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ORGAN DONATION AND ALLOCATION

TRANSPLANTATION IN TRANSITION: TWO DECADES OF EVOLUTION, DISRUPTION, AND REDEFINITION

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Summary

While advances in immunosuppression are stagnating, solid organ transplantation has experienced substantial growth over the past two decades, including changes in donor and recipient epidemiology, the establishment of donation after cardiocirculatory death, expanded use of *ex-situ* and *ex vivo* machine perfusion, and the adoption of robotic techniques for living donor organ procurement and graft implantation. These advances are changing the practice of organ procurement and transplantation, but they also present new challenges. Healthcare professionals, patients, caregivers, and healthcare organizations are encouraged to adapt to these changes by modifying their work methods, mindsets, and habits accordingly. A public discussion on the sustainability of modern transplant medicine, access to transplant care for socially disadvantaged patients, training the future workforce, expanding the benefits of transplantation beyond the traditional concept of utility, and addressing the ethical dilemmas associated with caring for increasingly complex patients is encouraged at both national and international levels.

Key words: transplantation, organ donation, evolution, ethics, dilemmas

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Abbreviations

CNI: calcineurin inhibitor
DCD: donation after cardiocirculatory death
DGF: delayed graft function
EAD: early allograft dysfunction
ECD: extend criteria donor
GLP-1: glucagon-like peptide-1
HCC: hepatocellular carcinoma
HCV: hepatitis C virus
HMP: hupothermic machine perfusion
KT: kidney transplantation
LDLT: living donor liver transplantation
LT: liver transplantation
NMP: normothermic machine perfusion
NRP: normothermic regional perfusion
MP: machine perfusion
mTORi: mammalian target of rapamycin inhibitors
PNF: primary nonfunction
PAKT: pancreas after kidney transplantation
PT: pancreas transplantation

PTA: pancreas transplantation alone
SCS: static cold storage
SOT: solid organ transplantation

INTRODUCTION

Over the past 20 years, most Western countries have experienced rapid changes in abdominal organ transplantation [1]. Comparing transplantation from two decades ago to today, the only consistent factor is the need to replace organ function in cases of end-stage failure. Nearly everything else has evolved, except for immunosuppression protocols, which have mostly remained based on calcineurin inhibitors (CNI) [2].

However, the donor profile has changed considerably: donors are now older and more complex, often because of longer stays in intensive care units [3]. These extended stays are often linked to a higher rate of infections, which, in the modern era, increasingly involve antibiotic-resistant organisms [4]. Additionally, donation after circulatory death (DCD) has become more common [3,5]. The use of these organs has proven feasible, partly due to the adoption of normothermic regional perfusion (NRP) [6] and end-ischemic *ex-situ* machine perfusion (MP) [7]. Still, it has also required significant organizational changes and a shift in mindset [7].

The indications for liver and, to some extent, pancreas transplantation have changed. For the liver, this shift is mainly due to a significant decline in chronic viral hepatitis cases, combined with an increase in metabolic liver diseases [8]. However, this rise has not been enough numerically to replace the decrease in viral hepatitis cases, potentially reversing the historical pattern from a donor shortage to a recipient shortage. Consequently, this shift has prompted a reevaluation of previous barriers that restricted or excluded transplant access for individuals with alcohol or substance use disorders [9]. It has also broadened the scope of what is now called transplant oncology [10]. In this context, it is essential to note that the improved understanding of tumor biology and the availability of more effective cancer treatments have narrowed the gap between transplantation and oncology to the extent that, in some cases, transplantation has become the optimal treatment option for certain tumors [10].

The advent of robotic surgery has also expanded into transplantation, not only for harvesting organs or parts of organs from living donors but also for implanting kidneys, pancreas, and liver [11]. Notably, robotic heart [12] and lung transplants [13] have already been performed.

All of this raises new ethical questions. Should we, and if so, when should we, impose limits on expanding transplant indications? Or is our primary goal to perform as many transplants as possible, especially when organ scarcity is no longer the main obstacle? In such a case, should we still require a high average likelihood of success, or is it acceptable to proceed based on the potential for success in each individual patient?

DECEASED DONORS

There is no doubt that, over the past twenty years, especially in Western countries like Italy, the deceased donor population has gradually aged, and the donor "quality" has declined due to increased risk factors for potential disease transmission to recipients and/or poorer transplant outcomes [14]. While this trend has led to the development of strategies aimed at better utilizing organs once considered "marginal," it is clear that transplant results may be negatively affected, particularly in the long term, a dimension where robust data are still largely absent.

In Italy, the average donor age, which is slightly lowered by including pediatric donors, increased from 57.8 years in 2014 to 62.1 years in 2023 [14]. The increase in donor age was more pronounced in regions with a higher number of donors. For example, in 2023, even though the national median age of deceased donors was 65 years (including DCDs), the median donor age was 73 years in Tuscany, 70 years in Emilia-Romagna, and 69 years in Veneto [14]. During the same period (2014-2023), the number of DCDs rose significantly from 6 to 211 (an increase from 0.1 to 3.5 donors per million population, pmp). At the same time, the percentage of donors classified as having non-standard biological risk climbed from 22% to 78% [14].

The case of Tuscany well illustrates the change in the epidemiology of deceased donation. In 2023, organs were obtained from 220 donors; however, only 169 (77%) had at least one organ transplanted. Concerning DCDs in the same year, cardiac death assessments were initiated for 57 potential donors, organs were retrieved from 30, and 12 donors' organs were ultimately used (representing 21% of cardiac death assessments and 40% of donors from whom organs were procured). Of the DCD donors used in Italy in 2023, 88% were over 50 years old, 52% were over 65, and 13% were aged 80 or older. Between 2019 and 2023, among 539 DCDs whose organs were transplanted in Italy, 462 (85.7%) were classified as Maastricht category III, 74 (13.7%) as category II, and 3 (0.5%) as category IV [14].

KIDNEY TRANSPLANTATION

The kidney is an organ whose function is significantly influenced by aging. After the age of 40, there is an average annual loss of approximately 1% of glomerular mass, which subsequently reduces organ function [15].

Additionally, the kidney is a primary target for hypertension and diabetes, conditions frequently observed in elderly deceased donors [16]. These conditions often serve as causes or contributing factors to acute cerebrovascular events that may lead to death and organ donation. Moreover, the kidney can experience acute injury related to the cause of death and the resuscitation process.

When considering all these factors together and comparing them with the primary goal of kidney transplantation (KT) – which is primarily to enhance quality of life – the expectations of patients (specifically, remaining dialysis-free with good renal function for as long as possible), and the potential to immunize the patient through transplantation (which may decrease the chances and success of later re-transplants) – it becomes clear that this "new" profile of renal donors presents unique challenges. The changing features of renal donors, initially described by the concept of "expanded criteria donors," have been more precisely detailed by the Kidney Donor Risk Index [17]. However, this index has needed regional adjustments, such as in Italy, to adequately reflect the additional risks associated with using non-ideal donors compared to average donors [14].

For recipients of isolated kidney transplants, these challenges become more intense due to increased competition for the limited pool of "ideal" grafts from specific patient groups, such as highly sensitized patients and those needing combined or urgent transplants because of a lack of dialysis access. One initial approach to addressing these issues has been the introduction of pre-transplant renal biopsy as a tool to provide morpho-functional correlation, to expand the use of kidneys previously considered marginal as dual rather than single transplants. Although this approach has a strong rationale, clear clinical validation demonstrating its long-term effectiveness is still lacking. Over time, renal biopsy has shifted from a permissive measure that allowed transplantation of organs that might otherwise be discarded based on clinical criteria to a necessary – and sometimes obstructive – part of organ evaluation, even when clinical parameters seem adequate. Renal histology is also affected by variability in interpretation, partly due to subjective factors and partly because of limited experience among pathologists, who often must provide urgent (on-call) assessments. Additional limitations of renal biopsy relate to the technique used (primarily core versus wedge biopsy) within the systemic framework, as biopsies may be performed by personnel not involved in the transplant team, requiring careful attention to procedural safety.

Another approach to increasing the use of kidneys from elderly donors involves adopting CNI-free or low-dose CNI immunosuppressive protocols, designed to reduce or avoid the nephrotoxicity associated with these agents [18]. This approach generated significant enthusiasm in the early 2000s, when it was believed that mammalian target of rapamycin inhibitors (mTORi) could support such regimens. However, over time, with few exceptions, these initial hopes have largely not been realized. To date, the standard immunosuppressive regimen in kidney transplantation remains based on calcineurin inhibitors combined with other agents. The possibility of reducing or eliminating calcineurin inhibitors is evaluated on a case-by-case basis, depending on specific donor–recipient compatibility, which is now better understood due to the role of eplets in histocompatibility [19].

The true "response" to this historic shift in renal donor epidemiology, where more deceased donors paradoxically provide fewer opportunities for lasting transplants, would be to expand living donor transplantation. This approach, which historically marked the beginning of the modern era of organ transplantation beyond KT alone, remains somewhat limited in Western countries due to various factors, many of which are cultural [20]. Among these may be a general lack of public awareness about the current realities of deceased donor kidney transplantation. It is perhaps difficult for the public to appreciate that, despite ongoing medical advances, results of kidney transplantation have experienced relative stagnation or even regression, primarily driven by changes in the deceased donor population.

LIVER TRANSPLANTATION

Liver transplantation (LT) is a treatment procedure designed to replace liver function in patients suffering from irreversible acute liver failure (e.g., fulminant hepatitis), those with acute-on-chronic liver failure, and patients with end-stage chronic liver disease [21].

The role of LT in cancer surgery has traditionally been limited to carefully selected patients with non-advanced hepatocellular carcinoma (HCC) [21]. Historically, and until about 10-15 years ago, LT was mostly performed on patients with chronic liver disease caused by viruses [21]. However, the development of direct-acting antivirals for hepatitis C virus (HCV), the availability of hepatitis B vaccines, and improved clinical management strategies have greatly decreased the number of such patients on transplant waiting lists. This shift has opened new treatment options for patients who were previously deemed unsuitable for LT [8]. More opportunities have arisen due to the significant rise in deceased donor numbers and the fact that aging has less harmful effects on the liver than on other solid organs. As a result, it is now possible to consider new categories of recipients who, previously, would have been contraindicated or accepted only under very selective criteria, based on the emerging concept of

transplant benefit [22,23]. This has also prompted changes in organ allocation policies.

The transplant benefit explains the survival advantage of liver transplantation compared to the best available alternative treatment [23]. It provides a framework to balance the traditional principles of urgency and utility, which have historically guided liver allocation [24]. The principle of clinical urgency prioritizes the sickest patients on the waiting list, who may still face suboptimal post-transplant outcomes due to their condition's severity and the organ's quality, whether ideal or marginal [24]. Conversely, the principle of utility focuses on patients with better baseline clinical conditions, who are more likely to have favorable outcomes and, in some cases, may do well even without transplantation [24]. The concept of transplant benefit has proven especially applicable in transplant oncology by defining the comparative advantage of LT over alternative oncologic or surgical approaches, and in patients with substance use disorders. In these contexts, it has significantly redefined transplant eligibility, expanding access to previously excluded populations [23].

Some of these new indications expand on existing criteria, such as permitting transplantation in patients with a history of alcohol or substance use disorder, even without the traditional six-month abstinence period, as long as they show favorable predictors of post-transplant sobriety and can support avoiding early relapse after the procedure [22].

For HCC patients, transplantation is now more frequently permitted beyond the Milan criteria, provided there is no macrovascular invasion or extrahepatic spread, especially when tumor downstaging has been successfully achieved through multimodal oncologic treatment [25]. Moreover, and somewhat unexpectedly, LT has been shown to prolong survival in a highly selected subset of patients with colorectal liver metastases, compared to all other available oncologic strategies [26]. Similarly, isolated liver metastases from neuroendocrine tumors, in well-selected patients, may benefit from transplantation with the intent to prolong survival beyond what is achievable with conventional oncologic or surgical therapies [27]. Among other neoplasms, although still mainly in clinical trials, emerging indications include intrahepatic and hilar cholangiocarcinoma, as well as a diverse group of rare primary liver malignancies that are not suitable for resection with standard surgical methods [28,29].

In this changing landscape, living donor liver transplantation (LDLT), even with the currently lower shortage of deceased donors, can play a crucial role. LDLT may offer transplant options for patients who exceed even the expanded criteria mentioned earlier, while providing the advantage of a scheduled, elective procedure that integrates well into multimodal oncologic treatment plans [30].

PANCREAS TRANSPLANTATION

Pancreas transplantation (PT) is the most reliable and reproducible form of beta-cell replacement therapy that can restore insulin independence in insulin-dependent diabetic patients [31]. The main indication is a patient with type 1 diabetes and diabetic nephropathy. In these cases, pancreas transplantation is typically performed as a simultaneous pancreas-kidney transplant (PKT). Other indications include pancreas after kidney transplant (PAKT), for those who have already received a kidney transplant or lost pancreas graft function after a simultaneous pancreas–kidney transplant, and pancreas transplant alone (PTA), primarily indicated in patients with brittle diabetes and hypoglycemia unawareness [32].

PT has the highest complication rate among all solid organ transplants [32]. The best outcomes are achieved using young donors (ideally under 45 years old), with a low body mass index, no risk factors for pancreatic injury, and who died from trauma. However, for the reasons mentioned above, such ideal donors have become increasingly rare. Moreover, over the past two to three decades, the improved management of type 1 diabetes has led to a reduction in the number of patients developing end-stage diabetic nephropathy or experiencing severe glycemic instability. Additionally, the onset of these complications has been delayed by approximately 10-15 years. As a result, the once "prototypical" transplant recipient (a type 1 diabetic with about 25 years of disease history and an average age of 35) has become less common, older, and often more overweight, partly due to longer and more intensive insulin therapy [33]. Consequently, there has been a decline in both the number of suitable donors and eligible recipients, resulting in a decrease in the total number of pancreas transplants performed [33].

To address this trend, selection criteria have been broadened for both donors and recipients. For donors, this includes using pediatric donors (including those with small body sizes), older donors, and those previously deemed marginal [34]. Additionally, in countries like the UK, pancreas transplants from DCDs have been established [35]. On the recipient side, there has been a consistent rise in the number of patients with non-type 1 diabetes, mainly type 2, who are insulin-dependent and have relatively low insulin resistance [33].

Data have shown that these expanded strategies enable PT to be performed with outcomes comparable to those achieved in the past, successfully resolving diabetes even in patients who do not fit the classical profile of type 1 diabetes [35]. In this evolution, bariatric surgical techniques and the availability of glucagon-like peptide-1 (GLP-1) receptor agonists have also played important roles.

MACHINE PERFUSION

Recent advances in *ex vivo* machine perfusion (MP), including hypothermic and normothermic techniques, have significantly enhanced our capacity to evaluate, restore, and schedule liver and kidney transplants [36]. MP provides a dynamic platform for objective viability assessment through continuous monitoring of metabolic, vascular, and functional biomarkers, such as bile flow, lactate clearance, perfusate pH, renal blood flow, urine output, and power-Doppler indices. These metrics enable clinicians to reliably recondition extended-criteria donor organs, which might otherwise be discarded, thereby increasing organ utilization and potentially decreasing wait-list mortality.

Randomized controlled trials comparing normothermic machine perfusion (NMP) of the liver to static cold storage (SCS) have shown a 50% reduction in graft injury, measured by hepatocellular enzyme release, a 50% decrease in organ discard rates, and a 54% increase in average preservation time [37]. Hypothermic oxygenated machine perfusion (HMP) is linked to lower rates of early allograft dysfunction (EAD), biliary complications, and the incidence of post-transplant non-anastomotic biliary strictures [38]. Recent long-term data confirm initial findings for both NMP and HMP [39,40]. Similarly, in KT, HMP has been shown to significantly reduce delayed graft function (DGF) and primary nonfunction (PNF), with beneficial effects on one-year graft survival in extended criteria donor (ECD) kidneys [41].

Beyond simple preservation, MP creates a regenerative and reparative environment. By keeping organs in a physiologically active state outside the body, teams can deliver therapeutic interventions, antioxidants, growth factors, antibiotics, or even cellular therapies to target ischemia-reperfusion injury, inflammation, or microvascular damage [42]. This controlled setting has enabled the successful recovery of organs previously considered unnecessary, with some centers reporting rescue rates as high as 70% during viability testing [43].

A key aspect of MP is its ability to adapt over time. In the past, liver and kidney grafts preserved through SCS had strict time limits. However, advanced perfusion systems have extended preservation periods from hours to days [44]. For example, protocols utilizing prolonged NMP have enabled safe liver preservation for up to 3 days, and experimental systems suggest it could be extended to 10 days [45]. This shift changes how transplants are scheduled, making them more like planned, elective procedures that better align with surgical plans, ICU staffing, and subsequent treatments. The advantages are numerous: hospitals can perform transplants during regular daytime hours, improve logistics, reduce emergency night-time surgeries, and make better use of resources. Additionally, extended perfusion enables sequential testing, supporting staged decision-making and potentially aiding organ regeneration through repeated interventions before implantation.

In summary, the integration of MP in LT and KT marks a watershed moment. It not only improves the viability assessment and regeneration of marginal organs but also introduces a temporal buffer, turning transplant from a race against the clock into a deliberate, elective process. As multiple large trials and registry analyses mature, healthcare systems must adapt allocation policies, invest in machine perfusion infrastructure, and train personnel to fully realize its potential. Doing so can increase transplant volumes, improve patient outcomes, and ultimately reshape the future landscape of SOT.

ROBOTIC TRANSPLANTATION

Although initially surprising and somewhat unexpected until recently, it is now possible to transplant almost all solid organs using robotic techniques. However, robotic transplantation is currently considered a standard approach only for KT in selected obese patients [46].

The earliest documented use of a robotic system in KT was by Hoznek in 2002 [47]. In this notable case, the robotic platform was used to perform vascular anastomoses through a traditional surgical incision [47]. The first fully robotic kidney transplant was performed by Geffner at Saint Barnabas Medical Center in New Jersey in January 2009, although this case was never officially published in a peer-reviewed journal. The first published case of robotic KT from a deceased donor in a recipient with morbid obesity was reported by Giulianotti at the University of Illinois at Chicago [48]. At the same time, Boggi subsequently performed the first robotic KT from a living donor in Pisa in July 2010 [49]. The first robotic PT (performed as pancreas-after-kidney transplantation), as well as the first simultaneous robotic pancreas and kidney transplant, were both carried out in 2010 by Boggi at the University of Pisa [50].

The first robotic LT using a whole graft from a deceased donor was performed by Khan at the Washington University School of Medicine in St. Louis in the summer of 2023 [51], while Lee et al. had previously performed a robotic split LT from a living donor at Seoul National University Hospital, South Korea [52].

The first fully robotic lung transplant– a single-lung procedure performed entirely with robotic surgery– was completed in April 2023 at Vall d'Hebron University Hospital in Barcelona by Dr. Albert Jáuregui [53]. The first fully robotic heart transplant in the world was carried out in September 2024 at the King Faisal Specialist Hospital & Research Centre (KFSHRC) in Riyadh, Saudi Arabia, by Dr. Feras Khaliel in a 16-year-old pediatric patient [12].

Remarkably, just sixteen years after Geffner's first robotic kidney transplant in 2009, the first global consensus conference on minimally invasive organ transplantation surgery was held in Riyadh in December 2024. This event officially recognized the role of robotic methods in modern transplantation [54].

Although the current use of robotics is limited by the availability of robotic systems, the technical expertise required of transplant surgeons, and strict selection criteria, the era of robotic solid organ transplantation has begun. As seen in other surgical fields, this area is likely to develop quickly in the coming years, driven by wider adoption and further technological advances of robotic platforms.

CONCLUSIONS

Organ transplantation is one of the most strictly regulated and standardized areas in modern medicine, to the point that it may seem, at least on the surface, to be unchanging. However, it is a field that is constantly evolving. Although the past twenty years have not brought significant breakthroughs in immunosuppression, nearly every other aspect of transplantation has changed, including donor and recipient profiles, organ assessment and preservation techniques, and even surgical methods. In fact, organ transplantation remains one of the fastest-changing and most dynamic fields in clinical practice. This ongoing transformation requires physicians and surgeons working in transplantation to maintain a high level of intellectual flexibility, enabling them to quickly adapt to these changes and help shape the future of the field.

Despite this progress, a key ethical principle must stay at the core: transplantation should not become a therapy looking for recipients but rather a therapy serving the recipients. The risk of reversing this idea partly arises from the need to involve and positively engage public opinion, since organ donation depends on public support. Unfortunately, this need can sometimes lead to unethical practices where the act of transplantation is used to gain public approval rather than being guided by sound ethical principles. Although these principles may be less immediately appealing to the public, they must remain the foundation of transplantation practice.

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References

1 Thongprayoon C, Kaewput W, Pattharanitima P, et al. Progress and recent advances in solid organ transplantation. J Clin Med 2022;11:2112. https://doi.org/10.3390/jcm11082112

2 Rush D. The impact of calcineurin inhibitors on graft survival. Transplant Rev (Orlando) 2013;27:93-95. https://doi.org/10.1016/j.trre.2013.04.003

3 Cowie S, Choy SH, Shah DM, et al. Healthcare system impact on deceased organ donation and transplantation: a comparison between the top 10 organ donor Countries with 4 Countries in Southeast Asia. Transpl Int 2023;36:11233. https://doi.org/10.3389/ti.2023.11233

4 Garcia-Parejo Y, Gonzalez-Rubio J, Garcia Guerrero J, et al. Risk factors for colonisation by Multidrug-Resistant bacteria in critical care units. Intensive and Critical Care Nursing 2025;86:103760. https://doi.org/10.1016/j.iccn.2024.103760

5 Smith M, Dominguez-Gil B, Greer DM, et al. Organ donation after circulatory death: current status and future potential. Intensive Care Med 2019;45:310-321. https://doi.org/10.1007/s00134-019-05533-0

6 Truog RD, Flescher A, Ladin K. Normothermic regional perfusion – The next frontier in organ transplants? JAMA 2023;329:2123-2124. https://doi.org/10.1001/jama.2023.9294

7 Tatum R, O'Malley TJ, Bodzin AS,et al. Machine perfusion of donor organs for transplantation. Artif Organs 2021;45:682-695. https://doi.org/10.1111/aor.13894

8 Spitz F, Dharmayan S, Mial-Anthony J, et al. Changes and future directions in liver transplantation in the United States. Livers 2025;5:7. https://doi.org/10.3390/livers5010007

9 Lee BP, Terrault NA. Liver transplantation for alcohol-associated liver disease: a call for national standards of best practices to monitor and bridge disparities in access and outcomes. Am J Transplant 2023;23:1097-1101. https://doi.org/10.1016/j.ajt.2023.03.026

10 Abdelrahim M, Esmail A, Abudayyeh A, et al. Transplant oncology: an emerging discipline of cancer treatment. Cancers (Basel) 2023;15:5337. https://doi.org/10.3390/cancers15225337

11 Broering DC, Raptis DA, Malago M, et al.; MIOT Collaborative. Revolutionizing organ transplantation with robotic surgery. Ann Surg 2024;280:706-712. https://doi.org/10.1097/SLA.0000000000006460

12 Khaliel FH, Haq MI, Alsullbud AK, et al. "First-in-human" totally robotic orthotopic heart transplant. J Heart Lung Transpl 2025;44:1000-1003. https://doi.org/10.1016/j.healun.2025.02.1685

13 Ascanio F, Abdallah NZ, Rosado J, et al. Towards standardization in robotic lung transplants: a novel approach in

minimally invasive thoracic surgery. Eur J Cardiothorac Surg 2025;67:ezaf042. https://doi.org/10.1093/ejcts/ezaf042

14 Report of the Italian Center for Transplantation. https://www.notifylibrary.org/sites/default/files/Report%20Analitico%202023%20Donazioni%20e%20Trapiant%20in%20Italia.pdf?utm_source=chatgpt.com. Accessed on July 6, 2025.

15 Denic A, Glassock RJ, Rule AD. Structural and functional changes with the aging kidney. Adv Chronic Kidney Dis 2016;23:19-28. https://doi.org/10.1053/j.ackd.2015.08.004

16 Ibrahim HN, Hebert SA, Murad DN, et al. Outcomes of hypertensive kidney donors using current and past hypertension definitions. Kidney International Reports 2021;6:1242-1253. https://doi.org/10.1016/j.ekir.2021.02.034

17 Zhong Y, Schaubel DE, Kalbfleisch JD, et al. Reevaluation of the kidney donor risk index. Transplantation 2019;103:1714-1721. https://doi.org/10.1097/TP.0000000000002498

18 Yan HL, Zong HT, Cui YS, et al. Calcineurin inhibitor avoidance and withdrawal for kidney transplantation: a systematic review and meta-analysis of randomized controlled trials. Transpl Proc 2014;46:1302-1313. https://doi.org/10.1016/j.transproceed.2014.02.010

19 Sypek MP, Hughes P. HLA eplet mismatches in kidney transplantation: more than just adding things up. Kidney Int Rep 2021;6:1500-1502. https://doi.org/10.1016/j.ekir.2021.04.027

20 Zazoulina J, Khehra K, Gill J. Motivators and barriers to living donor kidney transplant as perceived by past and potential donors. Can J Kidney Health Dis 2022;9:20543581221137179. https://doi.org/10.1177/20543581221137179

21 European Association for the Study of the Liver. EASL Clinical Practice Guidelines on liver transplantation. J Hepatol 2024;81:1040-1086. https://doi.org/10.1016/j.jhep.2024.07.032

22 Abdelrahim M, Esmail A, Abudayyeh A, et al. Transplant oncology: an evolving field in cancer care. Cancers (Basel) 2021;13:4911. https://doi.org/10.3390/cancers13194911

23 Vitale A, Volk M, Cillo U. Transplant benefit for patients with hepatocellular carcinoma. World J Gastroenterol 2013;19:9183-9188. https://doi.org/10.3748/wjg.v19.i48.9183

24 Aby ES, Lake JR. Basic principles of liver allocation and development over the years. Curr Opin Organ Transplant 2020;25:99-103. https://doi.org/10.1097/MOT.0000000000000732

25 Lingiah VA, Niazi M, Olivo R, et al. Liver Transplantation beyond Milan Criteria. J Clin Transl Hepatol 2020;8:69-75. https://doi.org/10.14218/JCTH.2019.00050

26 Line PD, Dueland S. Transplantation for colorectal liver metastasis. Curr Opin Organ Transplant 2024;29:23-29. https://doi.org/10.1097/MOT.0000000000001126

27 Kim J, Zimmerman MA, Hong JC. Liver transplantation in the treatment of unresectable hepatic metastasis from neuroendocrine tumors. J Gastrointest Oncol 2020;11:601-608. https://doi.org/10.21037/jgo.2019.11.03

28 Sapisochin G, Javle M, Lerut J, et al. Liver transplantation for cholangiocarcinoma and mixed hepatocellular cholangiocarcinoma: working group report from the ILTS Transplant Oncology Consensus Conference. Transplantation 104:1125-1130. https://doi.org/10.1097/TP.0000000000003212

29 Bonaccorsi-Riani E, Lerut JP. Liver transplantation and vascular tumours. Transpl Int 2010;23:686-691. https://doi.org/10.1111/j.1432-2277.2010.01107.x

30 Alim A, Erdogan Y, Dayangac M, et al. Living donor liver transplantation: the optimal curative treatment for hepatocellular carcinoma even beyond Milan Criteria. Cancer Control 2021;28:10732748211011960. https://doi.org/10.1177/10732748211011960

31 Dholakia S, Oskrochi Y, Easton G, et al. Advances in pancreas transplantation. J R Soc Med 2016;109:141-146. https://doi.org/10.1177/0141076816636369

32 Samoylova ML, Borle D, Ravindra KV. Pancreas transplantation: indications, techniques, and outcomes. Surg Clin North Am 2019;99:87-101. https://doi.org/10.1016/j.suc.2018.09.007

33 Al-Naseem AO, Attia A, Reda Gonnah A, et al. Pancreas transplantation today: quo vadis? Eur J Endocrinol 2023;188:R73-R87. https://doi.org/10.1093/ejendo/10.1093/ejendo/lvad032

34 Ito T, Gotoh M. Report from the Japan Registry of Pancreas Transplantation (2000-2012): outcomes of pancreas transplantation from marginal donors. Clin Transpl 2013:53-61.

35 Muthusamy AS, Mumford L, Hudson A, et al. Pancreas transplantation from donors after circulatory death from the United Kingdom. Am J Transplant 2012;12:2150-2156. https://doi.org/10.1111/j.1600-6143.2012.04075.x

36 Almeida S, Snyder W, Shah M, et al. Revolutionizing deceased donor transplantation: How new approaches to machine perfusion broadens the horizon for organ donation. Transplantation Rep 2024;9:100160.https://doi.org/10.1016/j.tpr.2024.100160

37 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. https://doi.org/10.1038/s41586-018-0047-9

38 van Rijn R, Schurink IJ, de Vries Y, et al.; DHOPE-DCD trial investigators. hypothermic machine perfusion in liver transplantation - A randomized trial. N Engl J Med 2021;384:1391-1401. https://doi.org/10.1056/NEJMoa2031532

39 Hefler J, Leon-Izquierdo D, Marfil-Garza BA, et al. Long-term outcomes after normothermic machine perfusion in liver transplantation - Experience at a single North American center. Am J Transplant 2023;23:976-986. https://doi.org/10.1016/j.ajt.2023.04.013

40 Eden J, Brüggenwirth IMA, Berlakovich G, et al. Long-term outcomes after hypothermic oxygenated machine perfusion and transplantation of 1,202 donor livers in a real-world setting (HOPE-REAL study). J Hepatol 2025;82:97-106. https://doi.org/10.1016/j.jhep.2024.06.035

41 Brat A, de Vries KM, van Heurn EWE, et al. Hypothermic machine perfusion as a National standard preservation method for deceased donor kidneys. Transplantation 2022;106:1043-1050. https://doi.org/10.1097/TP.0000000000003845

42 Karimian N, Yeh H. Opportunities for therapeutic intervention during machine perfusion. Curr Transplant Rep 2017;4:141-148. https://doi.org/10.1007/s40472-017-0144-y

43 Mergental H, Laing RW, Kirkham AJ, et al. Transplantation of discarded livers following viability testing with normothermic machine perfusion. Nat Commun 2020;11:2939. https://doi.org/10.1038/s41467-020-16251-3

44 Brüggenwirth IMA, Mueller M, Lantinga VA, et al. Prolonged preservation by hypothermic machine perfusion facilitates logistics in liver transplantation: a European observational cohort study. Am J Transplant 2022;22:1842-1851. https://doi.org/10.1111/ajt.17037

45 Cardini B, Oberhuber R, Fodor M, et al. Clinical implementation of prolonged liver preservation and monitoring through normothermic machine perfusion in liver

transplantation. Transplantation 2020;104:1917-1928. https://doi.org/10.1097/TP.0000000000003296

46 Spiers HVM, Sharma V, Woywodt A, et al. Robot-assisted kidney transplantation: an update. Clin Kidney J 2021;15:635-643. https://doi.org/10.1093/ckj/sfab214

47 Hoznek A, Zaki SK, Samadi DB, et al. Robotic assisted kidney transplantation: an initial experience. J Urol 2002;167:1604-1606.

48 Giulianotti P, Gorodner V, Sbrana F, et al. Robotic transabdominal kidney transplantation in a morbidly obese patient. Am J Transplant 2010;10:1478-1482. https://doi.org/10.1111/j.1600-6143.2010.03116.x

49 Boggi U, Vistoli F, Signori S, et al. Robotic renal transplantation: first European case. Transpl Int 2011;24:213-218. https://doi.org/10.1111/j.1432-2277.2010.01191.x

50 Boggi U, Signori S, Vistoli F, et al. Laparoscopic robot-assisted pancreas transplantation: first world experience. Transplantation 2012;93:201-206. https://doi.org/10.1097/TP.0b013e318238daec

51 Khan AS, Scherer M, Panni R, et al. Total robotic liver transplant: the final frontier of minimally invasive surgery. Am J Transplant 2024;24:1467–1472. https://doi.org/10.1016/j.ajt.2024.03.030

52 Lee KW, Choi Y, Hong SK, et al. Laparoscopic donor and recipient hepatectomy followed by robot-assisted liver graft implantation in living donor liver transplantation. Am J Transplant 2022;22:1230-1235. https://doi.org/10.1111/ajt.16943

53 Ascanio F, Royo-Crespo I, Rosado J, et al. Advances in robotic lung transplantation: development and validation of a new surgical technique in animal models. Interdiscip Cardiovasc Thorac Surg 2023;37:ivad179. https://doi.org/10.1093/icvts/ivad179

54 https://www.kfshrc.edu.sa/en/events/2024/11/minimally-invasive-organ-transplant-consensus-conference. Accessed on July 6, 2025.