Review Article

The Dallas Donation after Circulatory Death Transplantation Summit: expanding donation after circulatory death procedures through process improvement, broader utilization, and innovation

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Abstract: Despite a significant increase in utilization over the past decade, the number of donation after circulatory death (DCD) organs that are procured and transplanted in the United States (US) remains well below its potential. There is still room for expansion, as utilizing DCD organs to the fullest extent is currently the most viable solution to the persistent mismatch between supply and demand in transplantation. We convened a multidisciplinary transplantation summit to examine various aspects of DCD, with faculty members from around the world with clinical and academic interest in DCD donation and transplantation, including abdominal and cardiothoracic surgeons, organ procurement organization directors, hepatologists, and gastroenterologists. The conference focused on identifying barriers to DCD organ utilization and strategies to overcome these barriers. We divide the barriers to DCD utilization into three mains categories: (I) policy and process variation; (II) logistical and transportation challenges; and (III) higher risk perceptions related to DCD outcomes. For each barrier, we proposed a variety of solutions, providing an overview of the status of DCD donation in the US and suggestions on how to increase the use of DCD. There is a specific focus on ex situ machine perfusion, normothermic regional perfusion, and other opportunities to expand DCD utilization without negatively impacting recipient outcomes.

Keywords: Donation after circulatory death donation (DCD donation); marginal graft; donor pool; machine perfusion (MP)

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Introduction

The Donation after Circulatory Death (DCD) Transplantation Summit hosted by Baylor University Medical Center in Dallas and Southwest Transplant Alliance on April 1–2, 2022, brought together transplant professionals from around the world to discuss all aspects of DCD donation, with a focus on optimizing DCD outcomes and strategies to increase utilization through improving quality and acceptance of DCD donor organs for transplantation. The summit included ten transplant center division chiefs, five abdominal and thoracic transplant surgeons, five professors of transplant surgery, four presidents of donor centers, and two hepatology medical directors (Table S1). This multidisciplinary faculty discussed the trends in utilization and outcomes of DCD donation in the United States, providing context for why expanding DCD donation is essential for significantly increasing the number of organs available for transplantation. This article describes the barriers to increasing DCD donation and transplantation in the US and presents various strategies to overcome these barriers to improve the quantity and quality of DCD organs available for transplantation. Since liver transplantation, among all other organs, would greatly benefit from an expansion of its donor pool with DCD organs and since striking differences exist in DCD liver graft utilization among US centers, much of this article focuses on DCD liver donation and transplantation.

DCD donation as a viable option to increase the donor pool

DCD procedures were the standard method of organ procurement for human transplantation in the US before the development of the Harvard criteria for brain death (1). Once donation after brain death (DBD) was adopted, it quickly became the only method for organ procurement in the US, replacing DCD entirely for the subsequent two decades, considered a marginal graft (2). Beginning in the 1990s, single institutions in the US made efforts to revive DCD organ transplantation (3,4). With support from the Institute of Medicine and the Society of Critical Care Medicine on the ethical and medical acceptability of DCD donation, the number of DCD donors has grown from 41 in 1993 to 4,778 in 2022. In 2022, DCD represented 22.3% of total organ donors in the US (21,370 donors: 10,127 DBD donors, 6,465 living donors, and 4,778 DCD donors) (5-8). While there has been an impressive increase in DCD donation, death by cardiopulmonary rather than neurological criteria is far more common in the US, so DCD donation should be more common than DBD donation (9).

Over the last decade, DCD organ utilization has grown considerably (*Figure 1*), with a 265% increase for kidney, 285% increase for liver, and 1,109% increase for lung transplants from DCD donors. In the heart transplant field, DCD donation became a reality in 2019, rising from 0.1% in 2019 (with 7 patients receiving a heart from DCD donors) to 8.2% in 2022 (with 346 heart transplants from DCD donors) (10-12). Overall, 54% of US lung transplant centers performed at least one lung transplant utilizing a DCD donor between 2015 and 2020, and nearly 30% of US lung transplant programs have performed more than 15 DCD lung transplants as of 2022 (13).

Even though the utilization of organs from DCD donors has been steadily increasing in the US, there remains room for expansion, given that maximizing the utilization of DCD organs is the most readily available solution to the chronic gap between supply and demand in transplantation at this time. Notably, in the last 10 years, the DCD organ discard rate has increased 7-fold in comparison to an increase of 1.6-fold in DBD organs. Clearly, there seems to be a significant opportunity to identify actions aimed at improving DCD donor and graft selection and donor-recipient matching.

While there is great promise for growing organ transplantation with DCD donation, substantial barriers remain to expanding this practice (*Figure 2*, *Table 1*). In this paper, we divide the barriers into three mains categories, identified in the meeting: (I) policy and process variation; (II) logistical and transportation challenges; and (III) higher risk perceptions related to DCD outcomes. Overcoming these barriers will require a variety of solutions, including the

Figure 1 Growth in DCD organ utilization over the last decade for heart, liver, kidney, and lung transplantation. DCD, donation after circulatory death; DBD, donation after brain death.

utilization of *in situ* and *ex situ* machine perfusion (MP).

Policy and process variation in DCD donation: barriers and solutions

There is significant variation in DCD procurement guidelines, policies, and practices (*Figure 3*). DCD donation processes differ in terms of the location of withdrawal of life-sustaining treatment (WLST), the length of observation periods between the declaration and confirmation of death, the acceptability of premortem heparin administration, and the acceptability of premortem interventions (14-17). At the practical level of the workflows of a DCD donor, every hospital in the US has its own written DCD policy that addresses the location of withdrawal, premortem heparin administration, hands-off time, allowed total operating room (OR) time, prewithdrawal interventions, timing of prepping and draping, and timing of donor team entry to the OR (18). Each of these factors can have a direct impact on graft utilization and recipient outcomes. The location of WLST outside the OR (postanesthesia care unit or intensive care unit) can increase warm ischemia time due to the necessary time to transport the donor to the OR and position them on the operating table after the declaration of death. Furthermore, not every hospital allows the surgical team to perform premortem cannulation, enter the OR, or prep and drape the potential donor before the declaration of death. Premortem heparin administration is not universally allowed due to ethical concerns at a small minority of hospitals, and a recent study has shown the lack of administration is associated with worse transplant graft survival, especially in liver grafts (19). Therefore, many transplant centers are unwilling to accept donors who do not undergo premortem heparinization.

The time between the declaration of death and surgical incision, also known as the observation time, varies among

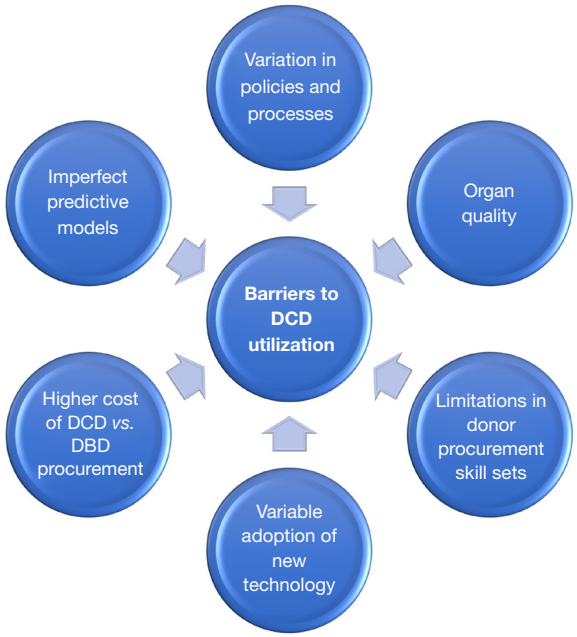

Figure 2 Barriers to DCD utilization. DBD, donation after brain death; DCD, donation after circulatory death.

hospitals. Depending on hospital and country, this time can range from 2 to 20 minutes, and prolonged times can have a direct detrimental impact on graft quality.

To make things more complicated, organ procurement organization (OPO) policies also vary. A recent survey analyzed the current policies of 57 OPOs compared to the American Society of Transplant Surgeons recommendation for DCD organ procurement and transplantation. For example, the American Society of Transplant Surgeons identifies the OR as the elected location of WLST, recommends premortem heparin, and proposes reducing the asystolic wait time to 2 minutes. However, among the 57 OPOs evaluated, only 23 OPOs followed the first recommendation, 53 followed the second, and 12 followed the third (20).

Additionally, although rapid recovery techniques are taught in nearly all abdominal transplant training programs, given the lower utilization of DCD thoracic organs, many training programs do not adequately prepare thoracic recovery surgeons for these donors, leading to variations in proficiency. Efforts by the American Society of Transplant Surgeons are underway to address this deficit (21).

Variation in hospital policies has the potential to negatively impact the acceptance of DCD donors specifically by programs that have greater concerns about outcomes. Moreover, the lack of uniform practices creates confusion and adds logistical burdens to accepting transplant centers and OPOs. An important consideration is whether this lack of standardization in practices ultimately affects the donor and the donor families by diminishing the likelihood of progression to death and contributes to the increased financial burden associated with DCD donation.

Recommendations for DCD policy and process standardization:

- Standardized national guidelines for best practices should include a preference for WLST in the OR, a longer total donor warm ischemia time limit of up to 2 hours, and allowance of prewithdrawal interventions with surrogate consent (e.g., predonation testing including cardiac catheterization and liver biopsy, heparin infusion, and femoral cannulation).

Logistical and transportation challenges in DCD donation: barriers and solutions

OPO practices in DCD procurement

In the US, there are significant differences among OPOs regarding the percentage of DCD organ donors procured versus the total number of deceased donor organ procurements. This difference is not simply explained by donor pool demographics, waitlist metrics, center competition, or DCD donor utilization (22).

The first step toward uniform increases in DCD donation is for OPOs to develop best practices for identifying, authorizing, and managing potential DCD donors and to identify systemic factors that create barriers to these best practices. For example, organizational and financial issues may drive lower rates of DCD donors in remote hospitals and decreased enthusiasm to pursue lower potential yield (e.g., 1 organ) DCD donors. Such donors still require the full deployment of OPO staff, which translates into costs in terms of time and money and may result in a net financial loss for the OPO. Another factor that can impact DCD donation is family or hospital time constraints on WLST that make getting donor surgical teams onsite impossible, thereby precluding procurement. This has become a particularly important factor when the utilization of DCD donor organs becomes more likely, as when *in situ* normothermic regional perfusion (NRP) or ex situ MP are utilized, both of which require time to mobilize teams and equipment to the donor hospital.

Suggestions for addressing OPO barriers to expanding

Table 1 Barriers in donation after cardiac death donation

Barriers	Proposed solutions and expansion of DCD utilization
Policy and process variation	
Variation in DCD procurement guidelines, policies, and practices; absence of national policy	Standardized national guidelines for best practices should include a preference for withdrawal of life-sustaining treatment in the operating room, a longer total donor warm ischemia time limit of up to 2 hours, and allowance of prewithdrawal interventions with surrogate consent (e.g., predonation testing including cardiac catheterization and liver biopsy, heparin infusion, and femoral cannulation)
Logistical and transportation challenges	
OPOs with significant low DCD utilization	OPOs with low-volume DCD should adopt policies and practices from high-volume DCD OPOs; OPO recovery surgeons should be utilized for expedited recoveries if transplant center surgeons are unavailable; OPOs should consider DCD transfer hospitals to centralize and standardize procurements
High costs associated with DCD acquisition	Improve efficiency in DCD donation: financial incentives should align with pursuing DCD donors in remote locations despite the potential for low organ yield. Proper financial analysis of the cost of DCD transplantation and the cost savings associated with the predicted significant increase in transplanted patients should be pursued to better characterize true costs. Technologies that allow for better organ assessment and utilization, such as NRP and *ex situ* machine perfusion, should be uniformly utilized for DCD donors to maximize organ yield
Higher risk perceptions related to DCD outcomes	
Quality concerns	The survival benefit of DCD transplantation should be evaluated with intention-to-treat analyses; implementation of a safety net for IC and appropriate risk adjustment in the Scientific Registry of Transplant Recipients are essential for increasing DCD graft utilization in the US
Donor and recipient selection	For liver transplantation, donor age >50 years, body mass index >25 kg/m^2, functional warm ischemia time >30 minutes, and prolonged cold ischemia time (>6 hours) are donor characteristics associated with a greater incidence of IC and poorer outcomes. These limits should be tested ideally with NRP or *ex situ* machine perfusion to mitigate excess risk
	Transplant centers with little DCD liver transplant experience can begin utilizing DCD donors in the lowest-risk donor-recipient scenarios to build comfort with this procedure
	Predictive models should be used to evaluate donor and recipient pairing to make tailored risk assessments based on specific matches. Limitations to predictive models should be recognized, as they do not account for *ex situ* machine perfusion or NRP

DCD, donation after circulatory death; OPO, organ procurement organization; IC, ischemic cholangiopathy; NRP, normothermic regional perfusion.

DCD donation include having low-volume DCD OPOs adopt policies and practices from high-volume DCD OPOs. For example, some OPOs have donor surgeons on staff who can deploy quickly, making expedited donor procurements more feasible. Also, some OPOs have partnered with high-volume DCD hospitals to build pathways that streamline and standardize DCD donation. Going a step further, some OPOs are utilizing centralized hospitals for the transfer of DCD donors so that donor care is optimized. DCD hospital hubs have the potential to decrease costs and streamline donor workflows (23,24).

Recommendations for OPO DCD policies and practices:

- OPOs with low-volume DCD should adopt policies and practices from high-volume DCD OPOs; OPO recovery surgeons should be utilized for expedited recoveries if transplant center surgeons are unavailable; OPOs should consider DCD transfer hospitals to centralize and standardize procurements.

Higher costs associated with DCD acquisition compared to DBD acquisition

Starting in February 2020, the US liver allocation policy was changed from the Share 35 framework to the acuity

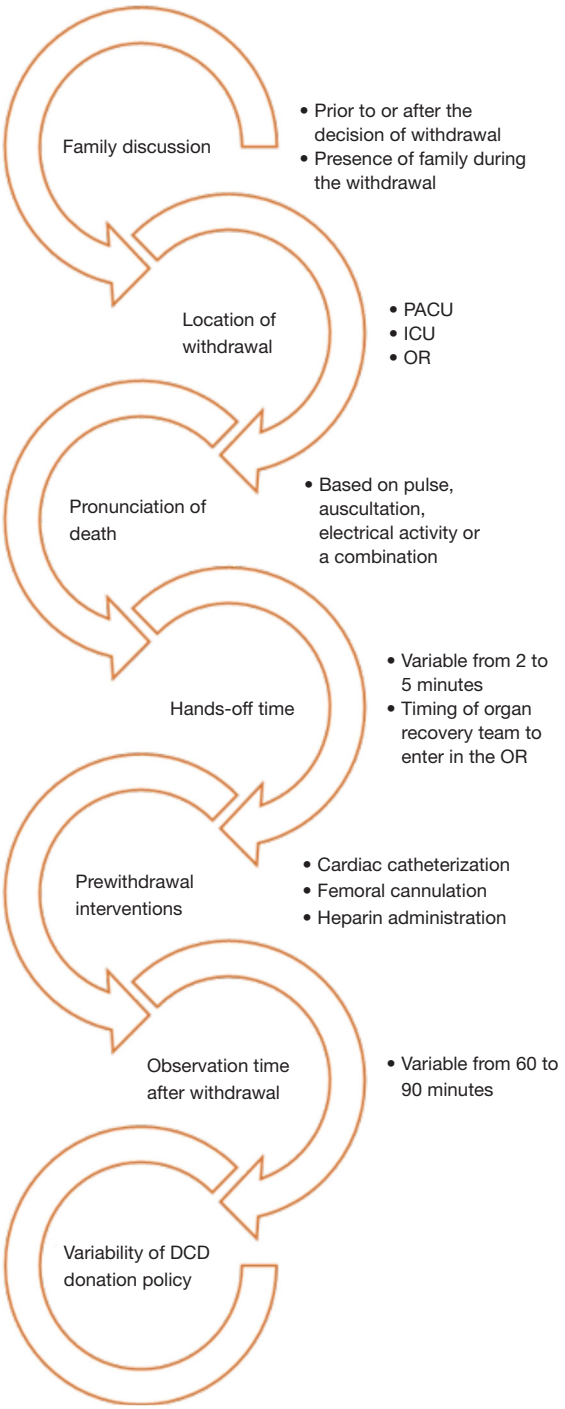

Figure 3 Donation after circulatory death policy elements that vary among hospitals. PACU, post anesthesia care unit; ICU, intensive care unit; OR, operating room; DCD, donation after circulatory death.

circles framework, to reduce geographic disparities in liver transplantation based on the variance in median Model for End-Stage Liver Disease score at transplant across regions (25). In a single-center analysis after acuity circles allocation, the differences in both donor service areas and center-level variance of median Model for End-Stage Liver Disease scores decreased, but flight-consistent procurements increased substantially (26).

Although the allocation of extended criteria grafts and DCD liver grafts is designed to incentivize the utilization of these grafts by the center more proximal to the donor, the financial burdens on OPOs and centers highly invested in utilizing these DCD grafts cannot be ignored. Understanding the real cost of DCD donation balanced with the true impact of the DCD donation in the whole process is essential. Increasing the utilization of DCD organs translates into a significantly higher rate of transplantation for all organs. In turn, the number of patients on the waiting list will decrease, and the end effect will be not only a decrease in mortality but a significant decrease in the financial burden of caring for patients with end-stage organ disease.

Multiple factors increase the cost of DCD donation: the location of the donor in relation to the OPO home base; difficulty in obtaining premortem diagnostics, leading to greater pre procurement uncertainty; and lack of adequate predictive models for determining which donors are likely to expire in the timeframe acceptable for donation.

There is evidence that single organ donors, specifically kidney donors, are not routinely pursued (27), specifically if donors are located in remote areas. There is also indirect evidence that the lack of proper premortem diagnostics may be one factor explaining why the acceptance rate of DCD organs is lower than that of DBD organs. To overcome inadequate premortem organ assessment, there is growing evidence that the possibility of assessing the quality of the DCD organs prior to final acceptance increases the rate of transplantation. For example, the use of NRP in DCD livers allows for evaluation of grafts that might be discarded based on preretrieval information or post-cross-clamp assessment after rapid-recovery DCD. During NRP, serum lactate, liver transaminases, glucose metabolism, and pH can be assessed and used to evaluate the graft quality (28-32). The data have shown that the percentage of potential DCD donors from whom organs are accepted but none are

transplanted differs by organ. In the case of liver grafts, this rate can be as high as 50%, while the rates for kidneys and lungs are around 40% (33,34).

Finally, criteria to assess and predict the probability of death within the timeframe for donation of a potential DCD donor after WLST are still imprecise (35). Developing accurate prediction models is considered the most useful step to limit the number of no-organ-yield donors and hence mitigate associated costs.

Recommendations to mitigate the high costs associated with DCD acquisition:

- Improve efficiency in DCD donation: financial incentives should align with pursuing DCD donors in remote locations despite the potential for low organ yield. Proper financial analysis of the cost of DCD transplantation and the cost savings associated with the predicted significant increase in transplanted patients should be pursued to better characterize true costs. Technologies that allow for better organ assessment and utilization, such as NRP and ex situ MP, should be uniformly utilized for DCD donors to maximize organ yield.

DCD outcome and risk perception: barriers and solutions

Risk perceptions

Many transplant centers are reluctant to accept organs from DCD donors because of concerns regarding recipient outcomes. For example, from 2013 to 2017, only 11 US transplant centers performed more than 50 DCD liver transplants, suggesting that almost half of the nation's experience was concentrated at this small number of centers (36). In particular, the development of ischemic cholangiopathy (IC) in liver grafts and delayed graft function in kidney grafts is a real problem (37). There is a historical difference in graft and patient survival between livers procured from DCD donors compared with organs procured from DBD donors (38-42). Hence, liver and kidney grafts procured from DCD donors are still considered by many centers to be marginal grafts.

However, more recent data and new methodologies for the assessment of DCD outcomes tell a more complete story of the value of DCD transplantation. In an analysis performed in the United Kingdom, 5-year patient survival was inferior for patients receiving a DCD in comparison to a DBD organ (78.1% *vs.* 82.6%). However, when the analysis was conducted with an intent to treat from the time of listing for transplantation, accepting a DCD graft conferred a significant survival advantage over waiting for a DBD organ (21). These results were confirmed in a US study where the acceptance of a DCD liver graft was not associated with an increased mortality risk when calculated from the time of patient listing (43). Moreover, while kidney grafts from DCD donors have higher delayed graft function rates, delayed graft function does not result in worse graft survival compared to DBD (44). In terms of graft and patient outcomes, recent studies have also confirmed that DCD lung and heart transplants perform as well as DBD transplants (45,46).

In the US, the pressure on transplant centers to maintain expected graft and patient survival rates may constitute a disincentive to the utilization of DCD organs despite risk adjustment, even though there is evidence that patient survival improves with accepting a DCD organ rather than remaining on the waiting list. When overall outcomes are analyzed, crude graft and patient survival are important metrics, but the survival benefit associated with the utilization of DCD organs should also be taken into consideration. There is rising evidence that intention-to-treat analyses would be a better metric to evaluate the true survival benefit of transplanting grafts from DCD donors (47,48).

One recent initiative for mitigating quality concerns in liver transplant using DCD grafts in the US is the implementation of a safety net for patients who develop IC after liver transplantation from a DCD donor (49). Prioritizing patients requiring retransplantation for DCD-related IC provides a positive incentive for the utilization of DCD liver grafts. In addition, making sure there is appropriate risk adjustment in the Scientific Registry of Transplant Recipients for DCD recipient outcomes is essential for increasing DCD graft utilization.

Recommendations in DCD outcome evaluation:

- The survival benefit of DCD transplantation should be evaluated with intention-to-treat analyses; implementation of a safety net for IC and appropriate risk adjustment in the Scientific Registry of Transplant Recipients are essential for increasing DCD graft utilization in the US.

Donor and recipient selection

A significant part of the conference was dedicated to the appropriate selection of DCD donors and the analysis of the variables that might be associated with improved graft and patient outcomes. While there was recognition of the fact that clinical and demographic differences between DCD and DBD donors were less significant in kidney selection,

it was agreed that the selection of DCD liver grafts is more complicated. There is, in fact, no significant difference in overall graft survival at 1 and 5 years between DCD and DBD kidneys (44), but there is still a lower overall 1-year graft survival between DCD and DBD liver grafts. This difference in graft survival is mainly due to the incidence of IC that affects between 10% and 30% of DCD liver transplant recipients (50,51).

Models are available to predict complications and graft loss after DCD liver transplantation and to assist with donor-recipient matching [UK DCD risk score (52) and the ID^{2}EAL score (25)]. These tools evaluate donor and recipient pairing to make tailored risk assessments based on specific matches. Rather than considering all risk factors independently, centers that want to begin or expand DCD liver transplantation can utilize these predictive tools to align with their risk tolerance and determine which DCD donors they are willing to consider. Regarding thoracic donor and recipient selection, predictive models have not been developed. Given the relatively limited experience with DCD heart donation, the debate between NRP versus ex situ MP remains active. With a rapidly growing international experience, many centers have planned to collaborate in prospective registries to ascertain best practices. Similarly, the early anecdotal experience with lungs from NRP donors warrants further exploration; given the relatively low volume of such donors, extensive collaboration would be necessary for adequate outcomes assessment.

Recent studies of older DCD liver recipients have shown similar outcomes compared to younger DCD and DBD liver recipients in terms of graft and patient survival, with conflicting results regarding the possible higher rate of biliary complications. However, pushing the limit on donor age is an issue that needs further evaluation, especially for DCD donors over age 70 years, as the impact of age, especially on biliary complications, is still uncertain (53-56). More than donor age, donor body mass index >25 kg/m^2 is associated with lower overall recipient survival, increased risk of early allograft dysfunction, and higher rates of postsurgical complications (57,58). Furthermore, the DCD donor characteristics associated with a greater incidence of IC and poorer outcomes include functional warm ischemia time >30 minutes and prolonged cold ischemia time (59). NRP and ex situ MP have the potential to improve the quality of extended criteria liver grafts and allow for better functional assessment prior to implantation. As centers consider pushing the limits of donor age, body mass index, and warm ischemia time, they should do so with added technologies that decrease the risk of primary nonfunction and biliary complications.

Similarly, the selection of DCD lung donors remains controversial. While some data exist regarding agonal and warm ischemic times (60), the reality is that national and international practices still vary widely. Recognizing this deficit, we recommended that all US DCD lung transplant centers participate in the United Network for Organ Sharing Organ Procurement and Transplantation Network DCD Lung Transplant Collaborative (61).

With this in mind and based on the current literature (59,62), the Dallas meeting identified recommendations regarding donor and recipient selection.

Recommendations for donor and recipient selection:

- For liver transplantation, donor age >50 years, body mass index >25 kg/m^2, functional warm ischemia time >30 minutes, and prolonged cold ischemia time (>6 hours) are donor characteristics associated with a greater incidence of IC and poorer outcomes. These limits should be tested ideally with NRP or ex situ MP to mitigate excess risk.
- Transplant centers with little DCD liver transplant experience can begin utilizing DCD donors in the lowest-risk donor-recipient scenarios to build comfort with this procedure.
- Predictive models should be used to evaluate donor and recipient pairing to make tailored risk assessments based on specific matches. Limitations to predictive models should be recognized, as they do not account for ex situ MP or NRP.

Opportunities to expand DCD utilization

The advent of new technology aimed at improving organ preservation and eventually organ functional recovery was recognized as one of the most exciting and promising factors to expand DCD utilization. Compared to rapid recovery with static cold storage, *ex situ* MP and NRP are 2 technologies that may revolutionize the utilization of DCD organs and improve the quality and outcomes.

There is growing evidence that MP offers the opportunity to improve graft assessment and quality by reducing exposure to hypoxia and graft injury during the storage phase between cross-clamp and implantation (63). The result is that these grafts may tolerate a significantly longer ischemia time while also being evaluated for function prior to implantation. For example, while on pump, the pH,

lactate, bile composition, perfusate aspartate transaminase/alanine aminotransferase ratio, and flow of a liver graft can be assessed.

Preliminary data suggest that the use of normothermic MP for liver transplantation is associated with a significant decrease in the incidence of IC and consequently better graft survival (3,28-32,64-71). Moreover, compared to static cold storage, hypothermic ex situ liver perfusion is associated with lower acute rejection rates, less primary nonfunction, less IC, and higher 5-year graft survival (56,72).

NRP may serve as an alternative to or adjunct for ex situ MP. The available data on NRP also suggest that the methodology is associated with improved liver graft outcomes and a decreased incidence of complications such as IC (73-77). For kidney transplantation, NRP is associate with a significantly lower rate of delayed graft function (78). The use of new technologies is associated with increased cost, but recent studies seem to suggest that they have cost-saving, cost-effective, and clinical benefits in the long term compared to the standard cold flush and static cold storage in terms of decreased posttransplant complications (79-81).

Conference discussions concluded that, while the preliminary data suggest that wider adoption of MP technology will improve DCD liver recipient outcomes and increase the number of DCD grafts available for transplantation, further research is needed to determine its optimal utilization. Nonetheless, there are promising indications that these technologies will allow an expansion of the DCD donor pool. The sum of the current emerging multiple tools (MP, common process for DCD organ procurements and functional graft evaluation during NRP/MP) seems promising to decrease one of the most important factors associated with low DCD utilization: the uncertainty of the outcome.

Recommendations for expanding DCD organ utilization:

- ❖ Reducing the uncertainty of poor outcomes associated with DCD transplantation (especially IC and delayed graft function) is essential to increasing DCD utilization. New technologies (MP and/or NRP) have the potential to improve outcomes and therefore increase utilization.

Conclusion and future prospects

The most important conclusion of the summit was the mutual agreement that DCD donation represents the only source of organs that will significantly increase the number of grafts available for transplantation in the US in the near future. Moreover, the wider acceptance and implementation of technologies like MP and NRP will allow for expanded graft utilization because of better recipient outcomes. To promote the expansion of DCD in the US, several barriers must be addressed. First, the standardization of DCD recovery policies and procedures is essential to achieve more uniform acceptance of DCD donors and mitigate some of the costs associated with DCD procurement (82). Second, OPOs must develop and implement best practices for the identification, authorization, and management of DCD donors. Third, cost-effective strategies for DCD procurements should be incentivized. Fourth, risk assessment models should be used for donor-recipient matching and new models should be developed to incorporate ex situ MP and NRP. Fifth, the wider utilization of technologies like *ex situ* MP and NRP to expand the donor pool, decrease the risk of poorer recipient outcomes, and increase overall graft and patient survival should be encouraged.

Further efforts are necessary to decrease the risk perception concerning DCD grafts in particular settings, as the attitudes of transplant centers, surgeons, OPOs, and regions can have an impact on the utilization of DCD donors.

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Footnote

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References

1. A definition of irreversible coma. Report of the Ad Hoc Committee of the Harvard Medical School to Examine the Definition of Brain Death. JAMA 1968;205:337-40.
2. Abt PL, Fisher CA, Singhal AK. Donation after cardiac death in the US: history and use. J Am Coll Surg 2006;203:208-25.
3. Casavilla A, Ramirez C, Shapiro R, et al. Experience with liver and kidney allografts from non-heart-beating donors. Transplantation 1995;59:197-203.
4. D'Alessandro AM, Hoffmann RM, Knechtle SJ, et al. Successful extrarenal transplantation from non-heart-beating donors. Transplantation 1995;59:977-82.
5. ; . Recommendations for nonheartbeating organ donation. A position paper by the Ethics Committee, American College of Critical Care Medicine, Society of Critical Care Medicine. Crit Care Med 2001;29:1826-31.
6. Institute of Medicine (US) Committee on Non-Heart-Beating Transplantation II: The Scientific and Ethical Basis for Practice and Protocols. Non-Heart-Beating Organ Transplantation: Practice and Protocols. Washington (DC); 2000.
7. Organ Procurement and Transplantation Network. Donor: Donation Year by Donation After Circulatory Death (DCD) [cited October 31 2022]. Available online: https://optn.transplant.hrsa.gov/data/view-data-reports/build-advanced/.
8. Organ Procurement and Transplantation Network. All-time records again set in 2021 for organ transplants, organ donation from deceased donors 2022 [cited October 31 2022]. Available online: https://optn.transplant.hrsa.gov/news/all-time-records-again-set-in-2021-for-organ-transplants-organ-donation-from-deceased-donors/.
9. Heron M. Deaths: Leading Causes for 2019. Natl Vital Stat Rep 2021;70:1-114.
10. Lentine KL, Smith JM, Hart A, et al. OPTN/SRTR 2020 Annual Data Report: Kidney. Am J Transplant 2022;22 Suppl 2:21-136.
11. Colvin M, Smith JM, Ahn Y, et al. OPTN/SRTR 2020 Annual Data Report: Heart. Am J Transplant 2022;22 Suppl 2:350-437.
12. Valapour M, Lehr CJ, Skeans MA, et al. OPTN/SRTR 2020 Annual Data Report: Lung. Am J Transplant 2022;22 Suppl 2:438-518.
13. Bobba CM, Whitson BA, Henn MC, et al. Trends in Donation After Circulatory Death in Lung Transplantation in the United States: Impact Of Era. Transpl Int 2022;35:10172.
14. Hessheimer AJ, Polak W, Antoine C, et al. Regulations and Procurement Surgery in DCD Liver Transplantation: Expert Consensus Guidance From the International Liver Transplantation Society. Transplantation 2021;105:945-51.
15. Kalisvaart M, Croome KP, Hernandez-Alejandro R, et al. Donor Warm Ischemia Time in DCD Liver Transplantation-Working Group Report From the ILTS DCD, Liver Preservation, and Machine Perfusion Consensus Conference. Transplantation 2021;105:1156-64.
16. Reich DJ, Mulligan DC, Abt PL, et al. ASTS recommended practice guidelines for controlled donation after cardiac death organ procurement and transplantation. Am J Transplant 2009;9:2004-11.
17. Ethical controversies in organ donation after circulatory death. Pediatrics 2013;131:1021-6.
18. Wall AE, Shabbir R, Chebrolu S, et al. Variation in donation after circulatory death hospital policies in a single donor service area. Am J Surg 2022;224:595-601.
19. Narvaez JRF, Nie J, Noyes K, et al. Transplant Outcomes of Donation After Circulatory Death Livers Recovered With Versus Without Premortem Heparin Administration. Liver Transpl 2020;26:247-55.
20. Choubey AP, Siskind EJ, Ortiz AC, et al. Disparities in DCD organ procurement policy from a national OPO survey: A call for standardization. Clin Transplant 2020;34:e13826.
21. Siddique A, Parekh KR, Huddleston SJ, et al. A call to action in thoracic transplant surgical training. J Heart Lung Transplant 2023;42:1627-31.
22. Sonnenberg EM, Hsu JY, Reese PP, et al. Wide Variation in the Percentage of Donation After Circulatory Death Donors Across Donor Service Areas: A Potential Target for Improvement. Transplantation 2020;104:1668-74.
23. Moazami N, Smith D, Galloway A. Logistics for expanding heart transplantation from donation after circulatory death using normothermic regional perfusion. JTCVS Tech 2022;12:110-2.
24. Smith DE, Kon ZN, Carillo JA, et al. Early experience with donation after circulatory death heart transplantation

using normothermic regional perfusion in the United States. J Thorac Cardiovasc Surg 2022;164:557-568.e1.
25. Asrani SK, Saracino G, Wall A, et al. Assessment of donor quality and risk of graft failure after liver transplantation: The ID(2) EAL score. Am J Transplant 2022;22:2921-30.
26. 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;27:756-9.
27. Lin Y, Teixeira-Pinto A, Opdam H, et al. Nonutilization of Kidneys From Donors After Circulatory Determinant of Death. Transplant Direct 2022;8:e1331.
28. Hessheimer AJ, de la Rosa G, Gastaca M, et al. Abdominal normothermic regional perfusion in controlled donation after circulatory determination of death liver transplantation: Outcomes and risk factors for graft loss. Am J Transplant 2022;22:1169-81.
29. Johnston CJC, Sherif AE, Oniscu GC. Transplantation of discarded livers: the complementary role of normothermic regional perfusion. Nat Commun 2021;12:4471.
30. Mergental H, Laing RW, Kirkham AJ, et al. Transplantation of discarded livers following viability testing with normothermic machine perfusion. Nat Commun 2020;11:2939.
31. Sellers MT, Nassar A, Alebrahim M, et al. Early United States experience with liver donation after circulatory determination of death using thoraco-abdominal normothermic regional perfusion: A multi-institutional observational study. Clin Transplant 2022;36:e14659.
32. Fernández-de la Varga M, Del Pozo-Del Valle P, Béjar-Serrano S, et al. Good post-transplant outcomes using liver donors after circulatory death when applying strict selection criteria: A propensity-score matched-cohort study. Ann Hepatol 2022;27:100724.
33. Costa J, Shah L, Robbins H, et al. Use of Lung Allografts From Donation After Cardiac Death Donors: A Single-Center Experience. Ann Thorac Surg 2018;105:271-8.
34. Organ Procurement and Transplantation Network. View Data Reports: Build Advanced [cited February 28 2022]. Available online: https://optn.transplant.hrsa.gov/data/view-data-reports/build-advanced/.
35. Kotsopoulos A, Vos P, Witjes M, et al. Prospective Multicenter Observational Cohort Study on Time to Death in Potential Controlled Donation After Circulatory Death Donors-Development and External Validation of Prediction Models: The DCD III Study. Transplantation 2022;106:1844-51.
36. Hobeika MJ, Menser T, Nguyen DT, et al. United States donation after circulatory death liver transplantation is driven by a few high-utilization transplant centers. Am J Transplant 2020;20:320-1.
37. Goldberg DS, Karp SJ, McCauley ME, et al. Interpreting Outcomes in DCDD Liver Transplantation: First Report of the Multicenter IDOL Consortium. Transplantation 2017;101:1067-73.
38. Foley DP, Fernandez LA, Leverson G, et al. Donation after cardiac death: the University of Wisconsin experience with liver transplantation. Ann Surg 2005;242:724-31.
39. Skaro AI, Jay CL, Baker TB, et al. The impact of ischemic cholangiopathy in liver transplantation using donors after cardiac death: the untold story. Surgery 2009;146:543-52; discussion 552-3.
40. de Vera ME, Lopez-Solis R, Dvorchik I, et al. Liver transplantation using donation after cardiac death donors: long-term follow-up from a single center. Am J Transplant 2009;9:773-81.
41. Jay C, Ladner D, Wang E, et al. A comprehensive risk assessment of mortality following donation after cardiac death liver transplant - an analysis of the national registry. J Hepatol 2011;55:808-13.
42. Jay CL, Lyuksemburg V, Ladner DP, et al. Ischemic cholangiopathy after controlled donation after cardiac death liver transplantation: a meta-analysis. Ann Surg 2011;253:259-64.
43. Taylor R, Allen E, Richards JA, et al. Survival advantage for patients accepting the offer of a circulatory death liver transplant. J Hepatol 2019;70:855-65.
44. de Kok MJ, McGuinness D, Shiels PG, et al. The Neglectable Impact of Delayed Graft Function on Long-term Graft Survival in Kidneys Donated After Circulatory Death Associates With Superior Organ Resilience. Ann Surg 2019;270:877-83.
45. Dhital K, Ludhani P, Scheuer S, et al. DCD donations and outcomes of heart transplantation: the Australian experience. Indian J Thorac Cardiovasc Surg 2020;36:224-32.
46. Van Raemdonck D, Keshavjee S, Levvey B, et al. Donation after circulatory death in lung transplantation-five-year follow-up from ISHLT Registry. J Heart Lung Transplant 2019;38:1235-45.
47. Kwong AJ, Flores A, Saracino G, et al. Center Variation in Intention-to-Treat Survival Among Patients Listed for Liver Transplant. Liver Transpl 2020;26:1582-93.
48. Zhu MZL, Levvey BJ, McGiffin DC, et al. An Intention-to-treat View of Lung Transplantation for Interstitial Lung Disease: Successful Strategies to Minimize Waiting

List and Posttransplant Mortality. Transplantation 2022;106:188-99.
49. Organ Procurement and Transplantation Network. Guidance to Liver Transplant Programs and the National Liver Review Board for: Adult MELD Exception Review [cited September 21 2023]. Available online: https://optn.transplant.hrsa.gov/media/esdjnjok/20200804_nlrb_adult_other_guidance.pdf.
50. Hessheimer AJ, Cárdenas A, García-Valdecasas JC, et al. Can we prevent ischemic-type biliary lesions in donation after circulatory determination of death liver transplantation? Liver Transpl 2016;22:1025-33.
51. Kalisvaart M, de Haan JE, Polak WG, et al. Comparison of Postoperative Outcomes Between Donation After Circulatory Death and Donation After Brain Death Liver Transplantation Using the Comprehensive Complication Index. Ann Surg 2017;266:772-8.
52. 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;68:456-64.
53. Giorgakis E, Khorsandi SE, Mathur AK, et al. Comparable graft survival is achievable with the usage of donation after circulatory death liver grafts from donors at or above 70 years of age: A long-term UK national analysis. Am J Transplant 2021;21:2200-10.
54. Cascales-Campos PA, Ferreras D, Alconchel F, et al. Controlled donation after circulatory death up to 80 years for liver transplantation: Pushing the limit again. Am J Transplant 2020;20:204-12.
55. Kohli DR, Harrison ME, Adike AO, et al. Predictors of Biliary Strictures After Liver Transplantation Among Recipients of DCD (Donation After Cardiac Death) Grafts. Dig Dis Sci 2019;64:2024-30.
56. Croome KP, Mao S, Taner CB. The Current Landscape of Liver Transplantation After Ex Situ Machine Perfusion and Normothermic Regional Perfusion in the United States. Liver Transpl 2022;28:1108-12.
57. Sasaki K, Nair A, Firl DJ, et al. Conditional probability of graft survival in liver transplantation using donation after circulatory death grafts - a retrospective study. Transpl Int 2021;34:1433-43.
58. Schlegel A, Foley DP, Savier E, et al. Recommendations for Donor and Recipient Selection and Risk Prediction: Working Group Report From the ILTS Consensus Conference in DCD Liver Transplantation. Transplantation 2021;105:1892-903.
59. Mathur AK, Heimbach J, Steffick DE, et al. Donation after cardiac death liver transplantation: predictors of outcome. Am J Transplant 2010;10:2512-9.
60. Levvey B, Keshavjee S, Cypel M, et al. Influence of lung donor agonal and warm ischemic times on early mortality: Analyses from the ISHLT DCD Lung Transplant Registry. J Heart Lung Transplant 2019;38:26-34.
61. United Network for Organ Sharing. UNOS using a collaborative improvement model to increase DCD lung transplantation. News release, December 14, 2022 2022 [cited September 21 2023]. Available online: https://unos.org/news/dcd-lung-transplant-collaborative/.
62. Schlegel A, van Reeven M, Croome K, et al. A multicentre outcome analysis to define global benchmarks for donation after circulatory death liver transplantation. J Hepatol 2022;76:371-82.
63. Miñambres E, Suberviola B, Dominguez-Gil B, et al. Improving the Outcomes of Organs Obtained From Controlled Donation After Circulatory Death Donors Using Abdominal Normothermic Regional Perfusion. Am J Transplant 2017;17:2165-72.
64. Barrou B, Billault C, Nicolas-Robin A. The use of extracorporeal membranous oxygenation in donors after cardiac death. Curr Opin Organ Transplant 2013;18:148-53.
65. Schlegel A, Muller X, Kalisvaart M, et al. Outcomes of DCD liver transplantation using organs treated by hypothermic oxygenated perfusion before implantation. J Hepatol 2019;70:50-7.
66. van Rijn R, Karimian N, Matton APM, et al. Dual hypothermic oxygenated machine perfusion in liver transplants donated after circulatory death. Br J Surg 2017;104:907-17.
67. van Rijn R, Schurink IJ, de Vries Y, et al. Hypothermic Machine Perfusion in Liver Transplantation - A Randomized Trial. N Engl J Med 2021;384:1391-401.
68. 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;157:189-98.
69. Ghinolfi D, Dondossola D, Rreka E, et al. Sequential Use of Normothermic Regional and Ex Situ Machine Perfusion in Donation After Circulatory Death Liver Transplant. Liver Transpl 2021;27:385-402.
70. van Leeuwen OB, de Vries Y, Fujiyoshi M, et al. Transplantation of High-risk Donor Livers After Ex Situ Resuscitation and Assessment Using Combined Hypo- and Normothermic Machine Perfusion: A Prospective Clinical Trial. Ann Surg 2019;270:906-14.

71. Hessheimer AJ, Riquelme F, Fundora-Suárez Y, et al. Normothermic perfusion and outcomes after liver transplantation. Transplant Rev (Orlando) 2019;33:200-8.
72. Tingle SJ, Figueiredo RS, Moir JA, et al. Hypothermic machine perfusion is superior to static cold storage in deceased donor kidney transplantation: A meta-analysis. Clin Transplant 2020;34:e13814.
73. Hessheimer AJ, Coll E, Torres F, et al. Normothermic regional perfusion vs. super-rapid recovery in controlled donation after circulatory death liver transplantation. J Hepatol 2019;70:658-65.
74. Watson CJE, Hunt F, Messer S, et al. In situ normothermic perfusion of livers in controlled circulatory death donation may prevent ischemic cholangiopathy and improve graft survival. Am J Transplant 2019;19:1745-58.
75. De Carlis R, Di Sandro S, Lauterio A, et al. Liver Grafts From Donors After Circulatory Death on Regional Perfusion With Extended Warm Ischemia Compared With Donors After Brain Death. Liver Transpl 2018;24:1523-35.
76. Ruiz P, Gastaca M, Bustamante FJ, et al. Favorable Outcomes After Liver Transplantation With Normothermic Regional Perfusion From Donors After Circulatory Death: A Single-center Experience. Transplantation 2019;103:938-43.
77. Antoine C, Jasseron C, Dondero F, et al. Liver Transplantation From Controlled Donors After Circulatory Death Using Normothermic Regional Perfusion: An Initial French Experience. Liver Transpl 2020;26:1516-21.
78. Wall A, Rosenzweig M, McKenna GJ, et al. Six-month abdominal transplant recipient outcomes from donation after circulatory death heart donors: A retrospective analysis by procurement technique. Am J Transplant 2023;23:987-95.
79. Boteon YL, Hessheimer AJ, Brüggenwirth IMA, et al. The economic impact of machine perfusion technology in liver transplantation. Artif Organs 2022;46:191-200.
80. Handley TJ, Arnow KD, Melcher ML. Despite Increasing Costs, Perfusion Machines Expand the Donor Pool of Livers and Could Save Lives. J Surg Res 2023;283:42-51.
81. Webb AN, Lester ELW, Shapiro AMJ, et al. Cost-utility analysis of normothermic machine perfusion compared to static cold storage in liver transplantation in the Canadian setting. Am J Transplant 2022;22:541-51.
82. Croome KP, Barbas AS, Whitson B, et al. American Society of Transplant Surgeons recommendations on best practices in donation after circulatory death organ procurement. Am J Transplant 2023;23:171-9.

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