NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

HEALTHTECH PROGRAMME

Ex-situ machine perfusion devices for deceased donor liver transplants

Final scope

1. Introduction

The use of ex-situ machine perfusion technologies for the preservation and evaluation of liver transplants from deceased donors has been identified by the NICE prioritisation board for assessment. This document describes the context and scope of the assessment. The final scope was informed by discussions at the scoping workshop held on 10th July 2025 and public consultation period from the 14th August to the 29th August 2025.

A list of abbreviations is provided in appendix A.

2. The condition

Liver transplantation is a treatment option for people with end-stage liver disease (for example, because of alcohol-related liver disease, metabolic, autoimmune or infectious conditions) and some people with liver cancer or acute liver failure. In children, the most common reason for liver transplantation is congenital biliary atresia. People with end-stage liver disease are at increased risk of dying from complications of the condition and symptoms can severely affect quality of life.

In the UK, more than 11,000 people die due to liver disease each year (British Liver Trust, 2023). There has been a 400% increase in liver-related deaths since 1970, and hospital admissions for liver disease have increased by about half over the last decade (Mansour, 2023b). On 31 March 2024, there were 614 adults and 64 children on the UK active liver transplant list (NHS Blood

and Transplant, 2024a). In 2023/24, 791 liver transplants in adults and 63 liver transplants in children were performed in the UK from deceased donors (NHS Blood and Transplant, 2024a).

In the UK, the majority of livers that are suitable for transplantation come from donors who have died. In 2023/24, 99% of adults and 72% of children who underwent liver transplantation received livers from deceased donors (NHS Blood and Transplant, 2024a). The remainder received liver transplants from living donors.

3. Current practice

People identified as needing a liver transplant are placed on a waiting list. The waiting list operates like a matching system, where a donor liver is allocated to the person most likely to gain the greatest benefit from that particular donated organ. The national UK median waiting time for an elective liver only transplant from a deceased donor is about 5 months in adults and 3 to 4 months in children, but this varies across transplant centres (NHS Blood and Transplant, 2024b).

Within the NHS, transplants are done by specialist liver transplant surgeons in 7 centres for adults and 3 centres for children across the UK.

Standard care for liver transplant involves removing the liver from deceased donors after either brainstem death (DBD) or circulatory death (DCD). The use of DCD livers is more common in adults than in children.

In adults, the majority of donated livers are transplanted as a whole organ. In children and small adults, split liver transplants are more common. This is because children and small adults require smaller grafts and there is a limited supply of whole livers from deceased paediatric and small adult donors. Split livers are usually obtained from carefully selected low-risk donors. According to experts, liver splitting is usually done at paediatric liver transplant centres. The smaller left lobe is transplanted into a child or small adult. If usable, the

larger right lobe may be transported to an adult liver transplant centre and used for an adult.

A donor liver for transplant is usually preserved using static cold storage. This involves flushing the donor liver with cold organ preservation solution and then placing it in a sterile bag in a cold storage icebox for transport. This is done by a specially trained team before the donor liver is transferred to the selected hospital for transplant as soon as possible, to minimise ischaemic damage to the organ. Livers are usually stored for a maximum of 8 to 12 hours in an icebox before transplantation.

Increasingly, organ retrieval teams do in-situ normothermic regional perfusion (NRP) before abdominal organs are removed from donors after circulatory death. In this procedure, instead of immediately cold-flushing the organs, the donor is first connected to a machine which perfuses the abdominal organs with an oxygenated blood supply for about 2 hours. This process helps make abdominal organs better able to withstand the subsequent cold storage process and increases their chances of working well after they are transplanted. During NRP, the function of the liver can be assessed.

According to NICE interventional procedures guidance 636 (2019), use of ex-situ machine perfusion devices for liver transplants is by special arrangement only. In the UK, ex-situ machine perfusion technologies are usually initiated at the hospital of the person having the transplant after the liver has been transported using static cold storage. According to experts, ex-situ machine perfusion technologies are rarely used in the UK to perfuse donor livers during transportation to the recipient transplant centre. Experts also noted that the use of ex-situ machine perfusion technologies varies across UK liver transplant centres, in terms of which technologies are used, how often they are used, the circumstances they are used for and how they are funded. The use of ex-situ machine perfusion for liver transplants is more common in adults than in children.

A list of related NICE guidance can be found in appendix B of this document.

4. Unmet need

There is a shortage of high-quality organs available for transplant in the UK and demand is rising due to the increasing prevalence of chronic liver diseases in the general population. At the same time, organ donors in the UK are becoming older, which is associated with a higher risk of comorbidities. According to experts, this has resulted in the growing use of suboptimal organs from extended criteria donors, who are older and may have conditions that affect liver function such as hepatic steatosis; and those who donated their liver after circulatory death. But these organs are at higher risk of worse outcomes (both short-term graft function and long-term complications) if they are preserved using static cold storage only.

The shortage of suitable donor organs results in significant mortality and morbidity for people on the waiting list for liver transplants. Around 12% of people listed in the UK between April 2021 and March 2022 for a liver transplant either died or became too sick for liver transplantation within a year of joining the waiting-list (NHS Blood and Transplant, 2024b).

In the UK, many donor livers are discarded because clinicians are concerned about giving potentially lower quality livers to people as they are at higher risk of worse outcomes. This includes livers that are declined either before retrieval or after they have been retrieved. In 2023/24, 18.5% of livers retrieved from donors after brainstem death (DBD) and 35.5% of livers retrieved from donors after circulatory death (DCD) were not transplanted (NHS Blood and Transplant, 2025). But, these decisions are based on the characteristics of the donor and the appearance of the liver because it is not possible to do a formal assessment of how well the liver is functioning during cold storage. This uncertainty may lead some clinicians to decline to transplant organs that could potentially be used.

The Department of Health and Social Care independent report: Honouring the gift of organ donation (2023) and NHS Blood and Transplant strategy: Meeting the need (2020) both highlight the need to embrace technological solutions

such as ex-situ machine perfusion devices to maximise the use of available organs to meet demand. But, in the absence of UK clinical guidance on the use of ex-situ machine perfusion technologies for liver transplants, differing practices have emerged across liver transplant centres, leading to variation in access to these technologies across the UK.

5. The technologies

This section describes the properties of the technologies based on information provided to NICE by companies and experts, and publicly available information. NICE has not carried out an independent evaluation of these descriptions.

Ex-situ machine perfusion is intended to preserve the donor liver outside the body. Machine perfusion of the liver is typically performed at hypothermic (4 to 12 °C) or normothermic (37 °C) temperatures. A donor liver can be perfused for several hours (depending on the technology), after which it can be implanted into a recipient in the conventional way.

In this procedure, the donor liver is placed in a perfusion machine, which pumps a specially formulated solution (supplemented with nutrients and metabolic substrates) through the organ's blood vessels. The circulating perfusion solution also clears waste products and prevents their accumulation. The precise configuration of each technology varies depending on the method of machine perfusion but typically comprises a reservoir, a pump, an oxygenator and a warming or cooling unit. Normothermic machine perfusion requires an oxygen carrier, which may or may not be human red blood cells; hypothermic machine perfusion does not. Normothermic machine perfusion also allows assessment of donor liver viability during preservation.

Ex-situ machine perfusion devices may be initiated prior to implantation at the recipient hospital after static cold storage during transportation. Some ex-situ machine perfusion technologies can also be initiated at the donor hospital and continued during transportation of the organ to the recipient hospital.

Some ex-situ machine perfusion devices can also provide a platform for liver splitting during machine perfusion.

The specific aims of machine perfusion technologies differ depending on the technology, but include:

- increasing utilisation of donated organs
- improving clinical outcomes for transplant recipients
- extending how long the liver can be preserved to allow more flexibility in the timing of the transplant operation, which may allow more day-time operations, provide more time for challenging cases and help address other organ allocation, transport and in-hospital logistical considerations. It may also support improved staff well-being and workforce sustainability.

Sections 5.1 to 5.5 describe the 5 included technologies.

5.1 Liver Assist (XVIVO B.V.)

Liver Assist is an in-hospital system for ex-situ machine perfusion of donor livers prior to transplantation into recipients. The intended patient population is people in need of a liver transplant, both adults and children. There are no known contraindications. The technology consists of two main components: the reusable Liver Assist device (CE marked class IIb) and a single use sterile perfusion set (CE marked class IIa). The donor liver is perfused with either a cold or warm oxygenated perfusion solution and nutrients, depending on the settings. The Liver Assist system is intended for hypothermic perfusion up to 24 hours and normothermic perfusion up to 6 hours. It can also slowly rewarm livers from hypothermia to normothermia (termed ‘controlled oxygenated rewarming’). The Liver Assist system may also be used as a platform for liver splitting during machine perfusion. The Liver Assist system is intended to be initiated at the recipient hospital.

Liver Assist is used by several NHS transplant centres.

5.2 *metra* (OrganOx Ltd)

The *metra* is a fully automated transportable normothermic ex-situ organ perfusion device intended to support livers from deceased donors aged over 16, for up to 24 hours. The intended patient population is adults active on the waiting list for liver transplantation, other than those with acute/fulminant liver failure. The donor liver is continuously perfused with oxygenated blood, medications and nutrients at normal body temperature. The *metra* is a UKCA marked class IIa medical device (CE class IIb). It is used with the *metra* disposable perfusion set (UKCA class IIa; CE class IIa) and bile salts (UKCA class IIa; CE class III). The *metra* can be initiated at the donor hospital or on arrival at the recipient hospital.

The *metra* is currently used in several NHS transplant centres in the UK.

5.3 Organ Care System (OCS) Liver (TransMedics)

OCS Liver is a portable ex-situ normothermic machine perfusion system intended for use with donor livers. The intended patient population is any person who is eligible for a liver transplant. OCS Liver maintains the donor liver in a functioning state by delivering oxygenated and nutrient-enriched, blood-based perfusion solution at near normal body temperatures. The OCS Liver system should not be used for livers with moderate or severe traumatic injury, livers with active bleeding or split livers. The device should be initiated at the donor hospital. The OCS Liver system consists of 3 main components: the OCS Liver console (CE marked class IIa), OCS Liver perfusion set (CE marked class IIb), and OCS bile salt solution (CE marked class III).

OCS Liver is not currently used in the NHS. TransMedics have subsequently advised NICE that they will not be making OCS Liver available to the NHS for the use case outlined in this scope and therefore have been withdrawn from this assessment.

5.4 PerLife Pro (Aferetica Srl)

PerLife Pro is an ex-situ machine perfusion system that can be configured for use with kidneys or livers. It is intended to be initiated at the recipient hospital. The device works by continuously perfusing the organ with oxygenated perfusion fluid. PerLife Pro is capable of supporting machine perfusion of livers at hypothermic and normothermic temperatures for up to 24 hours. It can also do controlled oxygenated rewarming. PerLife Pro may be used in both children and adults. The technology consists of two main components: the PerLife Pro machine unit (CE marked class IIa) and disposable liver perfusion kit (CE marked class IIa).

The company is currently working towards registering PerLife Pro with the MHRA so that it will be available to the NHS.

5.5 VitaSmart Hypothermic Oxygenated Machine Perfusion System (Bridge to Life Ltd)

VitaSmart is a hypothermic oxygenated machine perfusion system intended for ex-situ preservation of abdominal organs (i.e., kidney or liver). The intended population is people in need of a liver or kidney transplant who are on the transplant waiting list. VitaSmart may be used in both children and adults. VitaSmart is not transportable; it is intended to be initiated at the recipient hospital. The technology consists of a machine unit (CE marked class IIb), disposables (class IIa) and oxygenators (class IIa).

VitaSmart is currently used in several NHS transplant centres in the UK.

5.6 The place of technologies in the care pathway

This assessment will consider the use of ex-situ machine perfusion technologies for the preservation and functional assessment of livers from deceased donors, initiated on arrival at the hospital of the person having the transplant, after the liver has been transported using conventional static cold storage.

Where possible, the assessment will also consider potential changes to the national liver transplantation pathway, in line with proposals by NHS Blood and Transplant, including the use of ex-situ machine perfusion technologies during transportation of donor organs, as applicable.

6. Comparator

The comparator in this assessment is conventional static cold storage.

7. Patient issues and preferences

The demand for liver transplants exceeds the supply of available donor organs. This shortage leads to significant mortality and morbidity among those on the waiting list.

Waiting for a liver transplant is likely to be a stressful time and can lead to anxiety and depression, both for the person and their family and carers, due to the uncertainty of the situation, physical limitations imposed by the waiting period, potential for declining health, worries about surviving liver transplantation and concerns about potential complications of surgery and ongoing immunosuppressive therapy.

In current practice, patients are often required to attend hospital at very short notice, sometimes before the death of the donor has been confirmed. Not all organ retrievals lead to transplants and some surgeries are cancelled due to medical issues, logistical challenges or last-minute clinical decisions. Preparing for and attending transplantation surgeries that ultimately do not proceed can be very distressing for patients and their families. It may also be upsetting for the families of donors when donated organs are not used in transplantation procedures.

Individuals waiting for a liver transplant may face a difficult decision about whether to proceed with a particular donor liver, especially when the need for a transplant is urgent. In children and young people under 18, organ transplantation requires appropriate consent, often in emotional and stressful

circumstances. Some organs carry more risk than others, and it is not possible to accurately predict when another suitable donated liver will be matched. Some people may receive more offers for a donated liver than others. Among adults, individuals who have more severe disease, blood group A or are taller than average, generally do not have to wait as long for an offer of a deceased donor liver. As a result, some people may need to consider accepting more risk with their transplant than others.

All people on the waiting list are regularly reviewed to check whether they still meet national criteria for liver transplantation. If the person's condition changes, either improving or becoming too sick to benefit from transplantation, they may be temporarily or permanently removed from the waiting list.

People who receive transplants require lifelong follow-up and ongoing immunosuppressive therapy. For children and young people this will include a structured transition to adult services. Without careful planning and support, this transition can be a vulnerable period, and may be associated with reduced adherence to medication, increasing the risk of graft rejection.

Understanding the transplant process, coping with long-term medication and hospital visits, and managing school and social development may be particularly challenging for children and young people, and their families.

8. Potential equality issues

NICE is committed to promoting equality of opportunity, eliminating unlawful discrimination and fostering good relations between people with protected characteristics and others.

- End-stage liver disease can significantly affect people's daily living. Under the Equality Act 2010, a person has a disability if they have a physical or mental impairment that has a substantial and long-term effect on their ability to do typical day-to-day activities. Disease severity is an important factor in determining the allocation of liver transplants. People with more

severe liver disease and higher risk of mortality, are generally prioritised for liver transplantation ahead of people with less severe liver disease and lower risk of mortality, although other factors may also be considered.

- Adults from white or Asian backgrounds tend to wait less time for a liver transplant than adults from black or other ethnic minority backgrounds (NHS Blood and Transplant, 2024a).
- All of the major religions and belief systems in the UK are open to the principles of organ donation and transplantation. Organ donation is a personal choice and views on the matter can vary even among individuals within the same faith (NHS Blood and Transplant).
- There are different types of liver diseases that can be associated with alcohol, obesity, viral infection, and genetic factors. Overall, men are more likely to die from liver disease than women (British Liver Trust, 2024). In 2023/24, males represented 57% of deceased liver donors, 63% of transplant recipients and 55% of the active waiting list (NHS Blood and Transplant, 2024a).

Sex, disability, race and religion or belief are protected characteristics under the Equality Act (2010).

Additional considerations include:

- In England, the risk of dying prematurely from alcoholic liver disease is higher in people from more deprived areas (Office for Health Improvement and Disparities, 2024). People experiencing homelessness who develop end-stage liver disease may not access healthcare services and may not receive the support they need.
- Experts noted that some people living in rural locations may have experienced reduced levels of access to donor organs prior to the introduction of machine perfusion technologies, due to logistical considerations.

- Variations in the provision of ex-situ machine perfusion devices across liver transplant centres could lead to inequities in the allocation of livers, potentially favouring centres with greater capacity for machine perfusion.

9. Decision problem

The key decision questions for this assessment are:

- What is the clinical effectiveness of using ex-situ machine perfusion technologies for liver transplant?
- What is the cost effectiveness of using ex-situ machine perfusion technologies for liver transplant?
- What evidence is available to support the value proposition of ex-situ machine perfusion devices outlined in the scope, i.e.:
    - increasing the number of livers suitable for transplant?
    - improving the clinical outcomes of transplant recipients?
    - extending preservation time to allow more flexibility in the timing of the transplant operation?
- Are there any gaps in the evidence base?

Table 2: Decision problem

Populations	People active on the UK waiting list for liver transplantation from deceased donors.
Sub-groups	Where data permits, subgroups will be considered based on: • Higher risk donors for adult recipients. These might include extended criteria donors (particularly with steatotic livers) and donors following circulatory death. If possible, use of NRP of livers donated after circulatory death will also be considered. • Complex adult recipients. These might include people who have previously had a transplant or abdominal surgery, or those with advanced comorbidities and haemodynamic instability. • Logistical considerations for adults where cold ischaemia times are predicted to be extended beyond acceptable limits unless ex-situ machine perfusion is used. These

	might include: complex multi-organ transplants, challenging hepatectomies, liver splitting and prolonged preservation to allow time for allocation, transport and in-hospital logistics such as enabling day-time surgery. • Higher risk donors for children and young person (CYP) recipients. These might include extended criteria donors and donors following circulatory death. If possible, use of NRP of livers donated after circulatory death will also be considered. If possible, use of ex-situ machine perfusion during liver splitting will also be considered. • Complex CYP recipients. These might include people who have previously had a transplant or abdominal surgery. If possible, use of ex-situ machine perfusion during liver splitting will also be considered. • Logistical considerations for CYP recipients where cold ischaemia times are predicted to be extended beyond acceptable limits unless ex-situ machine perfusion is used. These might include complex multi-organ transplants, challenging hepatectomies, liver splitting and prolonged preservation to allow time for allocation, transport and in-hospital logistics such as enabling day-time surgery. If possible, use of ex-situ machine perfusion during liver splitting will also be considered.
Interventions	Ex-situ machine perfusion devices initiated on arrival at the hospital of the person having the transplant after the liver has been transported using conventional static cold storage. The following ex-situ machine perfusion devices will be considered: • Liver Assist (XVIVO B.V.) • metra (OrganOx Ltd) • PerLife Pro (Aferetica Srl) • VitaSmart Hypothermic Oxygenated Machine Perfusion System (Bridge to Life Ltd) Where possible, the assessment will also consider potential changes to the national liver transplantation pathway, in line with proposals by NHS Blood and Transplant, including the use of ex-situ machine perfusion technologies during transportation of donor organs, as applicable.
Comparator	Static cold storage (SCS) of donated livers.
Healthcare setting	Secondary and tertiary care, including retrieval and transportation of organs from donors to recipient hospitals.
Outcomes (may include but are not limited to)	**Waiting list and utilisation outcomes:** • Transplant utilisation (proportion of donor organs that proceeded to transplant rather than being discarded) • Size and duration of liver transplant waiting list • Mortality on liver transplant waiting list

	Clinical outcomes: • Overall participant survival at 1 year and maximum follow-up • Graft survival at 1 year and maximum follow-up • Re-transplantation at 1 year and maximum follow-up • Biliary complications at 6 months, 12 months and maximum follow-up (total and if data permits separately for biliary leakage, anastomotic biliary strictures and non-anastomotic biliary strictures) • Primary non-function of the graft (defined as irreversible graft dysfunction leading to recipient death or emergency retransplant within 7 days, excluding due to hepatic artery thrombosis) • Hepatic artery thrombosis within 28 days (total and if data permits separately for hepatic artery thrombosis leading to recipient death and emergency retransplant) • Inhospital incidence of post-reperfusion syndrome • Acute kidney injury post transplantation, measured using a validated classification system (e.g., stage 2 or 3 on the Acute Kidney Injury Network classification system) • Post-operative requirement for renal replacement therapy (total and if data permits separately for dialysis [including duration of dialysis] and kidney transplantation) • Early allograft function, measured with a validated model (7 days) (e.g., Early Allograft Dysfunction or Model for Early Allograft Function criteria) • Transaminase release during the first week post-transplant (participant serum) (until 7 days) • Mechanical failure of machine perfusion technology (if data permits, separately for mechanical failure leading to organ discard and change in method of preservation) • Serious adverse events (e.g., Clavien-Dindo classification, grade III or higher), including bowel perforation, post-transplant lymphoproliferative disorder, bleeding and infections (both donor-related and surgical infections) • Device related adverse events **Patient-reported outcomes:** • Health related quality of life, assessed using any validated scale (also from carer and/or family perspective) **Other** • Healthcare professional satisfaction and/or wellbeing **Costs and resource use:** • Cost of technology, including purchase costs/lease fee, consumable costs and cost of training, including cost of transplants that do not proceed to surgery

	• Cost of organ retrieval and transplant surgery (encompassing cases that do not proceed to transplantation), including:
	  ○ hospital length of stay (including ICU, separately)
	  ○ management of complications and adverse events (including dialysis, rehospitalisation and retransplantation)
	  ○ transportation of organs (including method of transport and whether ex-situ machine perfusion was used)
	• Cost of returning perfusion devices
	• Cost of managing condition on the transplant waiting list, including hospitalisation episodes
	• Staff time and cost according to specialism and level of pay, including theatre staff
	• Proportion and cost of daytime procedures compared with night-time procedures

Economic analysis	• The cost-effectiveness of interventions should be expressed in terms of incremental cost per quality adjusted life year. • Costs will be considered from an NHS and Personal Social Services perspective. The availability of any commercial arrangements for the interventions or comparator will be taken into account.
Time horizon	The time horizon for estimating clinical and cost effectiveness will be sufficiently long to reflect potential for differences in costs or outcomes between the technologies being compared.

10. Other issues for consideration

The longer preservation periods enabled by some machine perfusion technologies may contribute to more environmentally sustainable liver donation and transplantation practices by reducing reliance on time critical logistics compared to SCS, for example by allowing more livers to be transported in the UK by road rather than plane.

Increased use of ex-situ machine perfusion devices may affect the National Liver Offering Scheme (NLOS) and National Organ Retrieval Services (NORS) in ways not currently clear.

Where possible, the assessment will also consider potential changes to the national liver transplantation pathway, in line with proposals by NHS Blood and Transplant, including the use of ex-situ machine perfusion technologies during transportation of donor organs, as applicable.

The commissioning and policy framework for liver transplantation services varies across the devolved UK health systems. Implementation of recommendations will need to be considered by key national organisations involved in delivering the services.

NICE team

Technical team

Samantha Baskerville
Lead senior analyst

Robbie Pitcher
Lead technical analyst

Amany Salem
Technical analyst

Rebecca Owens
Technical adviser

Project team

Toni Gasse
Project manager

Elaine Sale
Project Administrator

Appendix A: Abbreviations

CYP	Children and young people
DBD	Donated after brainstem death (death that has been confirmed using neurological criteria)
DCD	Donated after circulatory death (death that has been confirmed using cardio-respiratory criteria)
ICU	Intensive care unit
MHRA	Medicines and Healthcare products Regulatory Agency
NRP	Normothermic regional perfusion
SCS	Static cold storage

Appendix B: Related NICE publications

NICE guidance

- Alcohol-use disorders: diagnosis and management of physical complications (2010; last updated 2017), NICE clinical guideline 100 (CG100)
- Cirrhosis in over 16s: assessment and management (2016; last updated 2023), NICE guideline 50 (NG50)
- Ex-situ machine perfusion for extracorporeal preservation of livers for transplantation (2019), NICE interventional procedures guidance 636 (IPG636)
- Extracorporeal whole liver perfusion for acute liver failure (2021), NICE interventional procedures guidance 690 (IPG690)
- Hepatitis B (chronic): diagnosis and management (2013; last updated 2017), NICE clinical guideline 165 (CG165)
- Living-donor liver transplantation (2015), NICE interventional procedures guidance 535 (IPG535)
- Non-alcoholic fatty liver disease (NAFLD): assessment and management (2016), NICE guideline 49 (NG49)
- Organ donation for transplantation: improving donor identification and consent rates for deceased organ donation (2011; last updated 2016), NICE clinical guideline 135 (CG135)

NICE quality standards

- Hepatitis B (2014), NICE quality standard 65 (QS65)
- Liver disease (2017), NICE quality standard 152 (QS152)

NICE advice

- OrganOx metra for liver transplant (2021), Medtech innovation briefing 275 (MIB275)