

Normothermic Regional Perfusion in Pancreas and Islet Transplantation from Donation After Circulatory Death: A Systematic Review

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Systematic Review

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Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11461945/v1>

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Additional Declarations: The authors declare no competing interests.

Normothermic Regional Perfusion in Pancreas and Islet Transplantation from Donation After Circulatory Death: A Systematic Review

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Funding: None.

Conflicts of interest: The authors declare no conflicts of interest.

Registration: PROSPERO, CRD420261540738

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Word count: abstract 298; text 3,436; references 55; tables 3; figures 6

ABSTRACT

Objective:

To compare pancreas transplantation, pancreas utilization and islet isolation and transplantation outcomes after normothermic regional perfusion (NRP) in donors after circulatory death (DCD) with those after super-rapid recovery (SRR) DCD and donation after brain death (DBD).

Background:

DCD pancreases are underused because of concern about warm ischemic injury. NRP restores oxygenated circulation before procurement and benefits the liver and kidney, but its effect on the pancreas and islets is uncertain.

Methods:

MEDLINE, Embase, Web of Science, Cochrane CENTRAL, ClinicalTrials.gov and congress proceedings were searched to October 2026 for comparative studies published from 2016. Risk of bias was assessed with ROBINS-I and certainty with GRADE; synthesis was narrative (SWiM).

Results:

Twelve reports from 4 independent data sources were included (10 on pancreas transplantation or utilization, 2 on islet isolation). In the UK registry (47 NRP vs 379 non-NRP DCD simultaneous pancreas-kidney transplants), 1-year pancreas graft survival was 93.6% vs 89.2% (adjusted HR for graft loss 0.56; 95% CI 0.17–1.80); in US registry data it was 91% after NRP, comparable to SRR. NRP was associated with numerically higher pancreas utilization (adjusted OR 1.6; 95% CI 0.98–2.64) Compared with DBD, pancreas graft survival and donation rates after NRP were similar. In one program, islet yield was higher after abdominal NRP than after DCD procurement without NRP or DBD procurement (median 471,739 vs 218,750 and 206,522 islet equivalents). Certainty was very low for every outcome.

Conclusions:

Pancreas graft outcomes after NRP DCD procurement were comparable to those after both SRR DCD and DBD procurement in the available evidence, but certainty was very low for every outcome, and the DBD comparisons were unadjusted. Utilization and islet yield estimates favored NRP but were imprecise. Pooled registry analyses with standardized pancreas and islet outcomes are needed before practice recommendations can be made.

INTRODUCTION

Pancreas transplantation, most often as simultaneous pancreas-kidney (SPK) transplantation, is the most effective treatment for selected patients with type 1 diabetes and end-stage kidney disease, restoring insulin independence and improving survival and quality of life. Access, however, is shrinking. In the United States, the number of adults waiting for a pancreas transplant rose by 24%, from 2,375 at the end of 2020 to 2,937 at the end of 2024, and new listings rose from 1,585 to 1,935 a year, while pancreas transplants in adults fell from 939 to 821 (Fig. 1).^{1–5} The deceased-donor transplant rate fell from 44.8 to 30.1 per 100 patient-years between 2019 and 2024, and 25.1% of pancreases recovered for transplantation in 2024 were not transplanted.¹ Deceased-donor pancreases are thus among the least utilized solid organs, a failure of utilization rather than supply.⁶ Islet transplantation, a less invasive alternative for selected patients, remains a small field: worldwide, 4,365 islet allotransplants were performed between 2000 and 2020, only 1,475 of them in North America.⁷

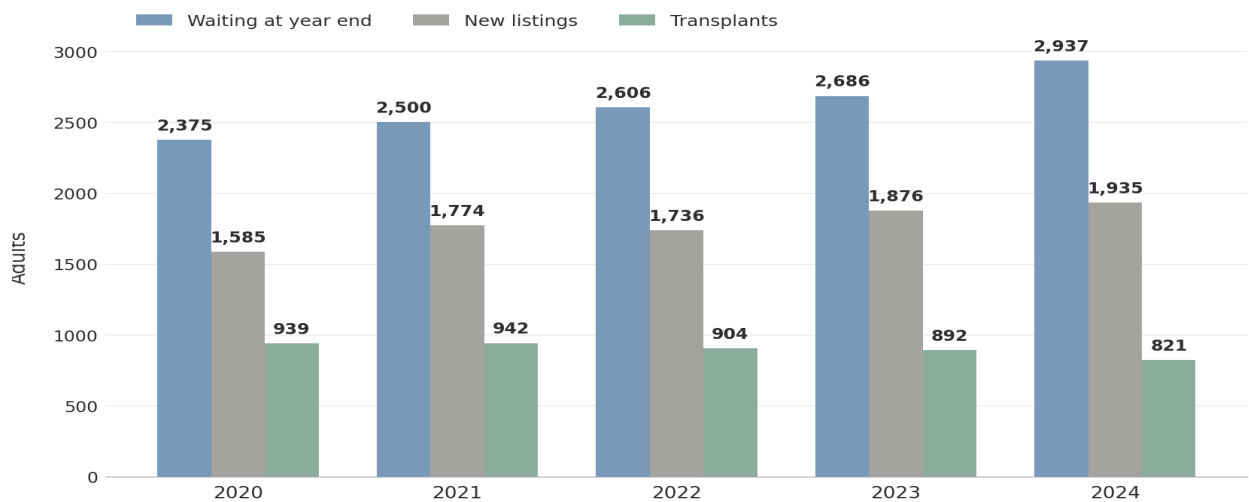


FIGURE 1. Adult pancreas transplant waiting list and transplants in the United States, 2020–2024. New listings and candidates waiting at year end are summed across simultaneous pancreas-kidney, pancreas after kidney and pancreas transplant alone; transplants are adult pancreas transplant recipients, including retransplants. Data compiled from the OPTN/SRTR Pancreas Annual Data Reports for 2020–2024 (references 1–5).

Donation after circulatory death (DCD) is the fastest-growing source of deceased donors, but DCD grafts account for only about 3% of US SPK transplants despite 5-year graft survival comparable to donation after brain death (DBD).⁸ Recovering more DCD pancreases for transplantation is therefore one of the few immediate ways to close the gap between demand and supply.

The pancreas is highly susceptible to ischemia-reperfusion injury. Warm ischemia during the agonal and asystolic phases depletes adenosine triphosphate, and reperfusion triggers oxidative stress, endothelial activation and sterile inflammation; early graft loss is driven predominantly by thrombosis and pancreatitis.⁹ Coagulation activation linked to endothelial injury, framed as immunothrombosis, may explain the vulnerability of this low-flow organ to early vascular

thrombosis.¹⁰ The islet compartment is particularly sensitive: longer ischemic times are associated with lower islet isolation yields.⁹

In standard DCD practice, organs are procured by super-rapid recovery (SRR), which limits but cannot reverse warm ischemia and offers no opportunity to assess organ function. Compared with DBD grafts, SRR DCD pancreases have more early complications, including graft thrombosis and hyperamylasemia, although long-term graft survival appears similar.^{11,12} Recipient risk rises with the length of the donor's dying process,¹³ and because acceptance decisions under SRR rest on donor characteristics and timings alone, surgeons frequently decline DCD pancreases.^{6,8}

Normothermic regional perfusion (NRP) uses an extracorporeal circuit to restore oxygenated normothermic blood flow to the abdominal organs (A-NRP) or to the thoracic and abdominal organs (TA-NRP) after death is declared, with exclusion of the cerebral circulation.^{14–16} In situ reperfusion before cold flush is intended to replenish cellular energy, wash out the microcirculation, convert a hurried DCD retrieval into a controlled procurement resembling DBD retrieval, and allow serial assessment of perfusate biochemistry before organs are accepted.^{14–16} For the liver and kidney, NRP is associated with higher utilization, fewer biliary complications and less delayed graft function.^{17–19} Whether the pancreas and its islets share these benefits is less clear: NRP may lengthen warm ischemia before perfusion begins,²⁰ early pancreas reports were small,^{18,21} recent registry analyses are imprecise,^{20,22} and existing reviews either predate these data or are narrative, including the only review to address islet transplantation.^{18,21,23}

We therefore performed a systematic review with the primary aim of comparing pancreas graft outcomes and utilization after NRP-assisted DCD procurement with SRR DCD and DBD procurement. A secondary aim was to compare islet isolation and transplantation outcomes from NRP-procured pancreases with those from SRR DCD and DBD pancreases.

METHODS

Protocol and Registration

The review was conducted and reported according to PRISMA 2020²⁴ and its extension for literature searches (PRISMA-S).²⁵ The protocol was registered in PROSPERO (CRD420261540738).

Eligibility Criteria

Populations were (1) adult recipients of pancreas allografts transplanted as SPK, pancreas after kidney (PAK) or pancreas transplant alone (PTA); (2) for utilization outcomes, controlled DCD donors; and (3) deceased-donor pancreases processed for islet isolation and recipients of the resulting islet allografts. The intervention was procurement from controlled DCD donors using A-NRP or TA-NRP, defined as in situ restoration of normothermic oxygenated circulation after death declaration and before cold flush. Comparators were DCD pancreases procured by SRR without NRP and DBD pancreases.

All outcomes were compared between pancreases procured with NRP and those procured by SRR DCD or from DBD donors. Pancreas transplantation (primary aim): the primary outcome was 1-year death-censored pancreas graft survival after NRP-assisted procurement, and the co-primary outcome was early graft thrombosis (arterial or venous, within 30 days or the index admission). Secondary outcomes were pancreas utilization (pancreases transplanted per eligible DCD donor), primary non-function (PNF), graft pancreatitis, anastomotic leak, re-laparotomy, patient survival, insulin independence, glycated hemoglobin, warm and cold ischemia times and, in SPK recipients, kidney delayed graft function (DGF).

Islet isolation and transplantation (secondary aim): outcomes for pancreases procured with NRP and processed for islet isolation were islet yield in islet equivalents (IEQ, total and per gram of pancreas), purity, viability, islet survival after culture, in vitro function (glucose-stimulated insulin secretion [GSIS] stimulation index) and the proportion of isolations meeting release criteria; in recipients of islets from NRP-procured pancreases, outcomes were islet graft function (C-peptide, insulin requirement), insulin independence and glycemic control.

Randomized trials, cohort studies and registry analyses with a concurrent comparator were eligible, including conference abstracts with extractable data, published from January 1, 2016, without language restriction. Case reports, single-arm series, series with fewer than five NRP-procured pancreases, reviews and preclinical studies were excluded; reviews were used for citation searching.

Information Sources and Search

MEDLINE (PubMed), Embase, Web of Science Core Collection, Cochrane CENTRAL and ClinicalTrials.gov were searched on October 14–15, 2026, without date, language or document-type limits. The search strategy combined controlled vocabulary and free-text terms for normothermic regional perfusion, donation after circulatory death, and pancreas or islet transplantation. The complete MEDLINE (PubMed) search strategy was prespecified in the registered review protocol and adapted for the other databases, Web of Science and Embase index the major transplant congress supplements. Islet-focused update searches of PubMed and congress abstract books were run on October 15, 2026. Reference lists of included studies and reviews were screened, and forward citation tracking was performed from six seed reports.

Study Selection and Data Extraction

Records were deduplicated by identifier, DOI and normalized title. Two reviewers (Malik Muhammad Makki and Samia Yunas.) independently screened all titles, abstracts and full texts in duplicate, resolving disagreements by discussion. Because several reports draw on the same national registries, overlap was assessed by registry, center and period, and the largest or most complete report from each independent cohort was used for each outcome. Data were extracted by one reviewer and checked by the second, and every bibliographic record was independently checked for bibliographic accuracy, retractions and errata.

Risk of Bias, Synthesis and Certainty

Risk of bias was assessed independently by both reviewers with ROBINS-I,²⁷ with confounding by era, center and donor selection pre-specified as the key domains. Random-effects meta-analysis with the Hartung-Knapp-Sidik-Jonkman adjustment was planned when at least three independent cohorts reported comparable outcomes;²⁸ otherwise results were synthesized narratively following the SWiM guideline.²⁹ Islet outcomes were synthesized separately from pancreas transplant outcomes. Planned subgroups were TA-NRP versus A-NRP, SPK versus PAK/PTA and Europe versus North America. Certainty of evidence was rated with GRADE.³⁰

RESULTS

Study Selection

Database searches identified 578 records; After deduplication, 353 records were screened and 335 were excluded at title/abstract review; 18 reports were sought for full-text assessment, 14 were retrieved, and 12 reports met eligibility criteria (Fig. 2).

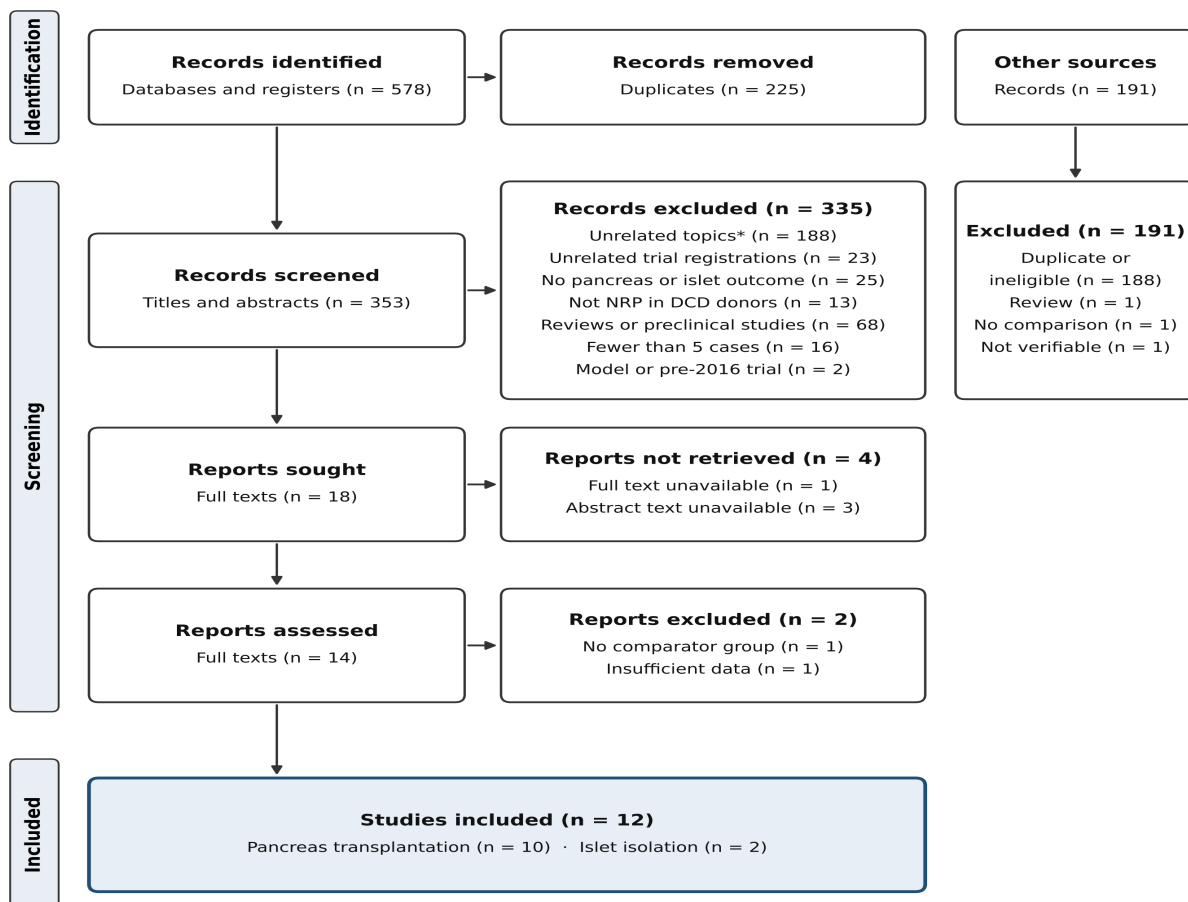


FIGURE 2. PRISMA 2020 flow diagram of study selection.

Study Characteristics

The reports were published between 2021 and 2025 and came from the United Kingdom (5), the United States (4), the Netherlands (2) and Spain (1) (Table 1). Eight were registry analyses, 2 single-center cohorts and 2 reports of one islet isolation program; 5 were conference abstracts.

Where NRP type was specified, NRP-TA predominated in the United States (25 of 33 NRP SPK donors, 76%)²² and NRP-A in the Netherlands.³⁸ In US registry data, NRP donors were older (median 28 vs 22 years) and NRP recipients younger (38 vs 48 years);²² in UK data, warm ischemic time was longer with NRP (median 17 vs 12 minutes), with donors and recipients otherwise well matched

TABLE-1

Report	Country Registry	Design	NRP type	Comparator	NRP vs comparator, n	Outcomes	Overlap
Owen 2025 ²⁰	UK, UKTR, 2013–2023	Registry, multivariable (abstract)	Not Specified	Non-NRP DCD	47 vs 379 SPK	1-y graft survival, aHR graft loss, WIT, insulin independence	Primary UK report
Sutherland 2025 ³⁹	UK, UKTR, 2013–2023	Registry (abstract)	Not Specified	Non-NRP DCD	As Owen 2025	As Owen 2025	Duplicate
Owen 2023 ⁴⁰	UK, UKTR, 2013–2021	Registry, univariable (Abstract)	Not Specified	Non-NRP DCD	36 vs 324 SPK	1-y pancreas, kidney, patient survival; CIT	Superseded
Richards 2021 ¹²	UK, Cambridge, 2008–2018	Single-center cohort	Not Specified	SRR DCD; DBD	13 vs 59 vs 139 SPK	Amylase, lipase, PNF, DGF, thrombosis, re-operation	Within UKTR
Fischer 2025 ²²	US, UNOS, 2021–2025	Registry	NRP-TA = 25, NRP-A = 8	SRR DCD	33 vs 104 SPK	1-y pancreas and kidney survival, kidney DGF	Primary US report
Wall 2023 ⁴¹	US, UNOS, 2020–2022	Registry, cardiac DCD donors	NRP-TA	SRR DCD	Pancreas n NR	6-mo graft survival, kidney DGF	Overlaps Fischer
Fischer 2025 (abstract) ⁴²	US, UNOS, 2014–2024	Registry (Abstract)	Not Specified	SRR DCD; DBD	17 vs 174 vs 7,764 SPK	Pancreas graft survival, anastomotic leak	Overlaps Fischer
Oniscu 2023 ¹⁷	UK, national, 2011–2019	Registry, donor level, risk-adjusted	Not Specified	Non-NRP DCD	Donors with ≥1 abdominal organ	Odds of pancreas transplantation	UK donor level
Bekki 2023 ⁴³	US, national, 2020–2021	Propensity-matched, donor level	NRP-TA	Non-NRP DCD	34 donors	Pancreas utilization	US donor level
Feo 2022 ⁴⁴	Spain, Santander, 2013–2020	Single-center, donor level	NRP	DBD	95 vs 152 donors	Pancreas donation rate	Independent
Doppenberg 2025 ³⁸	Netherlands, Leiden, NR	Retrospective, age-matched isolations	NRP-A	DCD without NRP; DBD	11 vs 42 vs 17 isolations	Islet yield, stimulation index	Independent
van Rooden 2023 ³⁷	Netherlands, Leiden, NR	Isolation cohort (abstract)	NRP-A	DCD without NRP; DBD	11 vs 42 vs 17 isolations	IEQ/g, survival after culture	Linked to Doppenberg

Risk of Bias

Four reports were at moderate and 5 at serious overall risk of bias (Fig. 3); linked reports were not rated separately. Confounding was the dominant concern: only the UK registry analysis, the two utilization analyses and the Leiden islet study adjusted or matched for donor risk. Selective reporting affected abstracts that reported the NRP group without its comparator²² or omitted pancreas-specific results.⁴¹

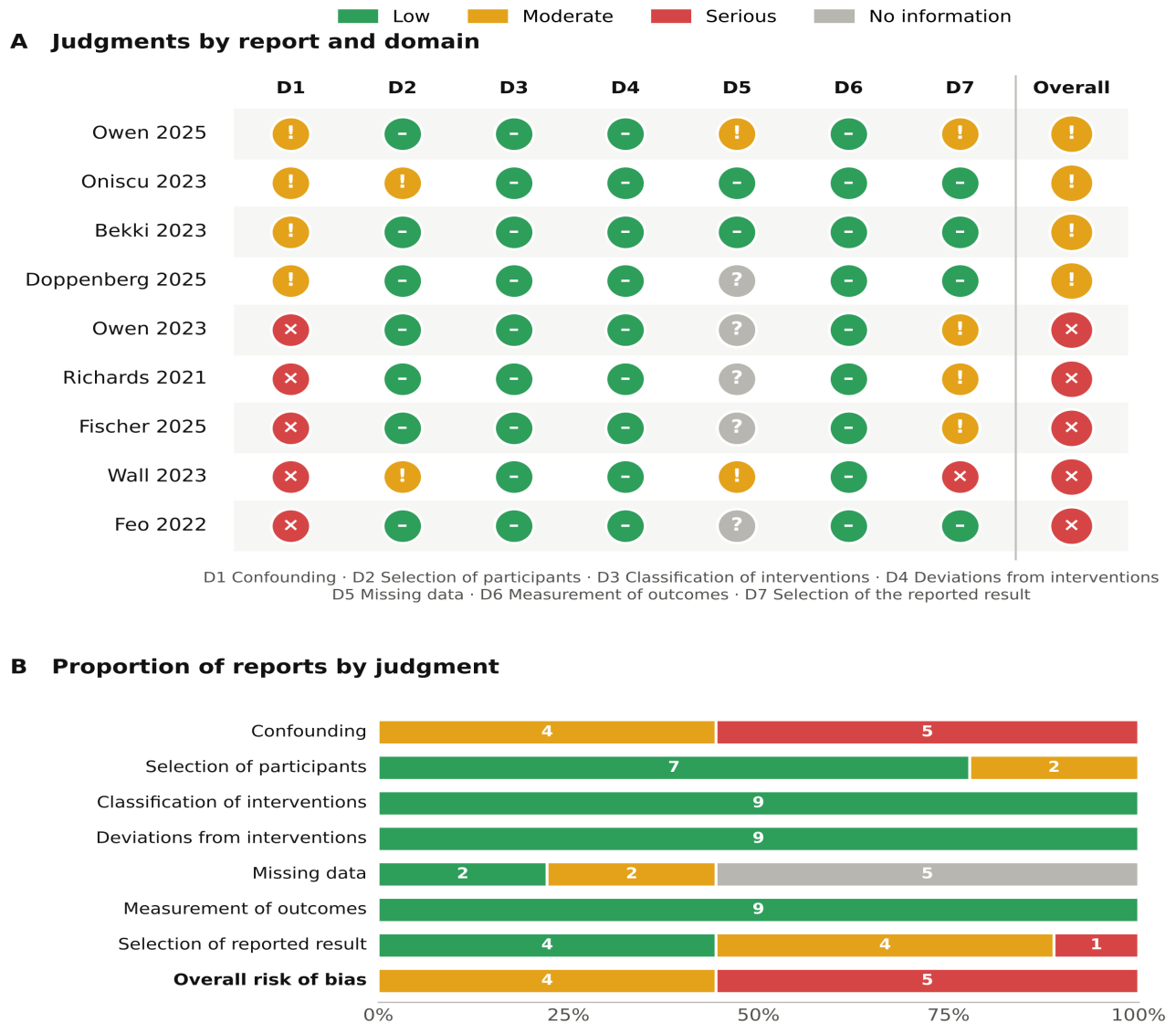


FIGURE 3.

Risk of bias of the 9 rated reports (ROBINS-I). A, Judgment for each report in each domain and overall. B, Number and proportion of reports by judgment in each domain. Linked reports sharing a data source were not rated separately.

NRP Versus Super-Rapid Recovery

After linked reports were combined, two independent cohorts compared recipient outcomes after NRP and SRR: the UK Transplant Registry^{12,20,39,40} and the US UNOS registry.^{22,41,42} Because no outcome had comparable group-level data from three cohorts, results were synthesized narratively (Fig. 4; Table 2).

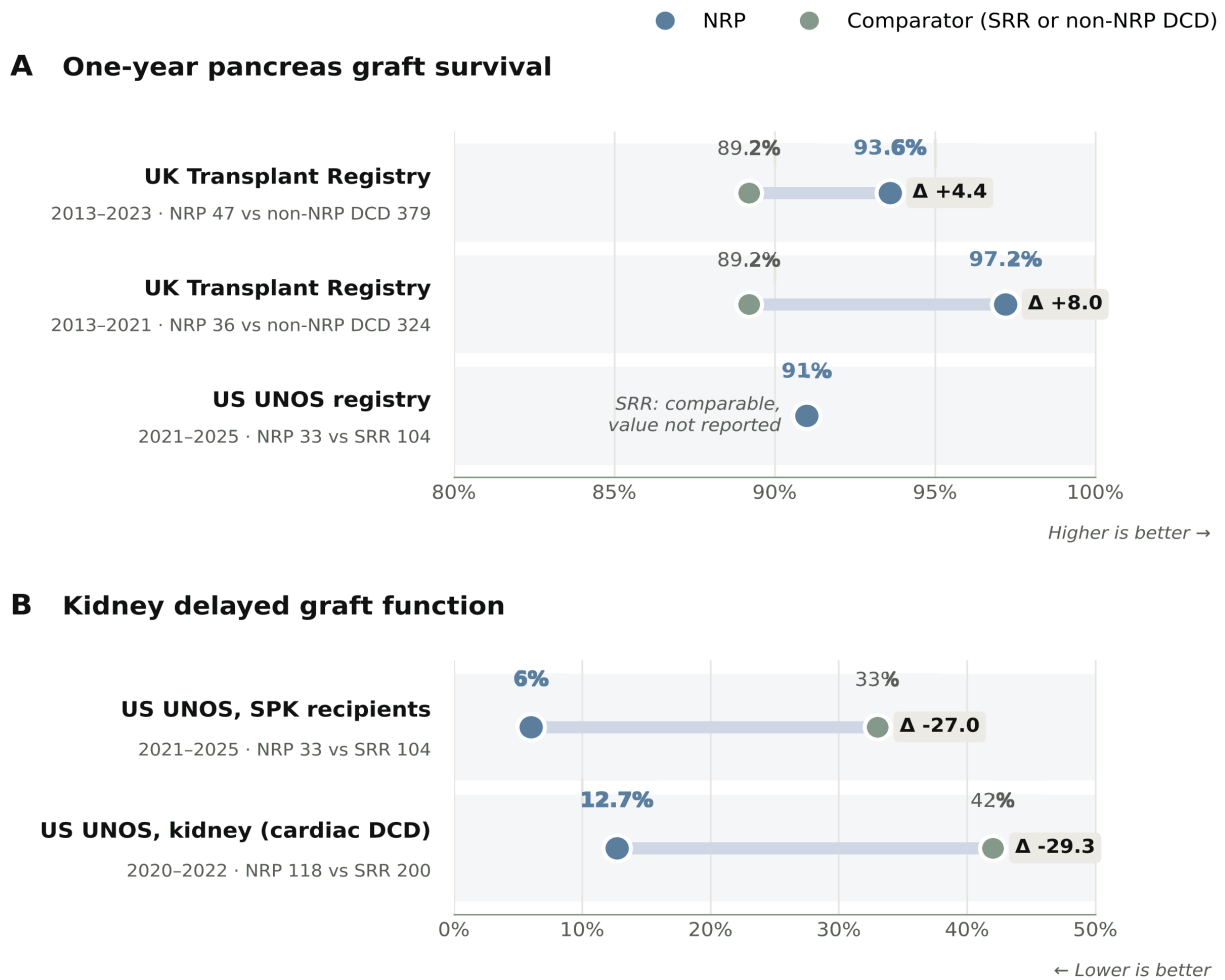


FIGURE 4. Study-level outcomes after NRP and comparator procurement. A, One-year pancreas graft survival. B, Kidney delayed graft function. Blue, NRP; gray, comparator (SRR or non-NRP DCD); Δ, difference in percentage points (NRP minus comparator); recipients per group are shown under each cohort. Values are shown as reported by each cohort and were not pooled because cohorts overlap; the US registry described graft survival after SRR as comparable without reporting a value.

TABLE 2. Summary of Findings and Certainty of Evidence (GRADE)

Outcome	Reports (cohorts)	NRP vs SRR DCD	NRP DCD vs DBD	Certainty	Main reasons
1-y pancreas graft survival	3 (2)	UK 93.6% vs 89.2%; aHR 0.56 (0.17–1.80); US 91% after NRP, comparable	Comparable (unadjusted)	Very low	Risk of bias, imprecision
Early graft thrombosis	1 (1)	No difference (13 vs 59)	Not reported	Very low	Risk of bias, imprecision
Primary non-function	1 (1)	No difference	Not Reported	Very low	Risk of bias, imprecision
Graft pancreatitis (peak lipase)	1 (1)	Lower after NRP	Not Reported	Very low	Surrogate, imprecision
Re-operation	1 (1)	No difference	Not Reported	Very low	Risk of bias, imprecision
1-y patient survival	1 (1)	100% vs 98.3%	Not Reported	Very low	Risk of bias, imprecision
Insulin independence	1 (1)	No association at 3 mo	Not Reported	Very low	Abstract only, imprecision
Pancreas utilization	3 (2)	UK aOR 1.6 (0.98–2.64); US 8.8% vs 2.2%	Similar donation rates (1 center)	Very low	Imprecision, indirectness
Kidney DGF	2 (1)	6% vs 33% (SPK); 12.7% vs 42.0% (kidney, cardiac DCD)	Not Reported	Very low	Risk of bias, overlap
Warm ischemic time	1 (1)	17 vs 12 min	Not Reported	Very low	Single cohort, abstract
Islet isolation yield	2 (1)	471,739 vs 218,750 IEQ vs DCD without NRP ($P < .01$)	471,739 vs 206,522 IEQ ($P = .03$)	Very low	Single center, surrogate

HR indicates adjusted hazard ratio; aOR, adjusted odds ratio; DBD, donation after brain death; DCD, donation after circulatory death; DGF, delayed graft function; IEQ, islet equivalents; NR, not reported; NRP, normothermic regional perfusion; SPK, simultaneous pancreas-kidney transplantation; SRR, super-rapid recovery. Certainty started at low for observational evidence.

Pancreas graft survival.

In the UK registry (47 NRP vs 379 non-NRP DCD SPK), 1-year pancreas graft survival was 93.6% vs 89.2% ($P = .206$); NRP was associated with lower graft loss without statistical significance (adjusted HR 0.56; 95% CI 0.17–1.80), with similar results after adjustment for the pancreas donor risk index.²⁰ The earlier UK analysis (36 vs 324) reported 97.2% vs 89.2%.⁴⁰ In the US registry (33 NRP vs 104 SRR DCD SPK), 1-year graft survival after NRP was 91%, described as comparable to SRR,²² and a 2014–2024 UNOS analysis (17 NRP vs 174 SRR) reported no pancreas graft failure within 1 year after NRP.⁴²

Thrombosis, PNF and pancreatitis.

No registry reported thrombosis by procurement group. In the Cambridge cohort (13 NRP vs 59 SRR), thrombosis, PNF and re-operation did not differ, and peak lipase in the first 3 days was lower after NRP.¹² Anastomotic leak did not differ between NRP and SRR in the UNOS analysis.⁴²

Patient survival and glycemic outcomes.

One-year patient survival was 100% vs 98.3%.⁴⁰ NRP was not associated with insulin independence at 3 months or with pancreas rejection.²⁰

Utilization.

In UK donor-level data (2011–2019), NRP was associated with 1.6-fold higher risk-adjusted odds of pancreas transplantation (95% CI 0.98–2.64; $P = .061$).¹⁷ In a US propensity-matched analysis of 34 TA-NRP donors, pancreas utilization was 8.8% vs 2.2% ($P = .06$).⁴³ The proportion of US DCD SPK donors procured with NRP rose to 24% between 2021 and 2025.²²

Kidney outcomes in SPK recipients.

Kidney outcomes were secondary contextual outcomes in SPK recipients. Kidney DGF was 6% after NRP vs 33% after SRR among US DCD SPK recipients,²² consistent with 12.7% vs 42.0% among kidney recipients from cardiac DCD donors.⁴¹ One-year kidney graft survival was 100% after NRP in both the US and UK SPK cohorts.^{22,40}

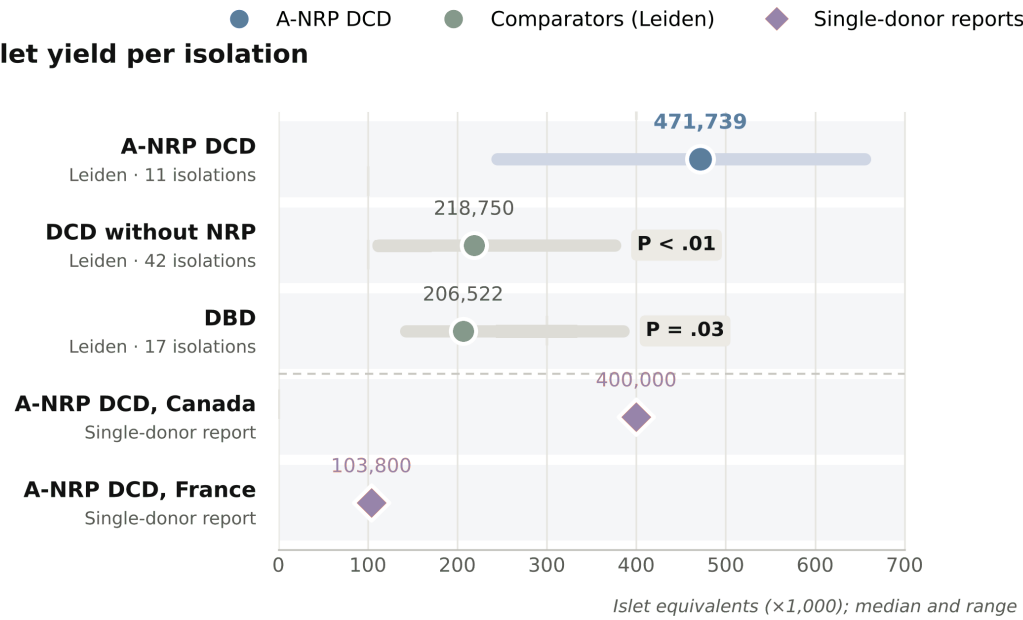
NRP DCD Versus DBD

Five reports from 4 independent data sources compared NRP DCD with DBD procurement (3 on pancreas transplantation or donation and 2 on islet isolation), none with adjusted outcomes (Table 2). Pancreas graft survival was comparable across NRP, SRR and DBD groups in the UNOS analysis (17, 174 and 7,764 recipients).⁴² In Cambridge, peak amylase and lipase were higher after SRR DCD than DBD, while NRP was associated with lower peak lipase than SRR.¹² A Spanish center in which all 95 controlled DCD donors underwent NRP reported pancreas donation rates similar to 152 contemporaneous DBD donors.⁴⁴

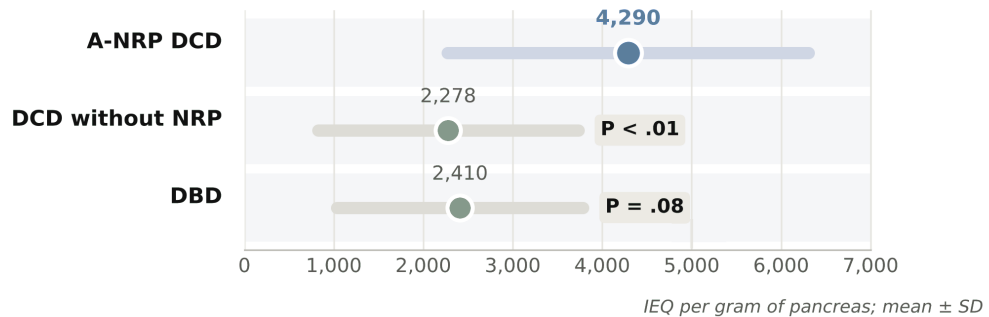
Islet Isolation and Transplantation

Two reports from one program (Leiden, the Netherlands) compared islet isolation after A-NRP with isolation from pancreases procured without NRP (Table 3; Fig. 5). Isolations after A-NRP yielded a median of 471,739 IEQ, compared with 218,750 IEQ after DCD procurement without NRP ($P < .01$) and 206,522 IEQ after DBD procurement ($P = .03$), in donor age-matched (60–75 years) isolations with similar baseline characteristics.³⁸ The congress report of the same program (11 A-NRP, 42 DCD without NRP and 17 DBD isolations) showed a yield per gram of pancreas of $4,290 \pm 2,017$ IEQ/g after A-NRP versus $2,278 \pm 1,453$ IEQ/g without NRP ($P < .01$) and $2,410 \pm 1,374$ IEQ/g after DBD procurement ($P = .08$), and islet survival after overnight culture of 96% versus 75% in both comparator groups (not significant).³⁷ The mean GSIS stimulation index was 4.91 in seven A-NRP preparations, and bilirubin and alanine aminotransferase concentrations during A-NRP correlated with islet yield ($r = 0.685$ and 0.491).³⁸ Purity, release rates and islet recipient outcomes were not reported by procurement group.

A Total islet yield per isolation



B Islet yield per gram of pancreas



C Islet survival after culture

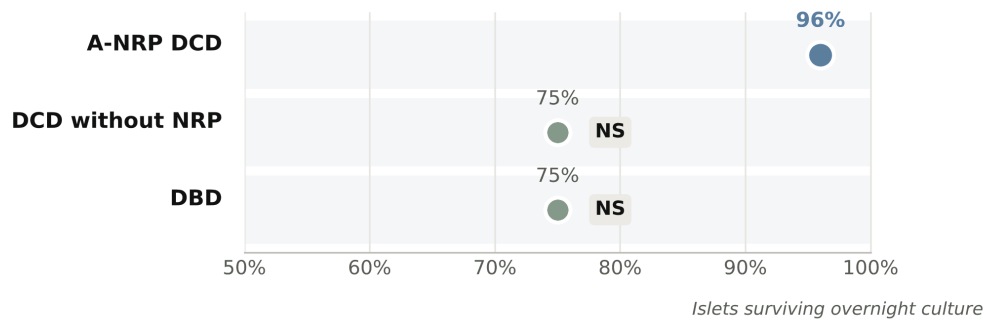


FIGURE 5.

Islet isolation outcomes after NRP-assisted and conventional procurement. A, Total islet yield per isolation (median and range) in the Leiden program. B, Yield per gram of pancreas (mean ± SD). C, Islet survival after overnight culture. P values compare each comparator with NRP-A; NS, not significant. Leiden groups: 11 NRP-A, 42 DCD without NRP and 17 DBD isolations.

TABLE 3. Islet Isolation and Transplantation from Pancreases Procured With Normothermic Regional Perfusion

Report	Donor and NRP	Groups, n	Islet yield	Quality and function	Transplant outcomes
Doppenberg 2025³⁸, Leiden, Netherlands; retrospective cohort	NRP-A	A-NRP vs DCD without NRP vs DBD; 11 vs 42 vs 17	Median IEQ: 471,739 vs 218,750 ($P < .01$) vs 206,522 ($P = .03$)	GSIS stimulation index 4.91 (7 A-NRP preparations); yield correlated with bilirubin ($r = 0.685$) and ALT ($r = 0.491$) during A-NRP	Not reported by group
Van Rooden 2023³⁷, Leiden; congress abstract	NRP-A	11 vs 42 vs 17	IEQ/g, mean $\pm$ SD: 4,290 $\pm$ 2,017 vs 2,278 $\pm$ 1,453 ($P < .01$) vs 2,410 $\pm$ 1,374 ($P = .08$)	Survival after culture 96% vs 75% vs 75% (NS)	Not reported
Esposito 2026³⁴, France; single-donor report	NRP-A	1 isolation	103,800 IEQ (1,958 IEQ/kg)	Viability 89%, purity 48%; met release criteria	Simultaneous islet-kidney: C-peptide 0 $\rightarrow$ 4.7 ng/mL at 2 mo; second DBD infusion at 2 mo

NRP-A indicates abdominal normothermic regional perfusion; ALT, alanine aminotransferase; BMI, body mass index (kg/m^2); DBD, donation after brain death; DCD, donation after circulatory death; fWIT, functional warm ischemia time; GSIS, glucose-stimulated insulin secretion; IEQ, islet equivalents; NS, not significant. Single-donor reports were below the inclusion threshold and are shown for context.

Subgroup Analyses and Certainty of Evidence

None of the planned subgroup analyses could be performed, because no report presented outcomes by NRP type or transplant type. Certainty was very low for every outcome, chiefly because of confounding and imprecision (Table 2); the large reduction in kidney DGF was not upgraded, because both estimates come from overlapping US registry data at serious risk of bias.

DISCUSSION

This systematic review identified 12 reports from 4 independent data sources on NRP-assisted DCD pancreas procurement. Pancreas graft survival after NRP was similar to or numerically higher than after SRR in every available estimate, and the only adjusted estimate pointed toward less graft loss with wide uncertainty.^{20,22} Against DBD, the benchmark for DCD pancreases, pancreas graft survival after NRP was comparable in US registry data,⁴² pancreas donation rates from NRP DCD and DBD donors were similar,⁴⁴ and early graft injury markers suggested that NRP narrows the gap between SRR DCD and DBD grafts.¹² Two donor-level analyses suggested higher pancreas utilization,^{17,43} For islet transplantation, one program reported a yield after A-NRP approximately double that after both SRR DCD and DBD procurement.³⁸ Certainty was very low for every outcome, and no study has compared adjusted recipient outcomes between NRP DCD and DBD pancreases.

NRP DCD Compared With DBD Donation

The relevant question for transplant surgeons is not only whether NRP improves on SRR but whether it makes a DCD pancreas equivalent to a DBD pancreas. In US registry data, pancreas graft survival was comparable across NRP DCD, SRR DCD and DBD recipients;⁴² in Cambridge, SRR DCD grafts had higher peak amylase and lipase than DBD grafts, whereas NRP lowered peak lipase relative to SRR;¹² a Spanish program in which every controlled DCD donor underwent NRP reported pancreas donation rates similar to those of DBD donors,⁴⁴ and islet yield after A-NRP exceeded that from DBD pancreases (471,739 vs 206,522 IEQ).³⁸ None of these comparisons was adjusted for donor or recipient risk, so equivalence with DBD remains a hypothesis rather than a finding.

The Pancreas-Specific Concern

The main argument against NRP for the pancreas is that protocols designed for the liver may prolong warm ischemia before perfusion begins, particularly where cannulation must follow death declaration.^{20,45} UK data confirm a longer warm ischemic time with NRP, yet adjusted graft loss was not higher,²⁰ and early Cambridge data showed lower peak lipase without more thrombosis or PNF.¹² Restoring oxygenated flow may therefore offset the additional warm time, although the confidence intervals cannot exclude meaningful harm or benefit. These findings align with the liver, where NRP reduces ischemic cholangiopathy, graft loss and recipient death,^{18,19,46} and with the kidney, where NRP reduces DGF in national registries and systematic reviews.^{17,41,47,48}

Utilization Versus Graft Outcomes

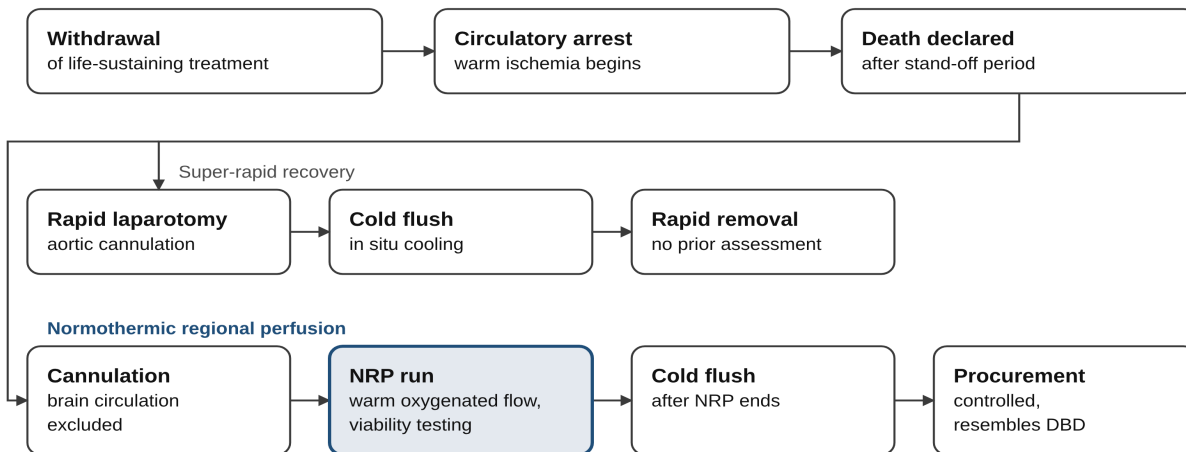
NRP may influence the number of pancreases transplanted as much as the outcome of each transplant. Both utilization estimates favored NRP but neither excluded no effect.^{17,43} Plausible mechanisms are pre-recovery functional assessment, a controlled procurement resembling DBD retrieval and greater surgeon confidence. If NRP increases utilization while maintaining graft survival, its net benefit to patients on the waiting list may exceed what graft-level comparisons show; conversely, acceptance of more marginal grafts after NRP could produce a modest excess of early complications that would not reflect harm from the technique itself.

Secondary Findings: Islet Transplantation

Although islet data are limited, islet programs may also benefit from NRP, because islet transplantation depends on recovering a sufficient mass of viable islets from each pancreas and ischemia lowers isolation yield.⁹ The Leiden data suggest that A-NRP may approximately double yield and that perfusate bilirubin and transaminases during NRP may help select pancreases for isolation.^{37,38} A narrative overview described islet results after NRP as comparable with, rather than better than, conventional DCD procurement,²³ so the yield advantage should be confirmed in multicenter data. Yield is a surrogate outcome; the clinically relevant end points are release rates, the number of infusions needed for insulin independence and long-term graft function, none of which has yet been reported by procurement technique.

Technical Considerations

NRP protocols differ chiefly in what may be done before death is declared. UK practice cannulates and heparinizes only after death verification, an approach compatible with successful NRP,⁴⁵ and the first UK series reported a median of 16 minutes from asystole to perfusion with 2 hours of NRP.¹⁴ Where permitted, premortem heparin and cannula placement shorten this interval, and US practice now follows American Society of Transplant Surgeons standards.¹⁶ A-NRP restricts perfusion to the abdomen, whereas TA-NRP also perfuses the thoracic organs while excluding the cerebral circulation^{15,49} (Fig. 6). Reported NRP durations range from at least 60 minutes in Spain¹⁵ to 2 hours in the United Kingdom,¹⁴ and the optimal duration for the pancreas, and pancreas-specific viability criteria during NRP, are undefined.



Reported NRP durations: at least 60 minutes (Spain, A-NRP) to 2 hours (UK). UK practice cannulates and heparinizes only after death. TA-NRP also perfuses thoracic organs; A-NRP occludes the descending aorta. Durations and steps vary by national protocol.

FIGURE 6.

International Practice and Ethics

NRP has been adopted widely in Spain and the United Kingdom^{15,50,51} and is expanding rapidly in the United States, including programs run by organ procurement organizations.⁵² A 2026 European consensus provides recommendations on adoption, perfusion parameters and organ evaluation.⁵³

Strengths and Limitations

This review searched five databases and registers together with congress proceedings, where much of the pancreas evidence resides, handled overlapping registry reports explicitly, synthesized islet outcomes separately and verified bibliographic records for accuracy, retractions and errata. Its limitations reflect the evidence base. The number of independent cohorts is small and estimates are imprecise; all evidence is observational and confounded by era, center expertise and donor selection; several key sources are conference abstracts; outcome definitions vary; most data come from SPK recipients in the United Kingdom and United States; the islet evidence comes from a single program and reports a surrogate outcome; and the protocol was registered after the searches. Reporting bias could not be assessed with fewer than 10 studies.

Implications for Practice and Research

- . Current evidence does not support treating NRP procurement itself as evidence of pancreas graft inferiority; acceptance decisions should continue to integrate donor, ischemic, technical, and recipient risk while stronger comparative data are generated
- Record the interval from asystole to full NRP flow, which is pancreas-relevant and varies with national cannulation rules.^{14,20,45}
- Standardize pancreas outcome definitions in NRP registries (thrombosis, pancreatitis, PNF, graft loss) together with NRP type, duration and perfusate biochemistry, in line with the European consensus.⁵³
- Develop and validate pancreas-specific viability criteria during NRP, including perfusate amylase, lipase and glucose trajectories.
- Report pancreas and islet outcomes for NRP DCD, SRR DCD and DBD donors side by side, including islet yield, purity, release rates and recipient outcomes, and pursue individual-patient data synthesis of UK, Spanish and US registries while SRR controls still exist. Because NRP also lowers kidney DGF and improves functional recovery,^{22,41,55} SPK analyses should report kidney and pancreas outcomes together.

CONCLUSIONS

Pancreas graft outcomes after NRP DCD procurement were comparable to those after both super-rapid recovery DCD and DBD procurement in the available evidence, which was of very low certainty throughout. Compared with super-rapid recovery, NRP may increase pancreas utilization and reduce kidney delayed graft function in SPK recipients; compared with DBD, pancreas graft survival and donation rates appeared similar in unadjusted comparisons. In islet transplantation, single-program data show a yield after NRP approximately double that of both super-rapid recovery and DBD pancreases, but recipient outcomes by procurement technique are unknown. Pooled registry analyses comparing NRP DCD with both SRR DCD and DBD pancreases, using standardized outcome definitions, are needed.

ACKNOWLEDGMENTS: Artificial intelligence used to write , correct and formulate draft .The authors reviewed and verified all screening decisions, extracted data, risk-of-bias judgments and the final text, and take full responsibility for the content of this article

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