

A Pragmatic Approach to Normothermic Regional Perfusion and Machine Perfusion in Donation After Circulatory Death Liver Transplantation

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Controlled donation after circulatory death (DCD) liver transplantation in Italy is uniquely challenged by a legally mandated 20 minute no-touch period after circulatory arrest, prolonging warm ischemia before intervention. In this setting, graft viability depends not only on donor selection but also on the rapid, effective establishment of normothermic regional perfusion (NRP). We describe a standardized technical approach to rapid NRP initiation and intraoperative graft triage in Maastricht category III DCD donation. After the no-touch period, percutaneous femoral cannulation is initiated while laparotomy and sternotomy are performed in parallel. In cases of failed cannulation or inadequate perfusion, a predefined surgical rescue strategy is applied. Graft selection is guided by a structured five-parameter assessment: when all criteria are met, grafts proceed to transplantation after hypothermic perfusion (HOPE/D-HOPE); when partially met, *ex situ* normothermic machine perfusion (NMP) is performed with transplantation only if functional recovery is achieved; when not met, grafts are discarded. Between November 2018 and December 2025, 38 donors were evaluated, and 33 grafts (87%) were transplanted. All transplanted grafts achieved 100% graft and patient survival. This standardized, reproducible approach may improve graft utilization and optimize integration of NRP and machine perfusion in settings with prolonged legally mandated no-touch intervals. *ASAIO Journal* 2026; XX:XX–XX

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Technical Note

Donation after circulatory death (DCD) liver transplantation represents a key strategy to expand organ availability, although its implementation remains highly dependent on national regulatory frameworks and institutional organization.^{1,2} In Italy, death declaration after circulatory arrest requires a legally mandated 20 minute no-touch period, one of the longest standstill intervals worldwide.³ For many years, this prolonged warm ischemic interval was seen as a major barrier to the development of DCD liver transplantation programs. Consequently, the Italian experience evolved differently from that of many other countries, where DCD transplantation was established before the widespread adoption of regional perfusion techniques. In Italy, instead, DCD liver transplantation developed in parallel with normothermic regional perfusion (NRP), which quickly became an essential part of the procurement process. Beyond its role as a preservation strategy, NRP enables functional resuscitation of abdominal organs after the prolonged ischemic insult imposed by the national regulatory framework, allowing organ assessment and supporting the safe use of DCD grafts.⁴

In this context, the interval immediately following the no-touch period represents a narrow and decisive window, during which delays in restoring oxygenated circulation may translate into clinically significant ischemic injury, particularly affecting the biliary epithelium. To address this constraint, we developed a standardized operative workflow for Maastricht category III DCD procurement, designed to minimize procedural latency, ensure rapid vascular control, and allow immediate correction of technical limitations.

All procedures are performed by a dedicated multidisciplinary team comprising a transplant surgeon, an anesthesiologist experienced in percutaneous vascular cannulation, a perfusionist, and an operating room nurse. Rather than relying on a dedicated training pathway, the program evolved through the integration of expertise already present within the institution, including anesthesiologists routinely performing extracorporeal cannulation and perfusionists actively involved in cardiothoracic transplantation and extracorporeal circulation. As procedural volume increased, procurement activities were progressively concentrated among surgeons with specific expertise in DCD recovery and normothermic regional perfusion. The consistency of team composition, combined

with systematic pre-procedural briefing and post-procedural debriefing sessions, promoted continuous workflow optimization, facilitated knowledge sharing, and contributed to the progressive maturation of the program.

Withdrawal of life-sustaining treatment is conducted in the operating room, ensuring that procurement can begin without delay. Before withdrawal, all equipment required for both percutaneous and open vascular access is prepared and readily available.

At the end of the no-touch period, NRP initiation is performed through the simultaneous execution of percutaneous and surgical maneuvers. Percutaneous femoral cannulation is attempted by the anesthesiologist while surgical access is established through a xiphoid-pubic laparotomy and median sternotomy. This parallel approach avoids the delays inherent in sequential strategies and ensures that, regardless of the success of percutaneous access, vascular control can be rapidly achieved.

Direct thoracic aortic clamping is performed early, allowing immediate regionalization and eliminating the need for endovascular balloon positioning, which may be associated with technical complexity, delayed deployment, or incomplete occlusion. This step is critical to rapidly reestablish oxygenated perfusion to the abdominal organs under controlled conditions.

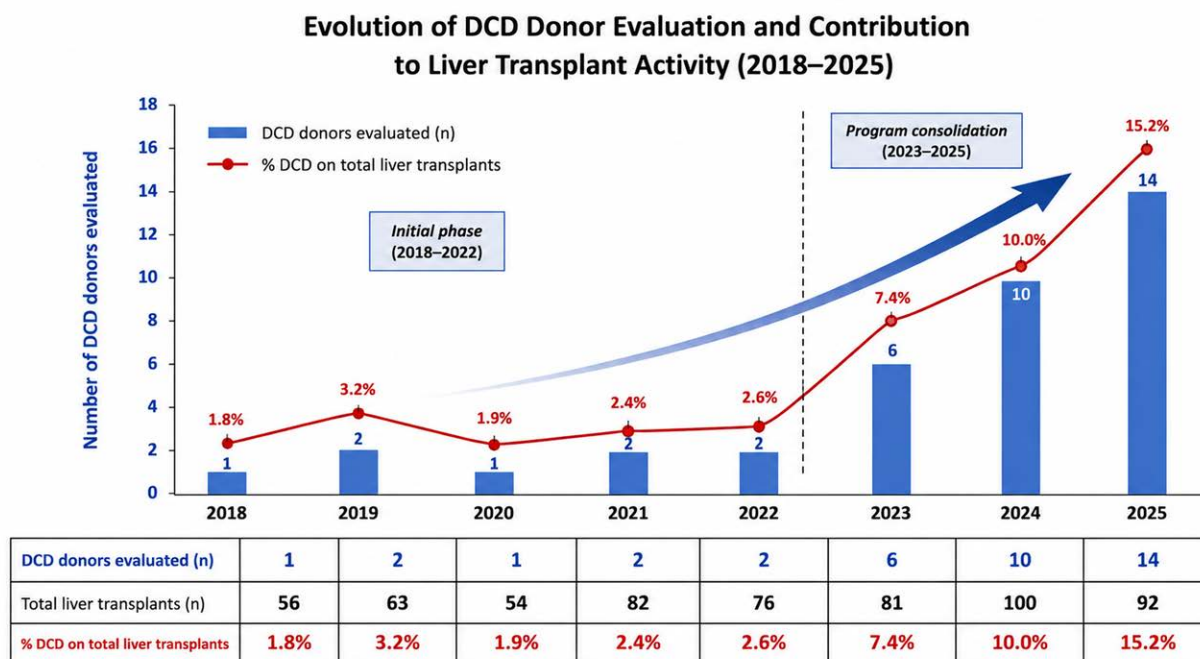
The initial phase of NRP requires active management and continuous reassessment. In cases of failed or inadequate arterial cannulation, direct access to the iliac artery or abdominal aorta is obtained without delay. Similarly, when venous

drainage is insufficient or complicated, the inferior vena cava is exposed and cannulated under direct vision, allowing immediate correction of vascular injury and restoration of effective outflow.

When perfusion flows remain suboptimal despite adequate cannulation, targeted maneuvers are performed to improve effective hepatic perfusion. These include selective reduction of the perfused vascular territory through ligation of the contralateral iliac artery or the inferior mesenteric artery, thereby redirecting flow toward the splanchnic circulation. This strategy is particularly useful in marginal donors with limited hemodynamic reserve.

Conversely, once adequate perfusion parameters are achieved, further dissection is intentionally limited. Under systemic heparinization, excessive surgical manipulation may lead to diffuse bleeding, hemodilution, and reduced perfusion stability, ultimately compromising the quality of reperfusion. The operative strategy therefore emphasizes early control followed by restraint.

Normothermic regional perfusion is maintained for a minimum of two hours before proceeding to cold perfusion and organ procurement, allowing metabolic recovery and functional assessment. Graft viability is evaluated using five predefined criteria: macroscopic appearance assessed before and during the early phase of NRP, lactate clearance trend over time, transaminase levels ($AST/ALT \leq 1,000$ Unit/L), perfusion flow (> 1.7 L/min/m²), and histological assessment, including the absence of confluent necrosis, macrovesicular steatosis $< 40\%$, and fibrosis less than or equal to Ishak stage 2.



DCD: donation after circulatory death; LT: liver transplant.

Figure 1. Evolution of DCD donor activity and contribution to liver transplant volume at our center (2018–2025). Annual number of DCD donors evaluated at our institution (blue bars) and corresponding proportion of DCD liver transplants relative to total annual liver transplant activity (red line). After an initial phase characterized by low procedural volume, DCD activity progressively increased over time, with a marked expansion from 2023 onward, ultimately accounting for approximately 10–15% of the overall liver transplant volume in the most recent years. DCD, donation after circulatory death; LT, liver transplantation.

Based on this evaluation, graft utilization is determined through a structured intraoperative decision algorithm. When all five criteria are satisfied, the graft proceeds to cold perfusion with Servator C solution, followed by static cold storage, dual hypothermic oxygenated perfusion (D-HOPE), and transplantation. If up to two criteria are not met, *ex situ* normothermic machine perfusion (NMP) is performed, and transplantation is considered only if adequate functional recovery is demonstrated. When more than two criteria are not satisfied, the graft is discarded without proceeding to *ex situ* perfusion. This approach reflects a deliberate and selective use of machine perfusion technologies, reserving NMP for cases in which uncertainty persists after NRP rather than applying it routinely.

Between November 2018 and December 2025, 38 DCD donors were evaluated, with an acceptance rate of 100%, and 33 grafts (87%) were transplanted.

Over the study period, a progressive increase in DCD donor activity was observed at our center. Despite a concurrent rise in the overall number of liver transplants performed, the contribution of DCD grafts to total liver transplant activity steadily increased over time, reaching approximately 10–15% of all liver transplants in the most recent years. This growth was accompanied by continuous refinement of procurement and perfusion strategies, improved multidisciplinary coordination, and progressive optimization of NRP management and graft assessment. These developments allowed the program to gradually expand its activity and safely use increasingly complex

DCD donors. The annual evolution of the program is summarized in Figure 1.

Table 1 summarizes the main donor-recipient features and the perfusion data. Donors had a median age of 69.5 years, and recipients had a median age of 62 years, with hepatocellular carcinoma representing the most frequent indication for transplantation. Eight grafts underwent NMP due to borderline findings during NRP, including two cases requiring sequential D-HOPE followed by NMP. Normothermic regional perfusion was initiated within 60 minutes of the agonal phase in 33 cases (87%), reflecting the effectiveness of the parallelized workflow.

In six cases (16%), failure of percutaneous cannulation required immediate conversion to direct surgical access, allowing successful establishment of perfusion and preventing graft loss. Early allograft dysfunction was frequently observed but remained transient, consistent with the known physiological impact of DCD procurement. Biliary complications occurred in 33% of cases ($n = 11$), a rate aligned with previously reported benchmark series.⁵ All biliary complications consisted of anastomotic strictures occurring within the first posttransplant year and were successfully managed by endoscopic treatment (ERCP), without graft loss or retransplantation. The majority occurred during the early years of the program, with five of the first eight transplanted grafts developing anastomotic strictures, whereas the incidence progressively declined following ongoing refinements in procurement techniques, perfusion management, and graft

Table 1. Donor and Recipient Characteristics, Perfusion Strategy, and Posttransplant Outcomes

Donor Characteristics (n = 38)	
Age, years—median (IQR)	69.5 (62–74.25)
Female sex—n (%)	16 (42%)
Donor risk index—median (IQR)	2.9 (2.8–3.1)
Recipient Characteristics (n = 33)	
Age, years—median (IQR)	62 (59–66)
Female sex—n (%)	8 (24%)
Indication for liver transplantation—n (%)	
HCC	22 (67%)
Cirrhosis (HCV)	2 (6%)
Cirrhosis (HBV)	1 (3%)
Primary biliary cholangitis	2 (6%)
Metabolic dysfunction–associated cirrhosis	3 (9%)
Alcohol-related cirrhosis	3 (9%)
Hospital stay, days—median (IQR)	17 (11–21)
Procurement and Perfusion	
Grafts transplanted/evaluated—n (%)	33/38 (87%)
NRP initiated ≤ 60 min from agonal phase—n (%)	33 (87%)
<i>Ex situ</i> NMP after NRP—n (%)	11 (29%)
Sequential D-HOPE + NMP—n (%)	2 (6%)
D-HOPE after NRP—n (%)	20 (55%)
Grafts discarded after NRP/NMP—n (%)	3 (8%)
Grafts discarded after NRP without <i>ex situ</i> perfusion—n (%)	2 (5%)
NRP Troubleshooting	
Surgical cannulation required—n (%)	6 (16%)
Arterial (abdominal aorta)	4 (10%)
Venous (IVC/atrium)	2 (5%)

D-HOPE, dual hypothermic oxygenated perfusion; HBV, hepatitis B virus; HCC, hepatocellular carcinoma; HCV, hepatitis C virus; IQR, interquartile range; IVC, inferior vena cava; LT, liver transplantation; NMP, normothermic machine perfusion; NRP, normothermic regional perfusion.

selection. All transplanted grafts achieved 100% graft and patient survival during follow-up.

This experience reflects a systematically higher-risk setting, characterized by prolonged mandatory no-touch intervals and elevated donor risk profiles. Within this context, the combination of rapid NRP establishment, direct vascular control, and structured intraoperative decision-making allowed outcomes that compare favorably with those reported in benchmark cohorts,⁵ despite less favorable baseline conditions.

Machine perfusion technologies have significantly improved outcomes in DCD liver transplantation^{6,7}; however, their indiscriminate use may not be justified in all settings. When NRP is promptly established and actively managed, it may provide sufficient functional recovery to allow direct transplantation in a substantial proportion of cases, reserving NMP for selected grafts with uncertain viability.

In systems where prolonged no-touch periods are mandated, the optimization of the early post-arrest phase becomes central to the success of DCD programs. A standardized approach integrating rapid access, intraoperative adaptability, and structured graft assessment may mitigate the impact of extended warm ischemia, improve graft utilization, and support a more rational allocation of perfusion technologies.

Although primarily developed for abdominal NRP, the workflow described in this report has also been adopted within our recently established thoracoabdominal NRP (TA-NRP) program. In this setting, the multidisciplinary team is expanded to include a senior cardiac surgeon responsible for sternotomy and supra-aortic vessel control to achieve thoracic regionalization before perfusion initiation. However, the fundamental organizational principles remain unchanged. In particular, thoracic and abdominal teams work simultaneously in parallel, with abdominal access obtained concurrently to allow immediate supraceliac aortic control as a rescue strategy should thoracic regionalization prove difficult or delayed. Consistent

with our philosophy of minimizing unnecessary dissection, supraceliac aortic isolation is performed only when required, thereby preserving procedural efficiency while maintaining a predefined pathway for rapid troubleshooting. These considerations suggest that the proposed framework may be readily adapted to multi-organ TA-NRP programs.

Beyond the Italian regulatory context, the organizational principles underlying this workflow are not specific to a 20 minute no-touch period and may be adapted to centers operating under different legal and logistical conditions.

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