SCOPING REVIEW

Comparative Efficacy of Preservative vs. Isotonic Fluids in liver transplantation: A scoping review

Muhammad Salman[1], Saira Imtiaz [2], Talha Bukhari[3], Irfan Ahmed[4]

Abstract

Objective: To evaluate the comparative efficacy of preservative solutions versus isotonic fluids in living donor liver transplantation.

Method: The scoping review was conducted from June 1, 2024, to January 1, 2025, and comprised comprehensive literature search across PubMed, Scopus, Cochrane Library and Cumulative Index to Nursing and Allied Health Literature databases for randomised/non-randomised trials, observational studies and case series comparing preservative solutions and isotonic fluids in living donor liver transplantation cases involving adults that were published in the English language up to October 2023. After data extraction, the volume and type of evidence was noted, consistent themes were identified, and critical gaps were highlighted.

Results: Of the 2,131 studies screened, 51(2.4%) were assessed for eligibility, and, of them, 1(1.9%) was reviewed in detail, involving 80 adult living donor liver transplantation recipients, divided equally into histidine-tryptophan-ketoglutarate and non-histidine-tryptophan-ketoglutarate groups. Outcomes, including early allograft dysfunction, postoperative complications, hospital stay, and 1-year survival rates, were comparable between the two groups. The non-histidine-tryptophan-ketoglutarate approach significantly reduced direct costs by $2,000 per graft.

Conclusion: Cold normal saline appeared safe and cost-effective for select living donor liver transplantation cases with short ischaemia time and minimal back-table work, potentially reducing costs compared to histidine-tryptophan-ketoglutarate.

Key Words: Liver transplantation, Saline solution, Cost-effectiveness, Preservative solutions, Isotonic fluids, Graft survival, Scoping review.

(JPMA 76: S81 :03 (Supple-1); 2026) **DOI: https://doi.org/10.47391/JPMA.AKU-10Surg-16**

Introduction

Living donor liver transplantation (LDLT) is a critical medical procedure that has significantly improved the prognosis for patients with end-stage liver disease (ESLD), offering a vital lifeline, and markedly enhancing survival rates in healthcare systems where deceased donor organs are scarce.[1,2] It is the most effective treatment for conditions, such as liver cirrhosis, severe acute hepatitis not responding to medical treatment liver cancer, and liver-based metabolic disorders, providing the best outcomes for patients with hepatocellular carcinoma (HCC).[3,4] Notably, liver transplant (LT) for acute liver failure has increased patient survival rates from over 15% to 80% in one year.[5]

A fundamental challenge in LT is maintaining the liver's viability from donor extraction to recipient implantation, ensuring minimal cellular damage and preserved functional integrity.[6-8]

[1]The Aga Khan University, [2,3,4]Pakistan Kidney and Liver Institute and Research Center, Lahore, Pakistan

Correspondence: Saira Imtiaz. **Email:** saira.khan@pkli.org.pk

ORCID ID: 0000-0003-1197-7565

In LDLT, the preservation process involves two critical ischaemic phases: cold ischaemia time (CIT) and warm ischaemia time (WIT). CIT begins with the donor liver's flushing with cold preservation fluid and continues until the graft is removed from the ice prior to implantation. Following this, WIT begins and extends until graft reperfusion. Both phases significantly impact graft function, with prolonged ischaemia times increasing the risk of complications, such as early allograft dysfunction (EAD) and biliary strictures. Traditional solutions, like histidine-tryptophan-ketoglutarate (HTK) and Celsior are widely used due to their metabolic buffering and organ protection capabilities. However, recent studies have explored alternatives, like isotonic fluids, as cost-effective substitutes, especially in LDLT scenarios where ischaemia times are often short.[9-12]

Preserving liver grafts in cold storage solutions is essential for cadaveric liver transplantation. Liver grafts are deprived of oxygen and nutrients, leading to the build-up of metabolic waste and disruption of ionic homeostasis, which results in increased acidosis and potential organ failure.[9] The choice of organ preservation solutions is crucial for protecting the liver graft from ischaemic damage during cold storage, which affects the extent of

reperfusion injury after revascularisation in transplantation.[13,14] These solutions, such as the University of Wisconsin (UW) solution, HTK solution and Celsior solution, are designed to protect the liver by maintaining cellular homeostasis and preventing metabolic deterioration. By doing this, the solutions extend the viability window of the liver during transport.[15]

There are more than two static cold preservation solutions used for liver transplantation; UW is an isotonic, high-potassium, phosphate-buffered solution that has been in clinical use since 1987, and the HTK solution which has been in clinical use since 1999. While UW remains the most widely used, the use of HTK is increasing due to advantages that include lower cost, decreased risk of hyperkalaemia, and reduced viscosity, culminating in improved microvascular perfusion.[16,17] In addition, the Institute Georges Lopez-1 (IGL-1) and Celsior are preservation solutions that can also be used to cold-store livers.[18-22]

Preservation solutions are routinely used in deceased donor liver transplantation (DDLT) during CIT to prevent graft injury. However, the use of these solutions in LDLT lacks standardisation. Routine isotonic solutions can be used in LDLT due to short ischaemia time. Given the increased procedural costs and complexity associated with preservative solutions, exploring alternative isotonic solutions, like cold normal saline (NS) or Ringer's lactate (RL), could offer similar results, especially in resource-limited settings.

The current scoping review was planned to assess the comparative effectiveness and outcomes of using preservative solutions versus isotonic fluids in LDLT, focusing on outcomes, such as graft survival, EAD, postoperative complications, length of hospital stay (LOS), survival rates, and cost effectiveness.

Materials and Methods

The scoping review was conducted from June 1, 2024, to January 1, 2025, in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR).[23] While it was initially registered as a systematic review with the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42024569521), the scarcity of eligible studies necessitated adopting a scoping review methodology to better explore the evidence landscape.

A comprehensive literature search was conducted across PubMed, Scopus, Cochrane Library, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases for randomised/non-randomised trials, observational studies, and case series comparing preservative solutions and isotonic fluids in LDLT cases involving adults. No filters were applied for study design or date to ensure comprehensive coverage; only English-language studies were included. Grey literature, such as conference abstracts, preprints, and letters, non-English studies without translations, and studies lacking quantifiable outcomes were excluded. The medical subject headings (MeSH) included "liver transplantation," "preservation solutions," and "isotonic fluids" (The full search strategy, including database-specific strings, filters, and screening details, is provided in Supplementary Material).

Two reviewers independently screened titles/abstracts and full texts using Rayyan software. Conflicts, if any, were resolved via consensus or third-party adjudication. Data was extracted using a standardised proforma and included study design, setting, population, preservation methods (solution type, ischaemia time), and outcomes (EAD, survival, costs).

Unlike systematic reviews, no risk-of-bias assessment was performed, as scoping reviews emphasise evidence mapping over appraisal. Findings were narratively synthesised to describe the volume and types of evidence, identify consistent themes, and highlight critical gaps. Grading of Recommendations, Assessment, Development and Evaluation (GRADE) assessment was omitted, as it is inappropriate for scoping reviews.

Results

After removing duplicates, 2,131 studies were screened. Of these screened studies, 51(2.4%) were assessed for eligibility, and, of them, 1(1.9%) was reviewed in detail (24) (Figure), involving 80 adult LDLT recipients, divided equally into HTK and non-HTK groups. The study was conducted at a single centre in Pakistan, and focussed on outcomes, like EAD, complications, survival and costs.

Outcomes, including EAD, postoperative complications, LOS, and 1-year survival rates, were comparable between the two groups. The non-HTK approach significantly reduced direct costs per graft (Table 1). The study had limitations as it had a non-randomised, unblended design. Besides, it was done at a single centre, did not include paediatric or high-risk recipients, and did not include long-term data beyond 1 year.

Discussion

The current scoping review highlights a critical evidence gap in preservation strategies for LDLTs, with only one study comparing HTK solution to NS meeting the

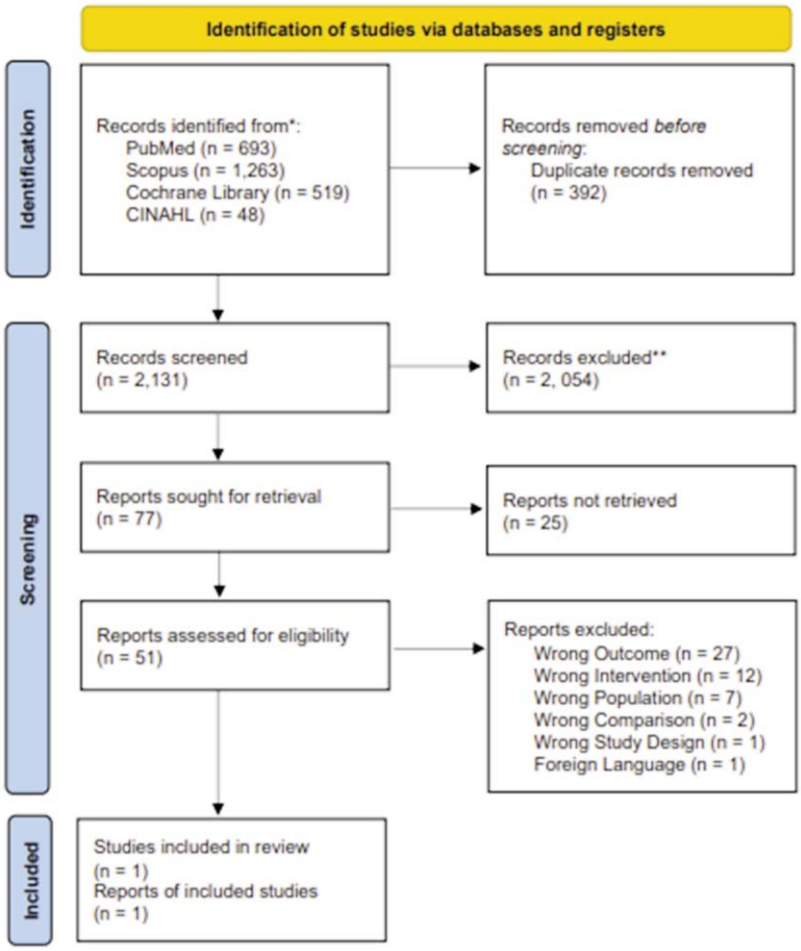

Figure: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) flow diagram.

Table-1: Comparison of clinical outcomes and costs between cold normal saline (NS) and HTK preservation solutions in liver transplantation.

Authors	Study Design	Variable	Non-HTK Group (Cold NS)	HTK Group	p-value
Dogar et al. 2022 [24]	Prospective, case-control study	Number of Recipients	40	40	-
		Early Allograft Dysfunction	5 (12.5%)	4 (10%)	0.72
		Biliary Leak	1 (2.5%)	0	0.31
		Biliary Stricture	6 (15%)	7 (17.5%)	0.76
		Hepatic Artery Thrombosis	1 (2.5%)	0	0.31
		Portal Vein Thrombosis	0	1 (2.5%)	0.31
		Mean Hospital Stay (days)	10.80 ± 2.36	11.78 ± 2.91	0.10
		30-day Mortality	1 (2.5%)	2 (5%)	0.72
		1-Year Mortality (excluding first month)	2 (5%)	2(5%)	1.0
		1-Year Survival Rate	92.5%	90%	0.71
		Direct Cost Comparison	Lower cost than HTK group	Higher cost	-

HTK: Histidine-tryptophan-ketoglutarate.

Table-2: Comparison of liver graft preservation solutions: composition, clinical features, and utilisation patterns in living donor liver transplantation (LDLT).

Solution	Key Features	LDLT Use	Reference
UW	High-potassium, lactobionate-based	Limited due to viscosity/cost	[26]
HTK	Low-viscosity, histidine-buffered	Widely adopted in Europe/Asia	[27]
IGL-1	UW-modified with polyethylene glycol	Emerging use for steatotic grafts	[28]
Celsior	Dual vascular/flush properties	Rare, limited evidence	[29]
NS	Isotonic, no additives	Anecdotal in resource-limited settings	[24]

UW: University of Wisconsin solution, HTK: Histidine-tryptophan-ketoglutarate, IGL-1: Institute Georges Lopez-1, NS: Normal saline.

inclusion criteria.[24] While the findings suggest NS may be a safe, cost-effective alternative in selected LDLT cases[24], these results require careful interpretation within the broader context of liver preservation science and clinical practice.

Liver graft preservation primarily aims at mitigating cold ischaemia-reperfusion injury (IRI), which progresses through three key mechanisms[25], like cellular oedema. Isotonic fluids, like NS, lack impermeants (e.g., lactobionate in UW, mannitol in HTK), potentially enabling swelling during prolonged storage.[25] Another mechanism is metabolic acidosis. The absence of buffering agents in NS (e.g., histidine in HTK) may exacerbate intracellular potential of hydrogen (pH) drops during ischaemia.[25] Another element is that of oxidative stress. Unlike specialised solutions, NS provides no antioxidants (e.g., glutathione in UW) to neutralise reperfusion-generated free radicals.[25]

However, in LDLT with short cold ischaemia times (CIT <2 hours), these limitations may be clinically non-significant, as Dogar et al. demonstrated comparable outcomes between NS and HTK groups.[24] This suggests that NS's low cost and simplicity could offer practical advantages when ischaemia time is minimised.

In terms of global preservation practices, current clinical approaches vary significantly between DDLT and LDLT [24,26-29] (Table 2).

Notably, while no guidelines explicitly prohibit NS in LDLT, the lack of comparative studies, as highlighted in the current review, perpetuates clinical uncertainty. The >$2,000 cost difference per case between NS and HTK [24,30] underscores the need for rigorous evaluation, particularly in resource-constrained settings.

The current review has limitations because of its reliance on a single, non-randomised study[24] that included no paediatric recipient or marginal grafts (e.g., steatotic livers). Besides, there was technical variability as it was unclear how back-table reconstruction complexity affected NS suitability.

Critical questions that have remained unanswered include the maximum safe CIT for NS in LDLT, long-term biliary outcomes (e.g., stricture rates), and the cost-benefit thresholds for solution selection.

Despite the limitations, however, the review has presented data that has clinical and policy implications. These include the cost-effectiveness of NS which could reduce LDLT costs by ~$2,000 per graft compared to HTK [24,30], potentially expanding access in low-resource settings. There is a need for protocol standardisation to clearly define NS-appropriate scenarios (e.g., short CIT, minimal back-table work). Multicentre randomised controlled trials (RCTs) comparing NS and HTK/UW, stratified by CIT and graft quality, are recommended.

Conclusion

Isotonic solutions, like NS, have the potential to serve as cost-effective alternatives to preservative fluids in selected LDLT cases with short CIT. However, the limited evidence from a single non-randomised study precludes broad recommendations. While promising for resource-constrained settings, adoption requires rigorous multicentre trials evaluating safety thresholds, long-term outcomes, and applicability to marginal grafts. Until further evidence emerges, specialised solutions remain standard, though NS may be considered for straightforward cases where cost reduction is critical. The findings have underscored the need for systematic research to establish evidence-based protocols.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

Registration and Protocol: Registered with the International Prospective Register of Systematic Reviews (PROSPERO) [CRD42024569521].

References

1. Nasralla D, Coussios CC, Mergental H, Akhtar MZ, Butler AJ, Ceresa CDL, et al. A randomized trial of normothermic preservation in liver transplantation. Nature 2018;557:50-6. doi: 10.1038/s41586-

018-0047-9.
2. Gorji L, Brown ZJ, Limkemann A, Schenk AD, Pawlik TM. Liver Transplant as a Treatment of Primary and Secondary Liver Neoplasms. JAMA Surg 2024;159:211-8. doi: 10.1001/jamasurg.2023.6083.
3. Durkin C, Bittermann T. Liver transplantation for alcohol-associated hepatitis. Curr Opin Organ Transplant 2023;28:85-94. doi: 10.1097/MOT.0000000000001044.
4. Everhart JE, Beresford TP. Liver transplantation for alcoholic liver disease: a survey of transplantation programs in the United States. Liver Transpl Surg 1997;3:220-6. doi: 10.1002/lt.500030305.
5. Shingina A, Ziogas IA, Vutien P, Uleryk E, Shah PS, Renner E, et al. Adult-to-adult living donor liver transplantation in acute liver failure. Transplant Rev (Orlando) 2022;36:100691. doi: 10.1016/j.trre.2022.100691.
6. Khalil A, Quaglia A, Gélat P, Saffari N, Rashidi H, Davidson B. New Developments and Challenges in Liver Transplantation. J Clin Med 2023;12:5586. doi: 10.3390/jcm12175586.
7. Papadopoulos D, Siempis T, Theodorakou E, Tsoulfas G. Hepatic ischemia and reperfusion injury and trauma: current concepts. Arch Trauma Res 2013;2:63-70. doi: 10.5812/atr.12501.
8. Heo MJ, Suh JH, Poulsen KL, Ju C, Kim KH. Updates on the Immune Cell Basis of Hepatic Ischemia-Reperfusion Injury. Mol Cells 2023;46:527-34. doi: 10.14348/molcells.2023.0099.
9. Masior Ł, Grąt M. Methods of Attenuating Ischemia-Reperfusion Injury in Liver Transplantation for Hepatocellular Carcinoma. Int J Mol Sci 2021;22:8229. doi: 10.3390/ijms22158229.
10 Baidya R, Crawford DHG, Gautheron J, Wang H, Bridle KR. Necroptosis in Hepatosteatotic Ischaemia-Reperfusion Injury. Int J Mol Sci 2020;21:5931. doi: 10.3390/ijms21165931.
11. Ito T, Naini BV, Markovic D, Aziz A, Younan S, Lu M, et al. Ischemia-reperfusion injury and its relationship with early allograft dysfunction in liver transplant patients. Am J Transplant 2021;21:614-25. doi: 10.1111/ajt.16219.
12. Bastos-Neves D, Salvalaggio PRO, Almeida MD. Risk factors, surgical complications and graft survival in liver transplant recipients with early allograft dysfunction. Hepatobiliary Pancreat Dis Int 2019;18:423-9. doi: 10.1016/j.hbpd.2019.02.005.
13. Totsuka E, Fung JJ, Lee MC, Ishii T, Umehara M, Makino Y, et al. Influence of cold ischemia time and graft transport distance on postoperative outcome in human liver transplantation. Surg Today 2002;32:792-9. doi: 10.1007/s005950200152.
14. Southard JH, Belzer FO. Organ preservation. Annu Rev Med 1995;46:235-47. doi: 10.1146/annurev.med.46.1.235.
15. Fuller B, Froghi F, Davidson B. Organ preservation solutions: linking pharmacology to survival for the donor organ pathway. Curr Opin Organ Transplant 2018;23:361-8. doi: 10.1097/MOT.0000000000000525.
16. Chan SC, Liu CL, Lo CM, Fan ST. Applicability of histidine-tryptophan-ketoglutarate solution in right lobe adult-to-adult live donor liver transplantation. Liver Transpl 2004;10:1415-21. doi: 10.1002/lt.20243.
17. Xu X, Zhu YF, Lv T, Zheng JL, Li YK, Zhang BH, et al. Histidine-tryptophan-ketoglutarate solution versus University of Wisconsin solution in adult-to-adult living donor liver transplantation: A propensity score matching analysis from mainland China. Medicine (Baltimore) 2020;99:e23584. doi: 10.1097/MD.0000000000023584.
18. Moray G, Sevmis S, Karakayali FY, Gorur SK, Haberal M. Comparison of histidine-tryptophan-ketoglutarate and University of Wisconsin in living-donor liver transplantation. Transplant Proc 2006;38:3572-5. doi: 10.1016/j.transproceed.2006.10.174.
19. Tabka D, Bejaoui M, Javellaud J, Roselló-Catafau J, Achard JM, Abdennebi HB. Effects of Institut Georges Lopez-1 and Celsior preservation solutions on liver graft injury. World J Gastroenterol 2015;21:4159-68. doi: 10.3748/wjg.v21.i14.4159.
20. Wiederkehr J, Igreja M, Nogara M, Goncalves N, Godoy M, Vilas R, et al. The of Institute George Lopez (IGL-1) Solution in Liver Graft Preservation-Experience With 100 Liver Transpant in a Single Center.: Abstract# A419. Transplant 2014;98:707.
21. Wiederkehr JC, Igreja MR, Nogara MS, Goncalves N, Montemezzo GP, Wiederkehr HA, et al. Use of IGL-1 preservation solution in liver transplantation. Transplant Proc 2014;46:1809-11. doi: 10.1016/j.transproceed.2014.05.040.
22. Wiederkehr JC, Igreja MR, Nogara MS, Gonçalves N, Godoy M, Drago C, et al. Comparison of IGL-1 with HTK Preservation Solution in Liver Transplantation-A Controlled Single-Center Series.: Abstract# P-408. Liver Transplantation 2014;20:S276.
23. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med 2018;169:467-73. doi: 10.7326/M18-0850.
24. Dogar AW, Ullah K, Shams-Ud-Din, Abbas SH, Hussain A, Ghaffar A, et al. Is a Preservation Solution for Living Donor Liver Transplantation Needed? Adding a New Chapter in LDLT! Transplant Direct 2022;8:e1396. doi: 10.1097/TXD.0000000000001396.
25. Petrenko A, Carnevale M, Somov A, Osorio J, Rodríguez J, Guibert E, et al. Organ Preservation into the 2020s: The Era of Dynamic Intervention. Transfus Med Hemother 2019;46:151-72. doi: 10.1159/000499610.
26. Southard JH, Belzer FO. Organ preservation. Annu Rev Med 1995;46:235-47. doi: 10.1146/annurev.med.46.1.235.
27. Chan SC, Liu CL, Lo CM, Fan ST. Applicability of histidine-tryptophan-ketoglutarate solution in right lobe adult-to-adult live donor liver transplantation. Liver Transpl 2004;10:1415-21. doi: 10.1002/lt.20243.
28. Tabka D, Bejaoui M, Javellaud J, Roselló-Catafau J, Achard JM, Abdennebi HB. Effects of Institut Georges Lopez-1 and Celsior preservation solutions on liver graft injury. World J Gastroenterol 2015;21:4159-68. doi: 10.3748/wjg.v21.i14.4159.
29. Dutkowski P, de Rougemont O, Clavien PA. Machine perfusion for 'marginal' liver grafts. Am J Transplant 2008;8:917-24. doi: 10.1111/j.1600-6143.2008.02165.x.
30. Feng S, Goodrich NP, Bragg-Gresham JL, Dykstra DM, Punch JD, DebRoy MA, et al. Characteristics associated with liver graft failure: the concept of a donor risk index. Am J Transplant 2006;6:783-90. doi: 10.1111/j.1600-6143.2006.01242.x.

Supplementary Material: Full Search Strategy for Scoping Review

1. Search Dates & Databases

- PubMed: Search conducted on January 15, 2025
- Scopus: Search conducted on January 16, 2025
- Cochrane Library: Search conducted on January 17, 2025
- CINAHL: Search conducted on January 18, 2025

a. Filters Applied (No filters were applied for study design or publication date)

- Language: English
- Population: Humans, adults

b. Notes

- Searches included MeSH terms, Boolean operators, field tags, quotation marks, and parentheses as per database requirements (full strings provided below).
- Screening, selection, and data extraction were performed as described in Methods.

2. Complete Search Strings by Database

Note: MeSH/ subject headings were adapted per database

2.1 PubMed

("liver transplantation"[Title/Abstract] OR "Hepatic Transplantation"[Title/Abstract] OR "Liver Graft"[Title/Abstract] OR "Living Donor"[Title/Abstract])

AND ("preservative solutions"[Title/Abstract] OR "Ringer's Lactate"[Title/Abstract] OR "Ringer Solution"[Title/Abstract] OR "Sodium Chloride"[Title/Abstract] OR "Normal saline"[Title/Abstract] OR "HTK Solution"[Title/Abstract] OR "Celsior"[Title/Abstract])

AND ("graft survival"[Title/Abstract] OR "allograft survival"[Title/Abstract] OR "patient survival"[Title/Abstract] OR "survival rate"[Title/Abstract])

AND ("postoperative complications"[Title/Abstract] OR "biliary complications"[Title/Abstract] OR "vascular complications"[Title/Abstract])

AND ("liver function tests"[Title/Abstract] OR "blood chemical analysis"[Title/Abstract])

AND ("length of stay"[Title/Abstract] OR "intensive care unit"[Title/Abstract])

AND ("cost-benefit analysis"[Title/Abstract] OR "health care costs"[Title/Abstract])

AND ("quality of life"[Title/Abstract] OR "health status indicators"[Title/Abstract])

2.2 Scopus

TITLE-ABS-KEY("liver transplantation" OR "Hepatic Transplantation" OR "Liver Graft" OR "Living Donor")

AND TITLE-ABS-KEY("preservative solutions" OR "Ringer's Lactate" OR "Ringer Solution" OR "Sodium Chloride" OR "Normal saline" OR "HTK Solution" OR "Celsior")

AND TITLE-ABS-KEY("graft survival" OR "allograft survival" OR "patient survival" OR "survival rate")

AND TITLE-ABS-KEY("postoperative complications" OR "biliary complications" OR "vascular complications")

AND TITLE-ABS-KEY("liver function tests" OR "blood chemical analysis")

AND TITLE-ABS-KEY("length of stay" OR "intensive care unit")

AND TITLE-ABS-KEY("cost-benefit analysis" OR "health care costs")

AND TITLE-ABS-KEY("quality of life" OR "health status indicators")

2.3 Cochrane Library

("liver transplantation" OR "Hepatic Transplantation" OR "Liver Graft" OR "Living Donor")

AND ("preservative solutions" OR "Ringer's Lactate" OR "Ringer Solution" OR "Sodium Chloride" OR "Normal saline" OR "HTK Solution" OR "Celsior")

AND ("graft survival" OR "allograft survival" OR "patient survival" OR "survival rate")

AND ("postoperative complications" OR "biliary complications" OR "vascular complications")

AND ("liver function tests" OR "blood chemical analysis")

AND ("length of stay" OR "intensive care unit")

AND ("cost-benefit analysis" OR "health care costs")

AND ("quality of life" OR "health status indicators")

2.4 CINAHL (EBSCOhost)

("liver transplantation" OR "Hepatic Transplantation" OR "Liver Graft" OR "Living Donor")

AND ("preservative solutions" OR "Ringer's Lactate" OR "Ringer Solution" OR "Sodium Chloride" OR "Normal saline" OR "HTK Solution" OR "Celsior")

AND ("graft survival" OR "allograft survival" OR "patient survival" OR "survival rate")

AND ("postoperative complications" OR "biliary complications" OR "vascular complications")

AND ("liver function tests" OR "blood chemical analysis")

AND ("length of stay" OR "intensive care unit")

AND ("cost-benefit analysis" OR "health care costs")

AND ("quality of life" OR "health status indicators")

3. Eligibility Criteria

Inclusion:

- Adult patients undergoing living donor liver transplantation
- Studies comparing preservative solutions (HTK, UW, Celsior, IGL-1) versus isotonic fluids (NS, Ringer's lactate)
- Study types: randomized/non-randomized trials, observational studies, case series
- Outcomes: graft survival, patient survival, EAD, postoperative complications, LOS, cost-effectiveness

Exclusion:

- Pediatric studies
- Non-English studies without translation
- Studies without quantifiable outcomes
- Letters, conference abstracts (unless full data available), preprints

4. Screening & Selection Process

- Two reviewers independently screened titles and abstracts
- Full texts were assessed for eligibility
- Conflicts resolved by discussion or third reviewer
- Screening was performed using **Rayyan software**

5. Number of Results per Database

Database	Results
PubMed	693
Scopus	1263
Cochrane library	519
CINAHL	48