ischemia time; *DBD*, donation after brain death; *DCD*, donation after circulatory death; *HCV*, hepatitis C virus; *LOS*, length of stay; *MELD-NA*, model of end-stage liver disease sodium; *NAT*, nucleic acid test; *OSU*, Ohio State University; *PVT*, portal vein thrombosis; *SD*, standard deviation

need for re-transplantation, as well as poorer patient quality of life [13, 14, 17]. However, our center data did not demonstrate an increased risk of biliary complications in DCD recipients compared to DBD recipients. This has been published by other centers, including the University of Toronto that reported similar rates of biliary complications, 5.2% in DCD grafts versus 4.8% DBD grafts with comparable 10-year patient and graft survival rates [11]. Several studies describe improvement in graft survival and decreased biliary complications over time, which may be a result of center experience with DCD donation [5, 12, 18, 19]. One limitation to our study is that there is no routine protocol in following patients that receive a DCD liver graft for developing ischemic cholangiopathy. One theory is that early identification of biliary issues allows for earlier intervention that may lead to prolonged graft survival. Further studies are required to evaluate the role of routine screening with long-term outcomes and cost–benefit analysis.

After 10 years of experience, a center in Ontario achieved significantly lower WIT and decreased rates of ischemic cholangiopathy [18]. Risk factors for biliary complications and graft loss include longer donor WIT, older donor age, higher donor BMI, longer CIT, and higher recipient MELD [5, 19]. Proficiency in procurement protocols decreases both warm and cold ischemia times which have been associated with biliary complications. Judicious donor and recipient selection criteria are critical to having DCD LT outcomes

comparable to DBD. With the current allocation, high MELD patients receive priority as they are at the "top of the list." DCD livers offer recipients with lower MELD scores, who are more compensated, an opportunity to receive a liver transplant. Since we have fully integrated DCD organs into our practice, we have gained experience in donor selection and utilization of DCD livers as well as identifying DCD recipient candidates. As demonstrated by higher rates of EAD after DCD liver transplant, it is critical to identify recipients that can tolerate the early dysfunction to have successful outcomes. In addition to center experience and proficiency in the technical aspects, donor and recipient matching is vital to the improvement of DCD LT outcomes.

We recognize that utilization of DCD organs are more time and resource intensive than for DBD organs. Up to half of all DCD procurements are unsuccessful as donors fail to progress to asystole or WIT exceeds 30 min. A study by the University of Michigan showed that 218 more miles was traveled for each successful DCD liver compared to successful DBD livers, which included miles traveled to donors for both DCD and DBD that were unsuccessful [20]. These increased travel and opportunity costs are undertaken by the transplant center, which may discourage some centers from aggressively pursuing DCD donors. Furthermore, potentially higher rates of graft failure and biliary complications can result in increased costs to the transplant center [16, 21, 22]. However, we demonstrate equivalent outcomes and similar
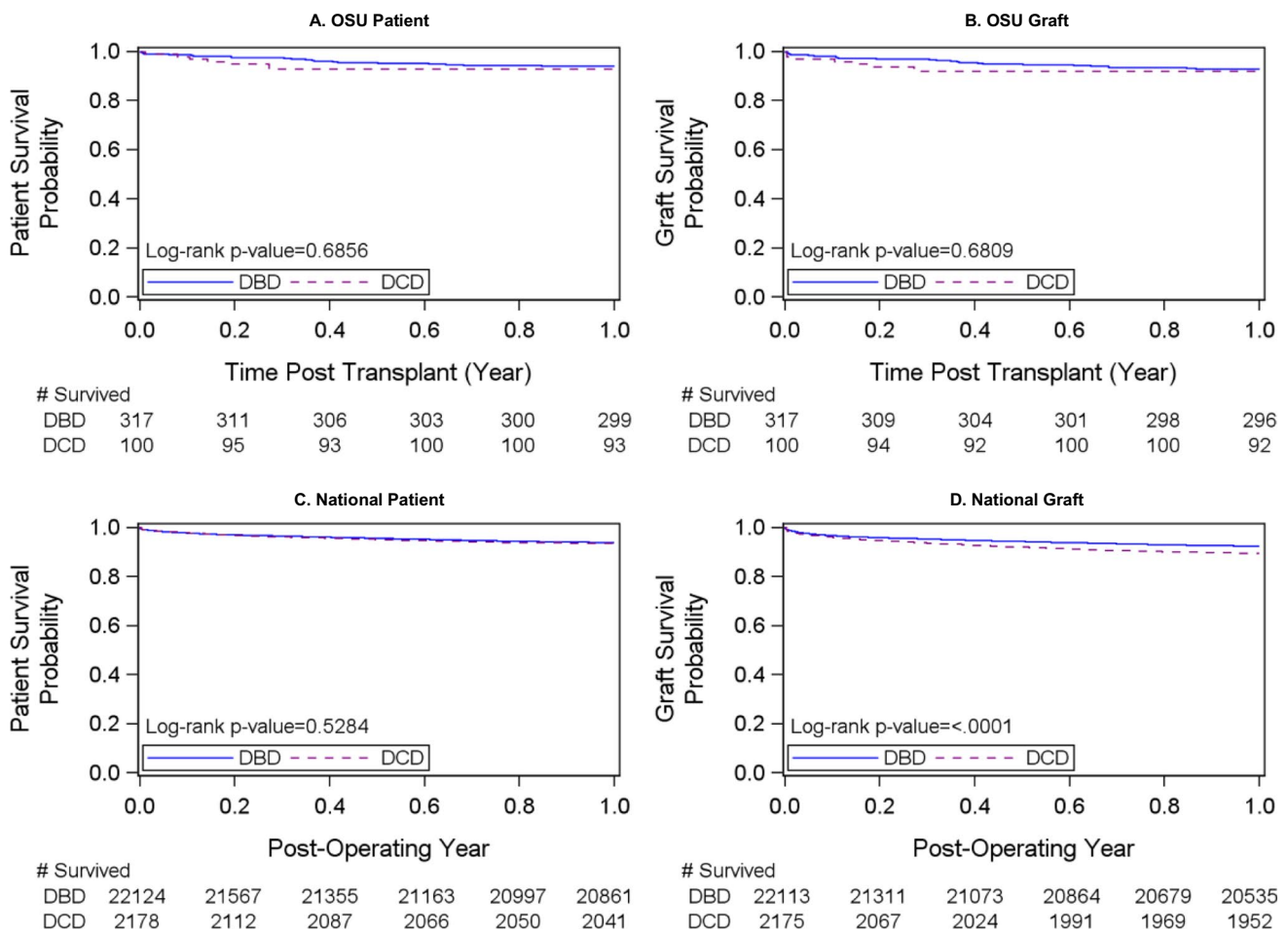
Fig. 1 Donation after circulatory death (DCD) liver transplant: 1-year Kaplan–Meier curves of Ohio State University (OSU) patient survival (**a**), OSU graft survival (**b**), national patient survival (**c**), national graft survival (**d**)

complications between DCD and DBD livers and that more frequent utilization of DCD liver grafts will lead to more transplants and ultimately result in a net gain in patients transplanted. As our experience has grown, we have had a lower threshold to fly out for recovery. Initially, surgical faculty accompanied transplant fellows for the DCD recovery. With the rapid adoption and volume at our center, fellows now perform the vast majority of recoveries. During the COVID-19 pandemic, we allowed local recovery for several recoveries with teams that have considerable experience with DCD recovery and use, which if adopted by more programs would be a way to offset some of the increased costs associated with DCD organ utilization.

While we and a number of other transplant centers have demonstrated good outcomes from DCD grafts, many other centers and OPOs have yet to adopt DCD liver transplantation as standard practice. The most recent year of experience from our center shows that over 30% of liver transplants performed are from DCD donors. However, DCD livers represent only 9% of all liver transplants nationally, and many

centers, both low and high volume, are underperforming. A separate analysis of the UNOS database found no clear driving factors for centers with high DCD liver utilization [9]. The highest utilizing centers exhibited more aggressive donor selection behavior overall, but this did not appear to be associated with waitlist mortality or geographic difference in organ availability. Similarly, many OPOs are underperforming which hinders the ability to expand the donor pool. We believe there is a missed opportunity for increasing the total number of liver transplants as well as OPO growth without decreasing activity or productivity from other centers and OPOs. Further investigation is necessary to elicit the motivating factors or barriers for transplant centers and OPOs to adopt wider usage of DCD LT.

Analyzing the contemporary use of DCD by transplant centers (as a percent of total transplants) highlights the opportunities many centers are missing. Of the 114 centers performing any DCD transplants, there were 41 under-performers, 23 super-performers, and 50 on par. If the under-performing centers were able to increase DCD use to the 9%

Table 3 Ohio State University recipient outcomes

Parameter	DBD $N=318$		DCD $N=100$		p-value
	N	Mean (SD)	N	Mean (SD)	
24 h ALT	317	548 (540.6)	100	915 (798.0)	**<.0001**
72 h ALT*	317	215 (123–419)	100	399 (248–611)	**0.0146**
24 h AST	317	879 (1544.9)	100	1693 (1712.5)	**<.0001**
72 h AST	317	282 (906.8)	100	247 (259.0)	**<.0001**
1 year ALP	300	111 (91.4)	95	109 (79.9)	0.8622
24 h bilirubin*	317	2.5 (1.4–4.7)	100	2.5 (1.5–3.8)	0.2100
1 year bilirubin	300	0.7 (1.36)	95	0.6 (0.33)	0.1141
24 h INR	316	1.5 (0.31)	100	1.5 (0.26)	0.5751
24 h lactate*	316	1.4 (1.0–2.1)	100	1.7 (1.1–2.3)	**0.0491**
24 h serum creatinine	317	1.61 (0.926)	100	1.46 (0.636)	0.0662
CIT	316	5.18 (2.053)	99	4.63 (1.298)	**0.0018**
ICU stay (days)	315	4 (11.1)	99	5 (11.2)	0.6376
LOS (days)	318	11 (14.3)	100	12 (12.6)	0.9307
OR time (min)	316	291 (80.7)	99	302 (75.0)	0.2397
WIT (min)	318	28 (9.4)	100	27 (5.8)	0.1666
	Count/total (%)		**Count/total (%)**		
EAD	53/318 (17%)		45/100 (45%)		**<.0001**
Need for reoperation (30 days)	57/318 (18%)		21/100 (21%)		0.5561
Readmission counts PO (0 to 30 days)	116/318 (36%)		34/100 (34%)		0.7203
Readmission counts PO (0 to 90 days)	156/318 (49%)		43/100 (43%)		0.3036
Readmission counts PO (0 to 180 days)	170/307 (55%)		47/95 (49%)		0.3467
HAT	3/318 (1%)		0/100 (0%)		1.0000
PNF	2/318 (1%)		2/100 (2%)		0.2431
Re-transplant	2/318 (1%)		2/100 (2%)		0.2431
1-year patient survival	299/318 (94%)		93/100 (93%)		0.6856
1-year graft survival	296/318 (93%)		92/100 (92%)		0.6809

*Due to skewness significantly affecting results, medians and IQR are reported

Abbreviations: *ALP*, alkaline phosphatase; *ALT*, alanine transaminase; *AST*, aspartate transaminase; *CIT*, cold ischemia time; DBD, donation after brain death; *DCD*, donation after circulatory death; *EAD*, early allograft dysfunction; *HAT*, hepatic artery thrombosis; *ICU*, intensive care unit; *LOS*, length of stay; *PNF*, primary non-function; *OSU*, Ohio State University; *OR*, operating room; *PO*, post operation; *SD*, standard deviation; *WIT*, warm ischemia time

Table 4 Ohio State University biliary interventions in the first year

Parameter	DBD $N=318$	DCD $N=100$	p-value
Recipient biliary intervention in first year	105/318 (33%)	27/100 (27%)	0.2702
Ischemic cholangiopathy	2/318 (0.6%)	2/100 (2%)	0.2431
Stricture	78/318 (24.5%)	22/100 (22%)	0.6874
Bile leak	17/318 (5.3%)	4/100 (4%)	0.7940

Abbreviations: *DBD*, donation after brain death; *DCD*, donation after circulatory death

national mean, this could considerably impact the number of patients transplanted. Of the 58 OPOs, there were 12 under-performers, 13 super-performers, and 33 on par. If the under performers could increase utilization of DCD donors, this could have a measurable impact on donor organ supply that could support further transplant center use. In a similar fashion, if the on-par performers could increase DCD donation to the super-performer level, the increase in donor livers could be significant.

The primary limitation of our study is that it is a single-center retrospective study, and we could not exclude potential bias. One could argue that increased experience with DCD LT and donor-recipient matching were confounding factors, but it also supports our argument that with increasing utilization of DCD liver grafts, there will be comparable outcomes to DBD liver grafts. Additionally, our study had a short follow-up time and we only reported patient and graft survival up to 1 year. With longer follow-up,
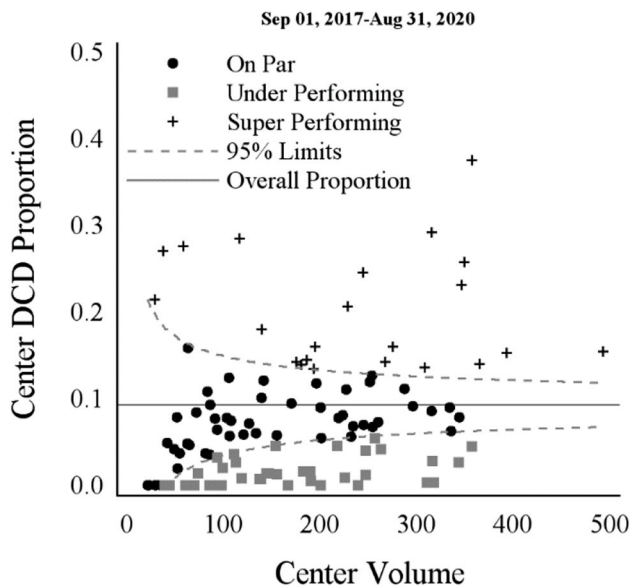
Fig. 2 Funnel plot of liver transplant centers that perform at least 20 liver transplants during the study period utilization of donation after circulatory death (DCD) liver grafts
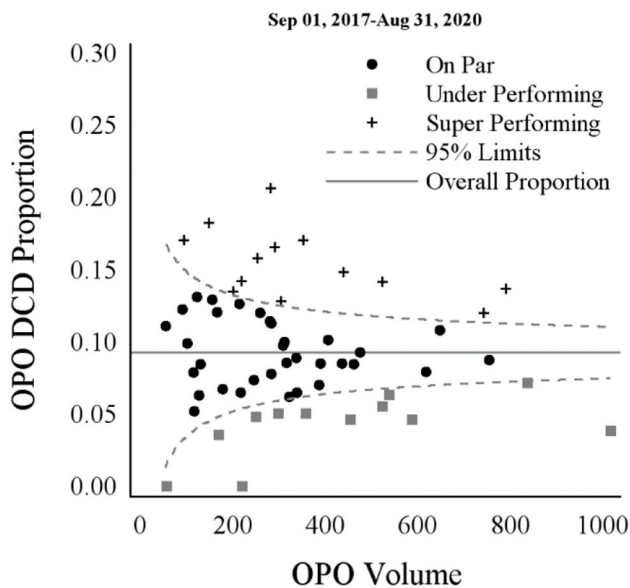

Fig. 3 Funnel plot of organ procurement organizations (OPOs) that perform at least 20 liver recoveries during the study period utilization of donation after circulatory death (DCD) liver grafts

we may find long-term differences between our DCD and DBD liver transplants. The time frame of data collection mostly included transplants that occurred prior to the implementation of the new liver allocation system in February of 2020. It is yet to be determined the impact of the new liver allocation policy on center donor utilization practices.

Conclusion

DCD livers can be used successfully with comparable outcomes to DBD LT in selected patients. We believe there is significant potential to increase the supply and utilization of DCD livers for transplantation. An aggressive adoption of this practice by under and on-par performing OPOs and transplant centers would have measurable impact on patient access to liver transplantation. With OPO and centers pursuing more DCD donors, there will be an overall net gain and expansion of the liver donor pool.

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