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The Association Between the Origin of the Donation After Circulatory Death Liver Recovery Team and Graft Survival: A National Study

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Background. Transplant centers have traditionally relied upon procurement teams from their own programs (transplant program procurement team [TPT]) to recover donation after circulatory death (DCD) livers and rarely use surgical procurement teams not affiliated with the recipient center (nontransplant program procurement team [NTPT]). However, in the era of wider geographic organ sharing, greater reliance on NTPTs is often necessary. **Methods.** We used national data to study the association between the origin of the donor procurement team (NTPT versus TPT) and the risk of DCD liver allograft failure. **Results.** Five hundred NTPT and 2257 TPT DCD transplants were identified: 1-y graft survival was 88.9 and 88.6%, respectively ($P = 0.962$). In a multivariable model, the origin of the procurement team was not associated with graft failure NTPT versus TPT (hazard ratio, 0.92; 95% confidence interval, 0.71-1.22; $P = 0.57$) but rather with known risks for DCD graft loss including donor age, degree of recipient illness, cold ischemic time, and retransplantation. The overall incidence of retransplantation and ischemic cholangiopathy as an indication for retransplantation were similar between NTPT and TPT. **Conclusions.** This data suggests that transplant centers may be able to safely use DCD livers recovered by local surgical teams.

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Donation after circulatory death (DCD) liver donation is an important modality to increase the supply of deceased donor organs. Historically, DCD liver allografts remain underutilized because of concerns of ischemic cholangiopathy (IC), primary nonfunction, and decreased graft survival.[1-5] However, contemporary data have demonstrated improvements in outcomes, which are now nearly equivalent to livers from donation after brain death, particularly among higher volume centers.[6-8]

Beyond concerns about graft outcomes, several additional barriers exist that contribute to the insufficient utilization of DCD livers. In general, there is dependence by transplant centers on DCD organ recovery by surgeons from their own program (transplant program procurement team [TPT]) and a reluctance to use surgeons not associated with the recipient center (nontransplant program procurement team [NTPT]). DCD liver recovery requires judgment, surgical skill to minimize the period from declaration of donor death to organ extraction, and timely communication to the recipient surgeon.[9] Additionally, a TPT-related surgeon can chaperone the organ during transport to ensure that the organ's cold ischemic time is minimized, as these discrete events influence graft outcomes.[10,11] Without prior knowledge of the surgeon's competence and their surgical recovery technique, centers may be reluctant to rely on a donor surgeon who is not affiliated with their transplant program.[9] This uncertainty is further compounded by variability in DCD protocols among donor hospitals and organ procurement organizations (OPOs).[12]

Underutilization of DCD donors by transplant centers is also a reflection of resource limitations. A large proportion of potential DCD donors do not progress to circulatory death,

but consume surgeon time and incur travel expense.[13,14] The result is hesitancy by transplant centers to send recovery teams when there is doubt as to the progression of the donor.[15-17] Whether greater utilization of a local procurement surgeon not affiliated with the transplant center (NTPT) could reduce resource consumption and encourage DCD utilization is unknown. Providing clarity on DCD liver transplant outcomes when a NTPT donor team recovers the liver may assuage concerns by recipient centers. A large US study found that graft outcomes were similar whether the donor surgeon was NTPT or TPT; however, DCD transplants were not specifically addressed.[18] More recently, a single-center analysis from a center with a large volume of DCD transplants indicated that graft outcomes as measured by survival, IC, and retransplant rates were similar among NTPT and TPT recovered organs.[19]

The question of whether DCD livers recovered by NTPT or TPT impacts liver outcomes is one of increasing importance given broader geographic allocation stemming from the adoption of acuity circles, concern for donor team safety during travel, resource limitations, and the utilization of commercial recovery services. The study presented here is the first investigation addressing whether the identity of the recovering team (NTPT or TPT) is associated with graft failure in DCD liver transplants on a national level.

MATERIALS AND METHODS

Study Design and Cohort Selection

This is a retrospective cohort study using data from the United Network for Organ Sharing (UNOS) transplant database. The University of Pennsylvania Institutional Review Board approved this study. All adults who underwent initial liver transplant between March 1, 2017, and December 31, 2021, with a DCD liver allograft were included. The following DCD liver donors and recipients were excluded from the analysis: pediatric donors, multiorgan recipients, and pediatric recipients.

Exposure and Outcome Ascertainment

The primary exposure was the source of the DCD procurement team. To classify whether a donor procuring team was affiliated with the recipient center (TPT) or a local team not affiliated with the recipient center (NTPT), we identified donor team affiliation using Centers for Medicare and Medicaid Services identifiers or UNOS 4 center or OPO letter codes from the UNOS database variable "LI_RECOV_PROV_NUM." Two hundred sixty-three unique procuring teams were identified. These were compared with recipient transplant center identifiers to create a binary variable distinguishing whether NTPT or TPT recovered the liver for transplant. We were unable to determine the identity of the recovering team for 26 DCD transplants. The primary outcome of interest was posttransplant graft failure, defined by time to retransplantation or death. Secondary outcomes included time to retransplantation and the indication for retransplantation. The primary exposure of interest was whether the liver allograft was procured by NTPT or TPT.

For this analysis, the following recipient covariates were examined using the Standard Treatment Analysis and Research UNOS file: age, race, sex, diagnosis, body mass index, medical disposition at time of transplant (home, inpatient, and intensive care unit), history of diabetes, dialysis status, Model for End-Stage Liver Disease (MELD) score at transplant, and history of exception score. The following donor covariates were examined: age, race, sex, body mass index, history of diabetes, and cause of death. In addition, the following transplant-related covariates were examined: total warm ischemic time, death to clamp time, functional warm ischemic time (first-time systolic blood pressure <60 mm Hg to cross-clamp [functional warm ischemic time]), cold ischemic time, the distance between donor and recipient hospital, and transplant year.

Statistical Analysis

Basic descriptive and inferential statistics were computed to compare DCD donor recipient characteristics between NTPT and TPT recovery team. Continuous data were summarized using medians and interquartile ranges (IQRs), and categorical data were summarized with frequencies and percentages. Differences in continuous covariates were analyzed using the Kruskal-Wallis test and categorical covariates were compared using the chi-square test. To evaluate differences in the primary outcome of posttransplant graft survival, we first performed unadjusted Kaplan-Meier analyses between NTPT and TPT and compared survival distributions using the log-rank test.

We then created mixed effects Cox proportional models to assess the hazard of graft failure. We included a random intercept to account for variation at the level of the transplant center. Covariates included recipient total warm ischemic time, age, recipient sex, recipient medical disposition at time of transplant (home, inpatient, and intensive care unit), recipient diagnosis, recipient MELD at time of transplant, cold ischemia time, recipient history of prior transplant, and use of local transplant surgeon. All variables selected in this analysis were chosen a priori based on known association with graft failure as well as clinical relevance to patient outcomes. Lastly, sensitivity analyses were performed, which excluded patients with a history of a prior liver transplant or centers that performed <30 transplants during the study period. An alpha threshold of 5% was used to determine the statistical significance.

RESULTS

Cohort Characteristics

Five hundred NTPT and 2257 TPT DCD liver transplants were performed in the United States between March 2017 and December 2021 by 100 centers. During this time, NTPT represented between 11.2% and 23.1% of all DCD liver transplants per year. NTPT DCD transplants were completed by 60 of the 100 transplant centers performing DCD liver transplants. These 60 centers performed 1849 TPT DCDs (median, 21.5 per center; IQR, 9.5–40.5 per center; **Figure S1, SDC**, http://links.lww.com/TXD/A697). A positive association existed between total DCD volume and NTPT DCD volume (**Figure S2, SDC**, http://links.lww.com/TXD/A697).

Donor characteristics were similar between NTPT and TPT, although as expected donor cold time and travel distance was greater among NTPT (Table 1). Recipient characteristics were largely similar between NTPT and TPT except that NTPT recipients included a larger non-White population (29.0% versus 22.1%; $P = 0.002$), a higher number of patients requiring

TABLE 1.

Demographic and transplant characteristics of recipients and donors of DCD livers procured by the transplant center versus local transplant surgeons

Donor and Recipient Characteristics	TPT	NTPT	*P*
Total n = 2757	2257 (81.9%)	500 (18.1%)	
Recipient characteristics			
Recipient sex			0.13
Male	1554 (68.9%)	362 (72.4%)	
Female	703 (31.1%)	138 (27.6%)	
Recipient age, mean (SD)	57.6 (1.0)	57.0 (15.2)	0.24
Recipient BMI at listing	29.2 (5.7)	29.7 (5.6)	0.06
Race			<0.01
White	1758 (77.9%)	355 (71.0%)	
Black	113 (5.0%)	27 (5.4%)	
Other	386 (17.1%)	118 (23.6%)	
Recipient medical status			0.31
Not hospitalized	1982 (87.8%)	437 (87.4%)	
Hospitalized not in ICU	220 (9.7%)	45 (9.0%)	
In ICU	55 (2.4%)	18 (3.6%)	
Recipient history of diabetes			0.81
Yes	743 (32.9%)	168 (33.6%)	
No	1514 (67.1%)	332 (66.4%)	
Receipt of dialysis twice in the prior week			<0.01
Yes	40 (1.8%)	13 (2.6%)	
No	2204 (97.7%)	478 (95.6%)	
Missing	13 (0.6%)	9 (1.8%)	
MELD at time of transplant, mean (SD)	18.9 (7.5)	18.3 (8.1)	0.03
Days on waiting list, mean (SD)	242.1 (465.8)	245.5 (537.3)	0.18
History of exception score			
Yes	782 (34.6%)	177 (35.4%)	0.79
No	1475 (65.4%)	323 (64.6%)	
Primary diagnosis			0.17
NASH	530 (23.5%)	103 (20.6%)	
Autoimmune	193 (8.5%)	33 (6.6%)	
Hepatitis	272 (12.1%)	72 (14.4%)	
Alcohol associated	748 (33.1%)	179 (35.8%)	
HCC	336 (14.9%)	81 (16.2%)	
Other	178 (7.9%)	32 (6.4%)	
Donor characteristics			
Donor sex			
Male	1529 (67.7%)	341 (68.2%)	0.89
Female	728 (32.3%)	159 (31.8%)	
Donor age, mean (SD)	38.8 (12.1)	39.2 (12.1)	0.19
Donor BMI	27.8 (6.1)	27.9 (6.4)	0.77
Donor race			0.10
White	1714 (75.9%)	384 (76.8%)	
Black	241 (10.7%)	39 (7.8%)	
Other	302 (13.4%)	77 (15.4%)	
Donor diabetes			0.81
No	1514 (67.1%)	332 (66.4%)	
Yes	743 (32.9%)	168 (33.6%)	
Donor cause of death			0.73
Anoxia (ref)	1212 (53.7%)	259 (51.8%)	
Cerebrovascular/stroke	386 (17.1%)	88 (17.6%)	
Head trauma	581 (25.7%)	131 (26.2%)	
Other	78 (3.5%)	22 (4.4%)	
Transplant characteristics			
tWIT, min	22.8 (5.8)	23.4 (6.0)	0.06
Death to clamp, min	6.1 (3.0)	6.4 (3.3)	0.17
fWIT, min	14.8 (11.7)	15.5 (12.3)	<0.01
Cold ischemic time, h, mean (SD)	5.3 (1.5)	6.6 (2.3)	<0.01

(continued)

TABLE 1.
Continued

Donor and Recipient Characteristics	TPT	NTPT	*P*
Distance between donor hospital and transplant center (nautical miles), mean (SD)	115.7 (156.1)	306.0 (265.3)	<0.01
Year transplanted			<0.01
2017	306 (13.6%)	61 (12.2%)	
2018	420 (18.6%)	53 (10.6%)	
2019	518 (23.0%)	109 (21.8%)	
2020	542 (24.0%)	163 (32.6%)	
2021	471 (20.9%)	114 (22.8%)	

Values are expressed as n (%) unless otherwise indicated.
BMI, body mass index; DCD, donation after circulatory death; fWIT, functional warm ischemic time; HCC, hepatocellular carcinoma; ICU, intensive care unit; MELD, Model for End-Stage Liver Disease; NASH, nonalcoholic steatohepatitis; NTPT, nontransplant program procurement team; ref, reference; TPT, transplant program procurement team; tWIT, total warm ischemic time.

dialysis before transplant (2.6% versus 1.8%; $P = 0.009$), and a lower MELD (18.3 ± 8.09 versus 18.9 ± 7.54; $P = 0.025$). Finally, livers procured by NTPT had a significantly longer distance between donor and recipient centers compared with TPT (306.0 ± 265.3 versus 115.7 ± 156.1; $P < 0.001$; **Figure S3, SDC**, http://links.lww.com/TXD/A697).

Graft Survival

During a median of 383 d of follow-up, there were 140 graft failures, of which 29 were with NTPT (5.8% total NTPT) and 111 with TPT (4.9% total TPT). The median time to graft failure was 171 d (IQR, 7–379 d) and 81 d (IQR, 6–248 d), respectively. Unadjusted graft survival was not different between NTPT and TPT (Figure 1). In a multivariable Cox model, the origin of the donor team was not associated with graft failure (NTPT versus TPT; hazard ratio, 0.92; 95% confidence interval, 0.71-1.22; $P = 0.57$; Table 2).

Overall, 126 (4.57%) patients subsequently underwent retransplantation after DCD graft failure, 29 NTPT DCDs (5.80%) and 97 TPT DCDs (4.30%). The cause of graft failure was identified in 96 recipients (**Table S1, SDC**, http://links.lww.com/TXD/A697). Eleven NTPT DCD graft failures were because of IC (37.93%), while this cause accounted for 27 TPT DCD graft failures (27.84%).

Two sensitivity analysis were conducted that excluded (1) centers with <30 transplants during the study period and (2) retransplants. Neither analysis demonstrated a significant association between origin of donor team and graft survival ($P = 0.46$ and $P = 0.31$, respectively, versus $P = 0.30$ whole cohort).

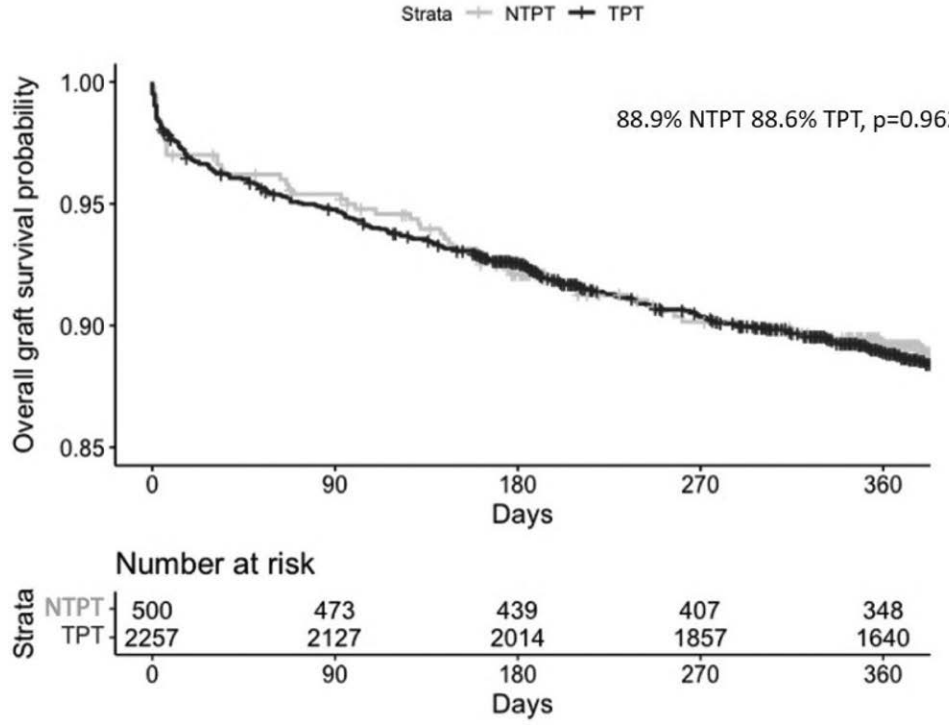

FIGURE 1. One-year unadjusted graft survival of TPT vs NTPT donation after circulatory death (DCD) transplants. No significant difference in graft failure was found between the TPT and NTPT groups at 1 y. NTPT, nontransplant program procurement team; TPT, transplant program procurement team.

TABLE 2.

Multivariable Cox model of variables associated with graft failure in DCD recipients

Donor and Recipient Characteristics	HR (95% CI)	*P*
Donor team origin		
TPT (ref)		
NTPT	0.92 (0.70-1.21)	0.57
tWIT	1.02 (1.00-1.04)	0.01
Age	1.02 (1.00-1.03)	0.01
Sex		
Male (ref)		
Female	0.80 (0.63-1.01)	0.06
Condition at time of transplant		
Not hospitalized (ref)		
Hospitalized non-ICU	1.15	0.44
Hospitalized in ICU	2.19 (1.31-3.65)	<0.01
MELD	1.00 (0.99-1.02)	0.84
Diagnosis		
NASH (ref)		
Autoimmune	0.89 (0.57-1.40)	0.62
Hepatitis	1.09 (0.77-1.54)	0.62
Alcohol associated	0.97 (0.73-1.30)	0.85
HCC	0.86 (0.59-1.23)	0.41
Other	0.92 (0.59-1.41)	0.69
Cold ischemia time, h	1.08 (1.02-1.14)	<0.01
History of prior transplant		
No (ref)		
Yes	4.36 (1.73-10.96)	<0.01
Transplant year		
2017 (ref)		
2018	1.19 (0.86-1.65)	0.30
2019	1.17 (0.84-1.64)	0.35
2020	1.33 (0.92-1.91)	0.12
2021	1.68 (1.09-2.58)	0.02
Donor cause of death		
Cardiovascular (ref)		
Trauma	0.96 (0.71-1.31)	0.82
Anoxia	1.16 (0.88-1.51)	0.28
Other	1.01 (0.64-1.59)	0.96

CI, confidence interval; DCD, donation after circulatory death; HCC, hepatocellular carcinoma; HR, hazard ratio; ICU, intensive care unit; MELD, Model for End-Stage Liver Disease; NASH, nonalcoholic steatohepatitis; NTPT, nontransplant program procurement team; ref, reference; TPT, transplant program procurement team; tWIT, total warm ischemic time.

DISCUSSION

Ample evidence demonstrates underutilization of DCD donor livers because of concerns about graft outcomes; specifically diminished graft survival because of IC and primary nonfunction. However, logistical and resource related barriers are also an impediment, as transplant centers are reluctant to send a donor team when they are unsure if the donor may expire within an acceptable period of time, such that the donor's warm time is prohibitive. The adoption of acuity circles for liver allocation has doubled the median distance between the donor center and the transplant center from 71 to 141 nautical miles, compounding constrained resources related to surgeon availability, increased organ recoveries requiring flights, and expense.[20-22] Utilization of a local donor surgical team may negate some of the logistical and resource related issues for the recipient center. However, transplant center physicians are also often reluctant to allow a local donor team not affiliated with the transplant center to recover the liver because of concerns about the donor surgeon's surgical skill and judgment as well as variability among OPO and hospital-related DCD donor protocols. Given reluctance among transplant centers to allow a local team, we sought to understand the national experience when DCD livers are recovered by a nontransplant-related team, as this may be informative to the organ donation and transplant community in the current era of wider geographic allocation.

Our analysis indicates that although cold ischemic time and distance between donor and recipient center is longer with NTPT DCD donor teams, graft survival was not associated with the origin of the donor team. Rather, graft survival was associated with the degree of illness of the recipient, cold ischemic time, retransplantation, and donor cause of death, many of which have been previously been recognized as mediating the risk of DCD graft failure.[23-25] Our findings are consistent with a recent single-center analysis from the Mayo Clinic in Arizona, which also demonstrated that the origin of the donor team did not impact graft survival, retransplantation rates, or incidence of IC.[19] Furthermore, sensitivity analyses excluding retransplants or centers with <30 liver transplants during the study period revealed similar results to the analysis of the entire cohort. As with the Mayo study, we did not identify a difference in retransplantation. However, we were unable to analyze the incidence of IC among all recipients, as this is not captured by UNOS. IC is, however, identified as an indication for retransplantation and was not different between NTPT and TPT livers.

Although we did not identify differences in graft survival between NTPT and TPT, these results should be viewed with caution, as our study is accompanied by several limitations related to the UNOS dataset. The nature of the relationship between the NTPT team to the recipient center is unknown. Recipient centers using NTPT DCD livers may have prior experience with the recovering surgical team; perhaps they had trained at the recipient center or routinely recovered livers for the recipient center. This level of familiarity and trust may be important to the successful use of a NTPT DCD. However, it is a relationship that cannot be elucidated from the UNOS data, as affiliation with an OPO or transplant center is not available. Without additional clarity, the adoption of NTPT surgical teams for DCD liver recovery should be pursued with thoughtfulness. As with any large database study, there may be additional unmeasured confounders that influence the findings, which we are unable to consider. Furthermore, unless a patient is retransplanted, UNOS does not require the cause of graft failure to be reported, limiting our analysis on the cause of graft failure.

A cautious optimism to the utilization of NTPT DCD livers should be viewed in the context of the current environment of perfusion technology. The rapid adoption of ex situ and in situ perfusion platforms for DCD liver transplantation and emerging evidence that outcomes are better than with static cold storage is likely to allay some of the concerns with respect to recovery of the DCD donor liver by a local team not affiliated with the transplant center.[26-29] The molecular changes within the liver allograft delivered by the various perfusion platforms may mitigate some of the differences in surgical skill and judgment, variations in donor agonal phase physiology, and dissimilarities in OPO and hospital DCD protocols. Furthermore, they will likely allow some extension of donor warm ischemic time. As third-party perfusion teams become more commonplace, it is essential to understand the impact of using NTPT DCD

organs. The current analysis provides some measure of comfort to transplant centers contemplating accepting a NTPT DCD organ, particularly when combined with machine perfusion.

Although other studies have investigated NTPT versus TPT use, ours is the first to address the difference in outcomes in DCD liver transplant on a national scale. In summary, this analysis identifies no association between the origin of the recovery team and the risk of DCD liver allograft failure. In the era of wider geographic organ allocation, limited resources, and concerns about donor team safety this finding may help assuage apprehension about NTPT surgical teams for DCD liver recovery and ultimately increase DCD liver utilization.

REFERENCES

1. Croome KP, Mathur AK, Aqel B, et al. Classification of distinct patterns of ischemic cholangiopathy following DCD liver transplantation: distinct clinical courses and long-term outcomes from a multicenter cohort. *Transplantation*. 2022;106:1206–1214.
2. Ruebner RL, Reese PP, Abt PL. Donation after cardiac death liver transplantation is associated with increased risk of end-stage renal disease. *Transpl Int*. 2014;27:1263–1271.
3. Abt P, Crawford M, Desai N, et al. Liver transplantation from controlled non-heart-beating donors: an increased incidence of biliary complications. *Transplantation*. 2003;75:1659–1663.
4. Croome KP, Taner CB. The changing landscapes in DCD liver transplantation. *Curr Transplant Rep*. 2020;7:194–204.
5. Wigmore SJ. Current challenges in liver transplantation following donation after cardiac death. *Transplantation*. 2010;90:1048–1049.
6. Chadha RM, Croome KP, Aniskevich S, et al. Intraoperative events in liver transplantation using donation after circulatory death donors. *Liver Transpl*. 2019;25:1833–1840.
7. Croome KP, Lee DD, Keaveny AP, et al. Improving national results in liver transplantation using grafts from donation after cardiac death donors. *Transplantation*. 2016;100:2640–2647.
8. Doyle MBM, Collins K, Vachharajani N, et al. Outcomes using grafts from donors after cardiac death. *J Am Coll Surg*. 2015;221:142–152.
9. Ausania F, White SA, Coates R, et al. Liver damage during organ donor procurement in donation after circulatory death compared with donation after brain death. *Br J Surg*. 2013;100:381–386.
10. Bekki Y, Kozato A, Kusakabe J, et al. Impact of the donor hepatectomy time on short-term outcomes in liver transplantation using donation after circulatory death: a review of the US national registry. *Clin Transplant*. 2022;36:e14778.
11. Taner CB, Bulatao IG, Willingham DL, et al. Events in procurement as risk factors for ischemic cholangiopathy in liver transplantation using donation after cardiac death donors. *Liver Transpl*. 2012;18:100–111.
12. Hobeika MJ, Glazner R, Foley DP, et al. A step toward standardization: results of two national surveys of best practices in donation after circulatory death liver recovery and recommendations from the American Society of Transplant Surgeons and Association of Organ Procurement Organizations. *Clin Transplant*. 2020;34:e14035.
13. Montgomery JR, Highet A, Hobeika MJ, et al. Going the distance for procurement of donation after circulatory death livers for transplantation-does reimbursement reflect reality? *Clin Transplant*. 2020;34:e13780.
14. Lindemann J, Dageforde LA, Vachharajani N, et al. Cost evaluation of a donation after cardiac death program: how cost per organ compares to other donor types. *J Am Coll Surg*. 2018;226:909–916.
15. Pine JK, Goldsmith PJ, Ridgway DM, et al. Predicting donor asystole following withdrawal of treatment in donation after cardiac death. *Transplant Proc*. 2010;42:3949–3950.
16. Scales NB, Herry CL, van Beinum A, et al. Predicting time to death after withdrawal of life-sustaining measures using vital sign variability: derivation and validation. *Crit Care Explor*. 2022;4:e0675.
17. Wind J, Snoeijs MGJ, Brugman CA, et al. Prediction of time of death after withdrawal of life-sustaining treatment in potential donors after cardiac death*. *Crit Care Med*. 2012;40:766–769.
18. Serrano OK, Vock DM, Snyder JJ, et al. Influence of the procurement surgeon on transplanted abdominal organ outcomes: an SRTR analysis to evaluate regional organ procurement collaboration. *Am J Transplant*. 2019;19:2219–2231.
19. Jadlowiec CC, Macdonough E, Pont K, et al. Donation after circulatory death transplant outcomes using livers recovered by local surgeons. *Liver Transpl*. 2022;28:1726–1734.
20. Wall AE, da Graca B, Asrani SK, et al. Cost analysis of liver acquisition fees before and after acuity circle policy implementation. *JAMA Surg*. 2021;156:1051–1057.
21. Chyou D, Karp S, Shah MB, et al. A 6-month report on the impact of the Organ Procurement and Transplantation Network/United Network for Organ Sharing acuity circles policy change. *Liver Transpl*. 2021;27:756–759.
22. Organ Procurement and Transplantation Network. Two year monitoring report of liver and intestine acuity circle allocation. Available at https://optn.transplant.hrsa.gov/media/k5yi4jvl/data_report_liver_full_2yrallocation_20220805_final_508_compliant.pdf. Accessed August 5, 2022.
23. Mathur AK, Heimbach J, Steffick DE, et al. Donation after cardiac death liver transplantation: predictors of outcome. *Am J Transplant*. 2010;10:2512–2519.
24. Paterno F, Guarrera JV, Wima K, et al. Clinical implications of donor warm and cold ischemia time in donor after circulatory death liver transplantation. *Liver Transpl*. 2019;25:1342–1352.
25. Schlegel A, Kalisvaart M, Scalera I, et al. The UK DCD risk score: a new proposal to define futility in donation-after-circulatory-death liver transplantation. *J Hepatol*. 2018;68:456–464.
26. Jochmans I, Hessheimer AJ, Neyrinck AP, et al; ESOT Workstream 04 of the TLJ (Transplant Learning Journey) Project. Consensus statement on normothermic regional perfusion in donation after circulatory death: report from the European Society for Organ Transplantation's Transplant Learning Journey. *Transpl Int*. 2021;34:2019–2030.
27. Markmann JF, Abouljoud MS, Ghobrial RM, et al. Impact of portable normothermic blood-based machine perfusion on outcomes of liver transplant: the OCS liver PROTECT randomized clinical trial. *JAMA Surg*. 2022;157:189–198.
28. Nasralla D, Coussios CC, Mergental H, et al; Consortium for Organ Preservation in Europe. A randomized trial of normothermic preservation in liver transplantation. *Nature*. 2018;557:50–56.
29. Schlegel A, Muller X, Dutkowski P. Hypothermic liver perfusion. *Curr Opin Organ Transplant*. 2017;22:563–570.