The role of T-tubes and abdominal drains on short-term outcomes in liver transplantation – A systematic review of the literature and expert panel recommendations

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Abbreviations

ERAS4OLT	Enhanced Recovery After Surgery for Liver Transplantation
GRADE	Grading of Recommendations Assessment, Development and Evaluation
ILTS	International Liver Transplantation Society
LT	Liver transplantation
QOE	Quality of evidence
RCT	Randomized controlled trial

Data statement

There is no data available for this manuscript. This is a literature review and analysis and references are included in the manuscript.

Abstract

Background

This systematic review and expert panel recommendation aims to answer the question regarding the routine use of T-tubes or abdominal drains to better manage complications and thereby improve outcomes after liver transplantation.

Methods

Systematic review following PRISMA guidelines and recommendations using the GRADE approach derived from an international expert panel to assess the potential risks and benefits of T-tubes and intra-abdominal drainage in liver transplantation (CRD42021243036).

Results

Of the 2996 screened records, 33 studies were included in the systematic review, of which 29 (6 RCT) assessed the use of T-tubes and 4 regarding surgical drains. Although some studies reported less strictures when using a T-tube, there was a trend towards more biliary complications with T-tubes, mainly related to biliary leakage. Due to the small number of studies, there was a paucity of evidence on the effect of abdominal drains with no clear benefit for or against the use of drainage. However, one study investigating the open vs. closed circuit drains found a significantly higher incidence of intra-abdominal infections when open-circuit drains were used.

Conclusions

Due to the potential risk of biliary leakage and infections, the routine intraoperative insertion of T-tubes is not recommended (Level of Evidence moderate - very low; grade of recommendation strong). However, a T-tube can be considered in cases at risk for biliary stenosis. Due to the scant evidence on abdominal drainage, no change in clinical practice in individual centers is recommended. (Level of Evidence very low; weak recommendation).

Introduction

The use of surgical drains and T-tubes as part of the liver transplantation (LT) procedure has always been a matter of controversy and has been largely driven by the surgeons' personal preferences. Some transplant surgeons feel that abdominal drains function as safety windows to evaluate the ongoing process in and around the liver, for bleeding and/or bile leaks allowing for expedited therapeutic interventions. Others believe that they are not as useful and only serve to increase potential risk for infection and may even be a reason for increased length of stay post-transplant.[1–6] A similar argument and debate is made over the use of T-tubes. It is well known that biliary complications are still a major cause of long-term morbidity after LT.[7–10] In addition to technical and vascular issues leading to biliary complications, surgeons have debated whether or not using a T-tube is contributing to or reducing the occurrence of these complications.[11–14] There have been many single center reports and meta-analyses on the subject.[15–18] Some have concluded that the use of T-tubes increases the risk of a bile leak and/or an infection, while others report a higher risk for biliary anastomotic stricture when T-tubes are not used.[12,17,19]

The Enhance Recovery for Liver Transplant recipients (ERAS4OLT.org) initiative from the International Liver Transplant Society (ILTS) was created to identify the main domains of ERAS and to develop international guidelines for liver transplant professionals based on the scientific evidence and expert opinion. The ILTS - ERAS4OLT.org Consensus Conference on Enhanced Recovery for Liver Transplantation, is a virtual meeting held in January 2022. As part of this initiative, the aim of this review is to address the question of whether T-tubes and abdominal drains should be regularly inserted to potentially detect earlier and/or to better manage complications and thereby improve outcomes after LT.

Methods

This study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[20] A systematic literature review was performed on March 30th 2021, searching the online databases Ovid, MEDLINE, Embase, Scopus, Google Scholar, Clinical.Trials.gov and the Cochrane Central Register of Controlled Trials. The systematic review protocol was registered on PROSPERO ID CRD42021243036.[21]

Eligibility criteria

Search terms were separately organized for (1) T-tube and (2) abdominal drainage according to the PICO (patient, intervention, control, and outcomes) criteria, among adults undergoing deceased donor LT, the interventions being the intra-operative insertion of (1) T-tube or (2) abdominal drainage, the control groups being patients who did not have a T-tube or abdominal drainage inserted, and the outcomes of interest being biliary complications for

T-tube studies specifically (e.g. biliary strictures, bile leaks, or biliary sepsis in the form of cholangitis) and overall complications, infections, and hospital length of stay for abdominal drains. Eligible studies included original comparative studies (randomized controlled trials [RCT] and prospective/retrospective studies) for post-transplant outcomes on adult recipients. For T-tube studies only those that had choledocho-choledochostomy for reconstruction of biliary continuity were included. Exclusion criteria for studies included patients <18 years of age, studies focusing on liver re-transplantations, living donor or split LT. Case reports, review articles, conference abstracts, commentaries and full texts written in languages other than English were also not considered. There was no limit on publication year.

Search and study selection

Bibliographic searches were performed by professional academic librarians of the University of Zurich[22]. Individual search strategies are shown in the *Supplementary Methods*. The search terms included; (drain OR drains OR "T-tube" OR "T Tube" or "T-tubes" OR "T Tubes" OR ("biliary drainage" AND "intraoperative")) AND ((liver OR hepatic) AND (transplant OR transplantation)). For further identification of missed or important studies, manual search was done to collect more data and by cross-searching these manuscripts. The definitive screened full texts for the assessment of eligibility provided by the librarians were divided by all panel members. Eligibility of the full texts was independently determined by each panel member, using the predefined criteria. A second assessment of all papers was performed by MK. Disagreements were resolved by consensus after re-assessment. A separate meta-analysis was not performed.

Data extraction, quality of evidence and recommendations grading

Study characteristics and data concerning the main comparative outcomes related to (1) T-tubes and (2) abdominal drains were collected and the data were summarized for each outcome. Subsequently, the "Grading of Recommendations Assessment, Development and Evaluation" (GRADE) approach was used for grading the quality of evidence and strength of recommendations.[23] The GRADE system was designed to provide a comprehensive and structured approach to rating the quality of evidence (QOE) for systematic reviews, and to grade the strength of recommendations for development of guidelines in health care. We applied the modified GRADE approach for QOE assessment derived from systematic reviews using estimates summarized narratively.[24] The QOE was rated separately for each outcome. The direction and strength of recommendation was assessed individually by all authors and disagreements resolved by consensus.[25,26]

Results

Study selection and characteristics

The initial literature search identified 5003 studies. After removal of duplicates, 2996 potential records were screened. 2852 records were excluded due to 12 criteria (**Figure 1**), resulting in 144 studies that received a full-text review. After exclusion of 111 studies due to duplicate study populations, not referring to T-tube or abdominal drains or non-comparative studies, 29 T-tube related and 4 abdominal drain related manuscripts were included for the systematic review. An overview of the included studies and a quality assessment according to the GRADE-approach is shown in **Table 1**. The 33 studies included a total of 5901 patients (5284 in T-tube and 617 in abdominal drain studies) and the study population size ranged from 28 to 884 patients. Six of the 29 T-tube studies were RCTs and one prospective cohort study. All other studies were retrospective studies.

Systematic review of the literature on outcomes related to the use of T-tubes

An overview of the systematic review on outcomes in relation to T-tube is shown in the upper part of **Table 2**. All 29 studies reported the incidence for biliary complications; ranging from 9.3% to 47% in the T-tube group and 8% to 54.6% in the no-T-tube group. Nine of the 29 studies did not report p-values between the two groups. From the 20 remaining studies, 10 studies favored not using a T-tube and 9 studies did not find a significant difference between both groups. A 1997 study from Spain was the only study reporting fewer biliary complications in the T-tube group (10% vs. 33%).[27] From the 6 RCTs, 2 did not report p-values, 1 favored the use of a T-tube, 1 did not find a significant difference and 2 found a lower incidence of biliary complications when no T-tube was used. Biliary leakage, a common problem with T-tubes was studied in 24 papers and ranged from 0% to 29.4% in the T-tube group, compared to 0% to 36.4% the no-T-tube group. Eleven papers reported p-values with 8 finding no significant difference and 3 papers found lower incidence of biliary leakage in patients without a T-tube. None of the papers favored the use of a T-tube in respect to biliary leakage. The potential benefit of T-tubes is a reduction in biliary strictures after LT.[17] This complication was assessed in 25 papers and compared of significance in 15 of them. The incidence of biliary strictures ranged between papers from 0% to 30.3% in the T-tube group and 4% to 45.6% in the no-T-tube group. Most of the papers (n=10) found comparable number of biliary strictures in both groups. Two papers described a lower incidence for strictures with a T-tube, but two other papers described a higher incidence with T-tubes. The development of infections after LT (mostly cholangitis) were reported by 8 studies and ranged from ranged from 3.0% to 26% in the T-tube group, compared to 0% to

12% the no-T-tube group. However, no study found a significant difference between the two groups.

Systematic review of the literature on outcomes related to the use abdominal drains

The use of abdominal drains was studied by four groups. There were 3 studies investigating outcomes of *drain vs. no drain*[3,5,6]. The overall complication rate with or without drains was assessed in two studies and no significant difference was observed (drain 67.2%-84% vs no drain 48.3%-80%)[3,5]. The potential benefit of abdominal drains, lies in their ability to serve as early warning signs for intra-abdominal complications, such as bleeding or biliary leakage. Biliary leakage was studied in 3 papers of which two papers did not provide a p-value and the paper from Schwarz et al reported an increased incidence of biliary leakage when an abdominal drain was used (13.8% vs. 1.7%; p=0.032).[3] On the contrary, infections are a potential risk of abdominal drains. Higher incidence of infections in the drainage group was reported by Schwarz et al. Only Schwarz et al reported a greater incidence of infections in the drainage group (63.8% vs. 39.7%; p=0.015), without differences in the other two studies.[3] Weiss and colleagues compared open-circuit (Easy-Flow) and closed-circuit (Robinson) drains and found significantly more intra-abdominal infections when open-circuit drains were used (50% vs. 22.5%; p<0.001).[4]

Quality of evidence and recommendations according to the GRADE Approach

The summary of findings for the main outcomes, including evidence profiles for QOE assessment and the final QOE grading according to the GRADE approach are summarized in **Table 3**. In the assessment of T-tube related studies, the QOE was rated moderate for biliary complications in general and low to very low for the other reported outcomes. Main reasons for downgrading were study limitations, inconsistency and imprecision. Despite the moderate to very low QOE for the use of T-tubes, the direction and strength of recommendation was strong to avoid routine insertion of T-tubes during LT. However, T-tubes can be considered in case of an increased risk of biliary strictures. This is subjective and left to the discretion and judgement of the operating surgeon. The QOE assessment for abdominal drains rated the evidence for all outcomes very low. Here, the main reasons for downgrading were study limitations (i.e., very small sample size), inconsistency, indirectness and imprecision. The recommendations according to QOE are shown in **Table 4**. Due to the very low quality of evidence on the usage of abdominal drains and the wide variance in clinical practice, no recommendation can be made to change clinical practice in individual centers. Due to the potential risk of intra-abdominal infections, when abdominal drains are used, it is recommended to not use open-circuit drains.

Discussion

This systematic review shows with moderate to very low evidence that T-tubes might prevent biliary strictures in high risk cases, but is balanced by an increased risk of overall biliary complications, such as bile leaks and cholangitis associated with T-tube removal. Therefore, the working group does not recommend the routine use of T-tubes in LT. The evidence on the use of abdominal drains was very limited and due to the differences in clinical practice we can make no recommendation to change in clinical practice in individual centers.

The use of T-tubes in LT has been debated for years. T-tubes were introduced with the hypothesis of giving mechanical support to the biliary anastomosis and thereby reduce the risk for biliary strictures or leakage.[17] They also allow for monitoring of bile production and provide a direct radiological access of the biliary tree.[28] However, the use of T-tubes has also been associated with an increased risk of leakage after removal of the tube and infections, such as cholangitis and peritonitis.[9,15] Consequently, many centers have changed their practice and do not routinely use T-tubes anymore. In a European survey on technical aspects in LT from 2018 a duct-to-duct biliary reconstruction without a biliary drain was the preferred method for 67% of the responding transplant centers.[29] The current systematic review with 29 comparative papers also provides a broader view of the subject. There was a tendency in some studies towards an increased incidence of overall biliary complications when T-tubes were used. The relationship between T-tubes and specific complications, such as strictures, leakage and cholangitis was less clear. The majority of the studies reported no difference in strictures or leakage, but a higher incidence of biliary leakage was observed in 3 studies. Some of the studies assessed the relationship between cholangitis and T-tubes, but no significant difference was observed in the individual studies. The level of evidence was considered moderate for biliary complications in general with minor study limitations. However, for the specific biliary complications (leakage, strictures and cholangitis), evidence was considered low or very low, mostly due to more severe study limitations and imprecision.

To comprehend the potential risks and benefits from T-Tubes, a total of 6 systematic reviews and meta-analyses have been written on this subject, with the last one from 2021 including 21 studies.[30] A summary is shown in **Table 5**. All meta-analyses concluded a protective effect of T-tubes on the development of biliary strictures after LT. However, two of meta-

analyses described a greater risk for biliary complications in general, due to a greater incidence of biliary leakage and cholangitis.[15,30] Furthermore, the most recent updated meta-analysis from 2021 found that the benefit of fewer strictures disappeared in the combined analysis from studies published after 2010.[18] The authors of all these studies concluded that T-tubes should not be used on a regular basis, but might be useful in cases with high risk of biliary strictures. The value of T-tubes with the balance between risks and benefits of this intervention has changed over the years, also due to the developments in biliary interventions in case of complications.

Anastomotic strictures after LT are still common, but nowadays are for the most part successfully managed endoscopically. This approach may require multiple endoscopic retrograde cholangiopancreatographies (ERCP), but has evolved significantly over the last years and has in general good outcomes.[31] Biliary leakage after removal is the main risk of T-tube usage and although it can also be treated endoscopically by stenting the leak, it often requires percutaneous drainage and at worst PTC placement or redo surgery to treat abscess formation and persistent leaks with a high risk of endangering the patient.[32] Cholangitis is another potentially life-threatening complication that has been reported in up to 25% in patients with a T-tube.[33] Due to the potential severe course of these complications, many centers have shifted toward a practice without routine T-tube placement. Selective use can be useful and considered for those at risk for biliary strictures, such as small caliber bile ducts, primary sclerosing cholangitis, longer cold ischemia times, split liver grafts, and also grafts from living donors.[34,35] However, in such cases a biliary reconstruction using a Roux-en-Y hepaticojejunostomy might be preferred.

Drains in abdominal surgery are used as tools to detect for postoperative problems, such as bleeding and anastomotic insufficiency and specifically biliary leakage in liver surgery. However, these drains are associated with intra-abdominal infections and their efficacy has been debated, resulting in an decreasing use in smaller and low-risk surgeries over the years. [36,37] Nonetheless, abdominal drains are the standard in LT.[29] In juxtaposition to the use of T-tubes, there are only a small number of studies investigating the benefit of these drains in LT. Our systematic review found 3 observational studies comparing drain vs. no drain. The three studies were inconsistent on the impact of abdominal drains on overall complications, infections and duration of hospital stay. Schwarz and colleagues found a higher incidence of bile leak in the drainage group, with half of them identified early through the drain. This study also showed more infectious complications when drains were used.[3] It was suggested by Weiss and colleagues not to use open-circuit drains, as these drains were

associated with significantly more intra-abdominal infections.[4] The question remains if the benefits of abdominal drains (i.e., early detection of postoperative complications) outweigh their risks (i.e., intra-abdominal infections and potential overtreatment of 'subclinical' biliary leaks or infections). However, the level of evidence on all outcome parameters was only considered very low due to severe study limitations, inconsistency, indirectness and imprecision. Therefore, no definitive statement on the usefulness of these drains can be made. We do not recommend changes to current practices with abdominal drains in individual LT centers. Yet, when surgical drains are used, we recommend not using open-circuit drains, because they might increase the risk for intra-abdominal infections.

Limitations

There was diversity in the outcomes assessed in the T-tube studies (biliary complications in general vs specific biliary complications), which complicates a universal analysis on this subject. Furthermore, approximately half of the individual T-tube studies were published prior to the year 2000. Many aspects of LT practice have changed over time, hence, translating published data on this subject has the potential to be anachronistic. Due to the exclusion of non-English language publications and conference abstracts, variations in publication bias cannot be assessed. However, the transparent framework provided by the GRADE approach to assess the quality of evidence may mitigate these potential limitations.

Conclusion

T-tubes in general are associated with a higher incidence of overall postoperative biliary complications, due to a greater risk of biliary leakage and cholangitis. However, they might reduce the risk of anastomotic biliary strictures in high risk cases. We do not recommend routine use of T-tube in LT, but selective use can be considered. (Quality of Evidence: very low to moderate | Grade of recommendation; strong against routine use of the intervention). The working group does not recommend changing individual transplant center practice with regard to the intraoperative use of abdominal drains, due to weak evidence. If drains are used, we do not recommend the use of open-circuit drains, due to the likely increased risk for intra-abdominal infections. (Quality of Evidence; very low | Grade of recommendation; weak).

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Conflict of interest

The authors declare no conflicts of interest.

Authorship

All authors qualify for authorship as per the International Committee of Medical Journal Editors (ICMJE) guidelines.

Author contributions

Marit Kalisvaart contributed to the review and interpretation of the literature, drafting the systematic review and writing and critical review of the manuscript.

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Sander Florman contributed to the review and interpretation of the literature, drafting the systematic review and writing and critical review of the manuscript.

Michael Spiro and Dimitri Aristotle Raptis have conceived and designed the project, the systematic review strategies, prepared the PROSPERO protocols, supervised screening the records and assessing the full-text articles for eligibility, prepared the structure of the statement manuscript template, critically revised and approved the manuscript.

Bijan Eghtesad contributed to the review and interpretation of the literature, drafting the systematic review and writing and critical review of the manuscript.

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Tables

Table 1 - Quality of T-tubes (first part) and abdominal drains (second part) included in the systematic review.

Use of T Tube drainage				
Paper	**Period**	**Study type**	**N=**	**Main outcomes assessed**
Shimoda[38]	1998	Retrospective CS	147	biliary complications, costs
Vougas[39]	1992	RCT	60	biliary complications/stricture, cholangitis, mortality
Weiss[40]	2005-2007	RCT	194	biliary complications/leakage/stricture, cholangitis, ITBL
Ferraz-Neto[41]	1993-1994	Retrospective CS	199	biliary complications/leakage/stricture, HAT
Rolles[42]	1988-1992	Retrospective CS	106	biliary complications/leakage/stricture
Carmelino[43]	2008-2012	Retrospective CS	506	biliary complications/leakage/stricture/fistula, overall complications
Benitez Cantero[44]	2008-2010	Retrospective CS	95	biliary complications/leakage/stricture
Lin[45]	2001-2005	Retrospective CS	88	biliary complications/leakage/stricture
Veltchev[46]	1988-2003	Retrospective CS	168	biliary complications/leakage/stricture
Koivusalo[47]	1982-1993	Retrospective CS	84	biliary complications/leakage/stricture/fistula
Alsharabi[11]	2003-2006	Retrospective CS	200	biliary complications/leakage/stricture
Leonardi[13]	1991-2000	Retrospective CS	115	biliary complications/leakage/stricture
Perrakis[48]	1992-2004	Retrospective CS	200	biliary complications
Nuno[27]	1994-1995	RCT	98	biliary complications/leakage/stricture
Amador[49]	2002-2004	RCT	107	biliary complications/leakage/stricture, cholangitis, mortality,
Li[50]	2002-2005	Retrospective CS	84	biliary complications/leakage/stricture
Thethy[51]	1992-2001	Retrospective CS	321	biliary complications/leakage/stricture
Jeffrey[52]	1994-1996	Retrospective CS	28	biliary complications/leakage/stricture
Senter-Zapata[53]	2002-2014	Retrospective CS	884	biliary complications/leakage/stricture
Elola-Olaso[54]	1986-2004	Retrospective CS	100	biliary complications/leakage/stricture, cholangitis, survival
Scatton[33]	1994-1997	RCT	180	biliary complications/leakage/stricture, cholangitis, survival
Dunham[55]	1985-1988	Retrospective CS	105	biliary complications
Wojcicki[56]	2002-2007	Retrospective CS	84	biliary complications/leakage/stricture, cholangitis, survival
Yuan[57]	1999-2005	Retrospective CS	279	biliary complications
Lopez-Andujar[58]	2011-2015	Retrospective CS	405	biliary complications/leakage/stricture, cholangitis
Lin[59]	2001-2006	Retrospective CS	104	biliary complications/leakage/stricture
Randall[60]	1993-1994	Retrospective CS	110	biliary complications/leakage/stricture
Garcia Bernardo[61]	2012-2013	Prospective CS	46	biliary complications/leakage/stricture, mortality
Lopez-Andujar[62]	2008-2010	RCT	187	biliary complications/leakage/stricture, cholangitis, complications, mortality
Use of abdominal drains				
Paper	**Period**	**Study type**	**N=**	**Main outcomes assessed**
Schwarz[3]	2000-2004	Retrospective CS; PSM	116	biliary complications/leakage/stricture, infections, bleeding, survival
De Rougemont[5]	2003-2009	Retrospective CS; PSM	105	biliary complications/leakage/stricture, infections, complications, mortality
Weiss[4]	7 years	Retrospective CS	256	abdominal complications, Easyflow vs Robinson drainage
Fernandez-Aguilar[6]	unknown	Retrospective CS	140	percutaneous drainage, biliary leakage, paracentesis, bleeding

RCT, randomized controlled trial; CS, cohort study;

Table 2. Systematic review on the use of T-tubes (first part) and abdominal drains (second part) outcomes after liver transplantation.

T Tube related studies

Author	N total	Biliary complications		Biliary stricture		Biliary leakage		Infections		
		T Tube	No T Tube	T Tube	no T Tube	T Tube	no T Tube	Type	T Tube	no T Tube
Shimoda[38]	147	32.9%	15.5%	6.60%	8.50%	22.70%	7.00%	.	.	.
Vougas[39]	60	16.6%	20.0%	6.67%	20.00%	.	.	Cholangitis	6.67%	0.00%
Weiss[40]	194	19.2%	34.7%	7.07%	8.42%	5.05%	9.47%	Cholangitis	5.05%	11.58%
Ferraz-Neto[41]	199	23.6%	11.2%	2.73%	5.62%	16.36%	3.37%	.	.	.
Rolles[42]	106	25.0%	22.0%	0.00%	11.00%	25.00%	11.00%	.	.	.
Carmelino[43]	506	27.0%	18.9%	19.60%	15.40%	7.44%	3.50%	.	.	.
Benitez Cantero[44]	95	40.0%	30.0%	8.90%	28.00%	17%	6.60%	.	.	.
Lin[45]	88	9.3%	15.6%	9.00%	11.00%	0	2%	.	.	.
Veltchev[46]	168	11.0%	33.0%	.	.	.	.	.	.	.
Koivusalo[47]	84	24.0%	12.0%	4.00%	10.00%	16%	3%	Peritonitis	20%	3%
Alsharabi[11]	200	17.0%	11.0%	8.00%	8.00%	11%	3%	.	.	.
Leonardi[13]	115	33.3%	24.0%	6.00%	14.00%	26.60%	10%	.	.	.
Perrakis[48]	200	34.7%	18.2%	.	.	.	.	.	.	.
Nuno[27]	98	10.0%	33.0%	2.00%	16.67%	6.00%	16.67%	.	.	.
Amador[49]	107	60.4%	11.1%	1.80%	5.50%	11.30%	5.50%	.	.	.
Li[50]	84	30.3%	11.8%	15.15%	7.54%	12.12%	1.96%	Cholangitis	3.03%	1.96%
Thethy[51]	321	25.0%	10.9%	17.86%	7.17%	17.86%	4.53%	.	.	.
Jeffrey[52]	28	47.0%	54.6%	29.41%	45.46%	29.41%	36.36%	.	.	.
Senter-Zapata[53]	884	44.2%	31.6%	30.29%	24.70%	21.15%	11.90%	.	.	.
Elola-Olaso[54]	100	30.0%	10.0%	12.00%	8.00%	6.00%	0.00%	Cholangitis	10.00%	2.00%
Scatton[33]	180	33.3%	15.6%	1.11%	4.44%	2.22%	2.22%	Cholangitis	26.00%	0.00%
Dunham[55]	105	44.0%	21.0%	.	.	.	.	.	.	.
Wojcicki[56]	84	31.0%	8.0%	9.00%	4.00%	17.00%	4.00%	Cholangitis	6.00%	2.00%
Yuan[57]	279	28.2%	20.4%	.	.	.	.	.	.	.
Lopez-Andujar[58]	405	13.0%	12%%	4%%	8.5%%	3.3%%	0.6%%	.	.	.
Lin[59]	104	10.0%	17%%	9.80%	15.10%	0.20%	0.20%	.	.	.
Randall[60]	110	22.0%	13.7%	13.63%	13.70%	8.40%	0.00%	.	.	.
Garcia Bernardo[61]	46	30.4%	21.7%	8.70%	13.0%	17.4%	8.7%	.	.	.
Lopez-Andujar[62]	187	25.3%	19.6%	2.10%	14.30%	4.20%	3.30%	Cholangitis	6.30%	0.00%

Abdominal drainage related studies

Author	N total	Overall complications		Biliary leakage		Hospital LOS in days		Infections/Ascites		
		Drain	No Drain	Drain	No Drain	Drain	No Drain	Type	Drain	No Drain
Schwarz[3]	116	67.2%	48.3%	13.8%	1.7%	22.9	18.6	All infections	63.8%	39.7%
De Rougemont[5]	105	84.0%	80.0%	10.0%	6.0%	19	24	Wound/ sepsis	8.0%	23.0%
Fernandez-Aguilar[6]	140	.	.	1.4%	2.9%	14	12	Ascites*	6.0%	30.0%
Open vs closed circuit		**Close**	**Open**	**Close**	**Open**	**Close**	**Open**		**Closed**	**Open**
Weiss[4]	256	.	.	6.0%	3.6%	.	.	Abdominal	22.5%	50.0%

CS, cohort study; NS not significant; RCT, randomized controlled trial

* Postoperative ascites requiring paracentesis

Table 3. Summary of Findings leading to the Quality of Evidence Assessment according to the GRADE approach for T-tubes (A) and abdominal drains (B).

Outcome	RCT	Observ. comp.	Non-comp.	N=	Effect from comparative studies	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Quality of Evidence (GRADE)
A - T-tube studies											
Biliary complications	3	18	8	3178	Tendency in 10/20 studies towards more biliary complications when a T Tube was used	serious	Not serious	Not serious	Not serious	Not likely	Moderate ●●●○
Biliary strictures	4	14	11	2504	Incidence in most studies comparable between groups	Serious	Serious	Not serious	Not serious	Not likely	Low ●●○○
Biliary leakage	3	13	13	1865	more biliary leakage observed in some studies	Serious	Not serious	Not serious	Not serious	Not likely	Low ●●○○
Infections*	1	3	4	378	Mostly more infections in T Tube group, without statistical significance	Serious	Not serious	Not serious	Serious	Not likely	Very low ●○○○
B - Abdominal drain studies											
Overall complications	0	1	1	105	one study reporting comparable outcomes	Very serious	Not serious	Not serious	Very serious	Not likely	Very low ●○○○
Biliary leakage	0	2	1	256	no consensus among studies	Very serious	Serious	Serious	Very serious	Not likely	Very low ●○○○
Hospital length of stay	0	2	1	361	no consensus among studies	Very serious	Very serious	Serious	Very serious	Not likely	Very low ●○○○
Infections **	0	3	0	361	no consensus among studies	Very serious	Very serious	Serious	Very serious	Not likely	Very low ●○○○

* Cholangitis or biliary peritonitis

** Overall infections, wound infections or sepsis

Table 4. Evidence to recommendation framework according to the GRADE approach.

Question: **Should T tubes be inserted intraoperatively to detect and manage early complications and hence improve short-term outcomes after liver transplantation?**			
Decision domain	**Judgement** Yes	No	**Reason for Judgement**
Balance between desirable and undesirable outcomes, with consideration of values and preferences		✓	Potential increased risk for biliary complications when a T-tube is used Subgroup: a T-tube could be used in case of high risk of biliary stricture risk for biliary stricture
Confidence in the magnitude of estimates of effect of the interventions on important outcomes	✓		Clear potential increased risk for biliary complications when T Tubes are used
Confidence in values and preference, and their variability		✓	The increased risk for biliary complications was not reported in all studies, but a negative trend with the use of T Tubes was seen
Resource implications	✓		Not using a T Tube would reduce the required resources
Overall Quality of Evidence:	low to moderate		
Recommendation: strong against	We do not recommend the routine intraoperative placement of a T-tube in liver transplantation		

Question: **Should abdominal drains be inserted intraoperatively to detect and manage early complications and hence improve short-term outcomes after liver transplantation?**			
Decision domain	**Judgement** Yes	No	**Reason for Judgement**
Balance between desirable and undesirable outcomes, with consideration of values and preferences		✓	There is no data supporting for or against the use of abdominal drains. There is a wide variance in the usage of abdominal drains in the current LT practice
Confidence in the magnitude of estimates of effect of the interventions on important outcomes		✓	Subgroup analysis: the use of an open-circuit drain might increase the risk for intra-abdominal infections
Confidence in Values and Preference, and their Variability		✓	
Resource implications	✓		The use of abdominal drains is common in LT practice, it is feasible and carries low costs
Overall Quality of Evidence:	very low		
Recommendation: weak recommendation	There is no evidence to change routine practice in individual centers, open circuit drains should be avoided due to increased risk of infection.		

Table 5 – Summary of published meta-analyses in the literature on the use of T-Tubes in liver transplantation.

Author	Year	# studies	N =	Type of Study*	biliary complications			biliary stricture			biliary leakage			cholangitis		
					Effect size OR, 95% CI		favors	Effect size OR, 95% CI		favors	Effect size OR, 95% CI		favors	Effect size OR, 95% CI		favors
Sotiropoulos[15]	2009	9	10277	R&NR	1.97	(1.46-2.67)	**noT**	0.43	(0.27-0.70)	**T**	1.17	(0.68-1.99)	NS	4.30	(1.51-12.24)	**noT**
Riediger[17]	2010	5	6399	R only	1.15	(0.28-4.72)	NS	0.46	(0.23-0.90)	**T**	1.17	(0.40-3.47)	NS	NA		-
Huang[16]	2011	13	16088	R&NR	1.58	(0.85-2.94)	NS	0.55	(0.38-0.81)	**T**	1.44	(0.96-2.18)	NS	3.60	(0.63-20.53)	NS
Sun[63]	2015	15	18233	R&NR	1.50	(0.88-2.57)	NS	0.49	(0.34-0.69)	**T**	1.39	(0.95-2.02)	NS	4.27	(0.86-21.16)	NS
Zhao[18]	2021	17	21999	R&NR	1.41	(0.66-2.98)	NS	0.62	(0.42-0.90)	**T**	1.04	(0.63-1.70)	NS	2.00	(0.59-6.84)	NS
Song[30]	2021	24	32200	R&NR	1.54	(1.06-2.24)	**noT**	0.60	(0.47-0.78)	**T**	2.34	(1.57-3.48)	**noT**	2.78	(1.19-6.51)	**noT**

Author	Quality: Protocol followed	Quality: Individual study quality	Quality: Quality distribution	Bias check	Verdict
Sotiropoulos	QUOROM	Jadad composite scale	3xA, 1xC, 5xD	Egger	Abandon T-Tubes in liver transplantation
Riediger	QUOROM	Not mentioned	-	Not mentioned	T-Tubes might reduce biliary stricture rate, but there is not enough evidence to support routine use
Hua	Not mention	Jadad composite	4x3 pnt, 1x2 pnt,	Beggs	Less risk of biliary strictures when a T-Tube is

ng	ed	scale	8x1 pnt	Funnel	used
Sun	Not mentioned	Jadad composite scale	-	Not mentioned	A T-Tube useful in case of high risk of stricture
Zhao	PRISMA 2009	Jadad composite scale	5x3 pnt, 3x2 pnt, 9x1 pnt	Egger	Routine use of T-Tube is not supported
Song	PRISMA	Jadad + Newcastle Ottawa Score	5x3 pnt, 1x2 pnt; NOS 8x 8-9 pnt, 10x 6-7 pnt	Begg + Egger	No routine use of T Tube, but can be used in high risk for biliary strictures

*Type of studies: randomized and non-randomized pooled or randomized only

Figure legends

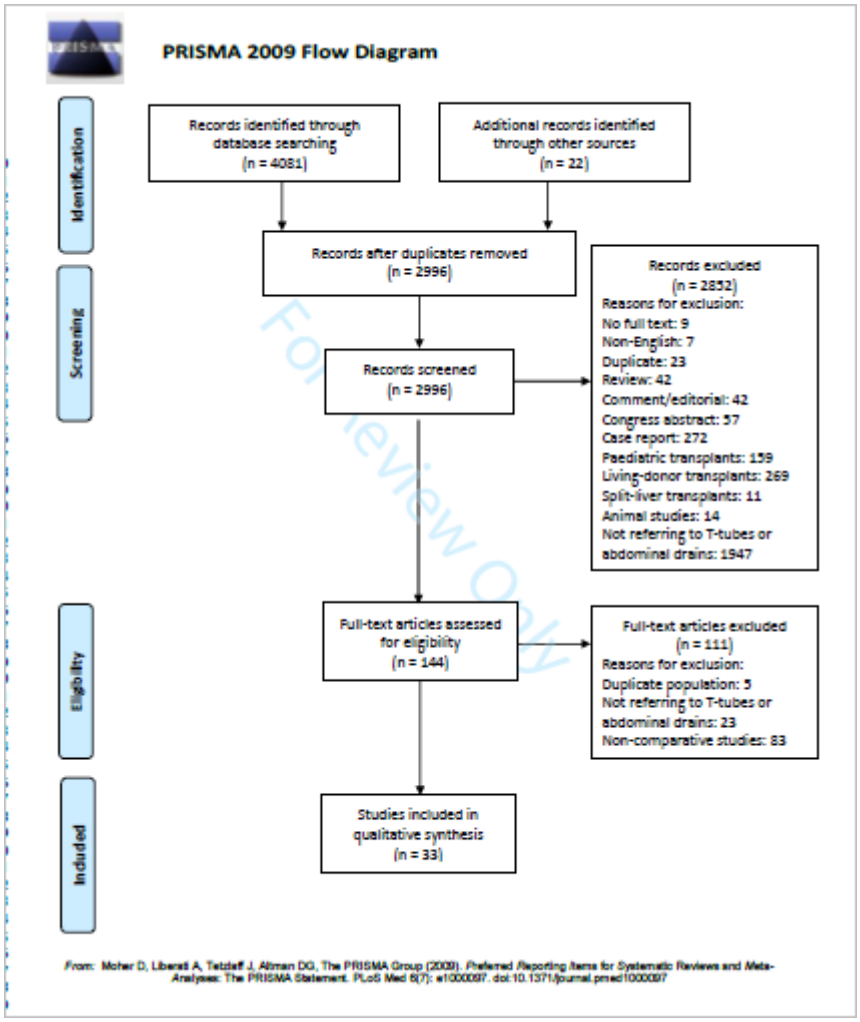

Figure 1. Flow diagram for of study selection for the systematic review.