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Incidence of Surgical Site Infections (SSIs) in Liver Transplantation: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: No systematic review study has previously been done to exclusively addresse the incidence of surgical site infection in liver transplant patients. This systematic review was conducted to determine the pooled incidence of postoperative SSIs after liver transplantation.
Materials & Methods: A systematic literature search was conducted in accordance with PRISMA guidelines and using relevant keywords in the PubMed, Web of Science, and Scopus databases up to August 22, 2025. Two reviewers independently carried out data extraction. Prospective or retrospective studies that reported the incidence of SSIs were included. The Newcastle–Ottawa scale was used to evaluate the risk of bias in the selected studies. The pooled incidence was calculated using R software Version 4.2.0.
Findings: Among the 722 publications assessed, 37 observational studies were included in this meta-analysis, involving 15589 adult and pediatric patients undergoing surgery. Using a random-effects model, the pooled incidence of SSIs was 16.37% (95% CI: 13.48-19.73%). Organ/space infection 10.61% (95% CI: 7.06- 15.63%) was the most common type of surgical site infection, followed by superficial infection 2.60% (95% CI: 16.2-2.16%) and deep infection 1.94% (95% CI: 1.0-2.52%). A higher incidence was observed in pediatric patients 23.21% (95% CI: 16.44-31.71%) compared to adult patients 13.60% (95% CI: 10.81-16.98%).
Conclusion: Surgical site infections after liver transplantation are frequent worldwide, especially in pediatric patients. Organ/space infection is the predominant type of surgical site infection in liver transplantation. Because organ/space infection is mainly caused by intraoperative factors, risk factors during surgery should be further investigated in liver transplant patients.

Keywords: Liver, Transplantation, Surgical site infection, Incidence

CITATION LINKS

[1] Olowo-Okere A, et al. Occurrence of... [2] Borchardt RA, Tzizik D. Update on... [3] Lin J, et al. The incidence of... [4] Natori Y, et al. Surgical... [5] Allegranzi B, et al. Burden of... [6] Allegranzi B, et al. New WHO... [7] Freire MP, et al. Surgical... [8] Hellinger WC, et al. Surgical... [9] Verwilghen D, et al. Monitoring and... [10] Jin S, et al. Risk factors... [11] Barone M, et al. Systematic... [12] McElroy LM, et al. A meta-analysis... [13] Shamseer L, et al. Preferred... [14] Stang A. Critical evaluation... [15] Aktas A, et al. Surgical... [16] Asensio A, et al. Effect of... [17] Avkan-Oguz V, et al. Bacterial... [18] Ayvazoglu Soy EH, et al. Early... [19] Banach DB, et al. Epidemiology and... [20] Bandali A, et al. Duration of... [21] Barchiesi F, et al. Carbapenem-resistant... [22] Brigati E, et al. Surgical site... [23] Bruns N, et al. Surgical site... [24] Drapeau CM, et al. Surgical site... [25] Freire MP, et al. Surgical site... [26] García Prado ME, et al. Surgical site... [27] Hellinger WC, et al. Association of... [28] Hollenbeak CS, et al. The effect of... [29] Hollenbeak CS, et al. Surgical site... [30] Hrenczuk M, et al. Surgical site... [31] Iinuma Y, et al. Surgical site... [32] Jafarpour Z, et al. Bacterial infections... [33] Leibovici-Weissman Y, et al. Early post-liver... [34] Mowrer C, et al. Beta-lactam... [35] Nafady-Hego H, et al. Pattern of... [36] Oliveira RA, et al. A retrospective... [37] Parekh JR, et al. Beyond death... [38] Park C, et al. Severe... [39] Pouladfar G, Jafarpour Z, et al. Bacterial infections... [40] Rolak SC, et al. Risk factors... [41] Schaeffer DF, et al. Surgical... [42] Schnickel GT, et al. Understanding the... [43] Schreiber PW, et al. Surgical site... [44] Shah H, et al. Surgical site... [45] Statlender L, et al. Perioperative... [46] Tun T, et al. Low rate of... [47] Vazin A, et al. Incidence... [48] Viehman JA, et al. Surgical Site... [49] Yamamoto M, et al. Changes in... [50] Oliveira RA, et al. Risk factors... [51] Jahangir F, et al. Incidence and... [52] Mentor K, et al. Meta-Analysis... [53] Bhangu A, et al. Surgical site... [54] Azharuddin M, Sharma M. P9.22: Surgical... [55] Okui J, et al. Severity of... [56] Coello R, et al. Adverse impact... [57] Lawson EH, et al. Risk Factors... [58] Catania VD, et al. Risk Factors for...

Introduction

Surgical site infections (SSIs) are defined as infections that occur at the incision site, deeper underlying tissues, spaces, and/or organs within 30 days of a surgical procedure (or up to 90 days for implanted prosthetics) [1, 2]. These infections include superficial incisional infections (SII), skin and soft tissue infections, deep incisional infections (DII), muscle and fascia infections, and organ/space infections (O/SI), an infection of any part of the body that is opened or manipulated during the operative procedure [1, 2]. SSIs are one of the most prevalent surgical complications [3, 4]. They affect up to one-third of all surgery patients, with a pooled SSI incidence exceeding 11 cases per 100 surgical operations (range: 1.2 to 23.6) in low- and middle-income countries (LMICs) [5, 6].

Surgical site infections are common in liver transplant patients with considerable consequences.

SSIs are more common in liver transplant patients than in other types of organ transplantation [4]. People who undergo liver transplants frequently develop SSIs within the first 60 days following surgery. Previous research on liver transplant recipients has shown that SSIs are responsible for prolonged hospital stays in intensive care units (ICUs), use of mechanical ventilation linked to acute kidney injury, multi-organ failure, allograft loss, septic shock, and death [7, 8]. SSIs create a considerable burden in terms of patient morbidity and death and impose extra costs on healthcare systems and payers globally [3, 9].

Previous reviews have investigated the risk factors of surgical site infection in liver transplant recipients [10] as well as post-operative complications and mortality risk in obese liver transplant candidates [11]. A study calculated the pooled incidence rates of 17 major postoperative complications, including SSIs, between 2002 and 2012 [12]. Given the significant variability in the reported incidence rates of SSIs and its potentially severe complications across studies as well as the lack of a systematic review integrating the available data, a systematic review and meta-analysis is warranted to determine an accurate and comprehensive estimate of the incidence of surgical site infection in the liver transplant population. Such a study (for example, the study by Abbasian et al.) could provide a more robust estimate of this incidence rate by quantitatively combining the results of all relevant studies and identifying sources of heterogeneity between studies, contributing to the development of more effective preventive strategies and planning for better health care delivery.

Objectives: This article aimed to fill this critical gap in the medical literature and provide a comprehensive perspective for surgeons, infectious disease specialists, and health care providers.

Materials and Methods

This systematic review and meta-analysis was conducted according to the standard methodological guidelines of PRISMA (preferred reporting items for systematic reviews and meta-analyses) [13]. No previous registration was made for the systematic review.

Search strategy and information sources: A comprehensive literature search was conducted in MEDLINE, PubMed, Web of Science, and Scopus databases using MeSH terms up to August 22, 2025. Unpublished studies, grey literature, and abstracts without full text were excluded. The search strategy included the terms liver transplantation, surgical site infection, surgical wound infection, operation site infection, prospective study, longitudinal study, cohort study, follow-up study, as well as their synonyms and variants. Detailed search strategies are presented in Appendix 1. An extra hand search was conducted by two authors (S.N. and F.J.) using references in the included papers.

Selection process: Two reviewers independently screened titles and abstracts, read full texts, and compared results to meet the inclusion criteria of this review. All disagreements were resolved through debate and consensus, with input from another reviewer. Details of the selection process are presented in the PRISMA flowchart in Figure 1.

Eligibility criteria: This review included prospective and retrospective cohort studies reporting the incidence of SSIs. Clinical trial, case-control, and cross-sectional studies were excluded to avoid bias due to trial effects or selection bias. Case reports, commentaries, conference abstracts, and review articles were excluded. The restriction to cohort studies was applied to ensure that estimates of SSI incidence after liver transplantation were based on longitudinal data, which reflect real-world conditions and are less prone to recall or selection bias. If studies assessed multiple procedures, only SSI outcomes in liver transplant patients were included in this study.

Data extraction: Two reviewers (S.N. and F.J.) independently extracted data using a previously-created form and amended it based on the first three extractions. The following raw data were extracted: author name, publication year, country where the study was conducted, research type, age group, population, SSI type (superficial, deep, and organ/space infections), and follow-up. The incidence rate of SSIs was

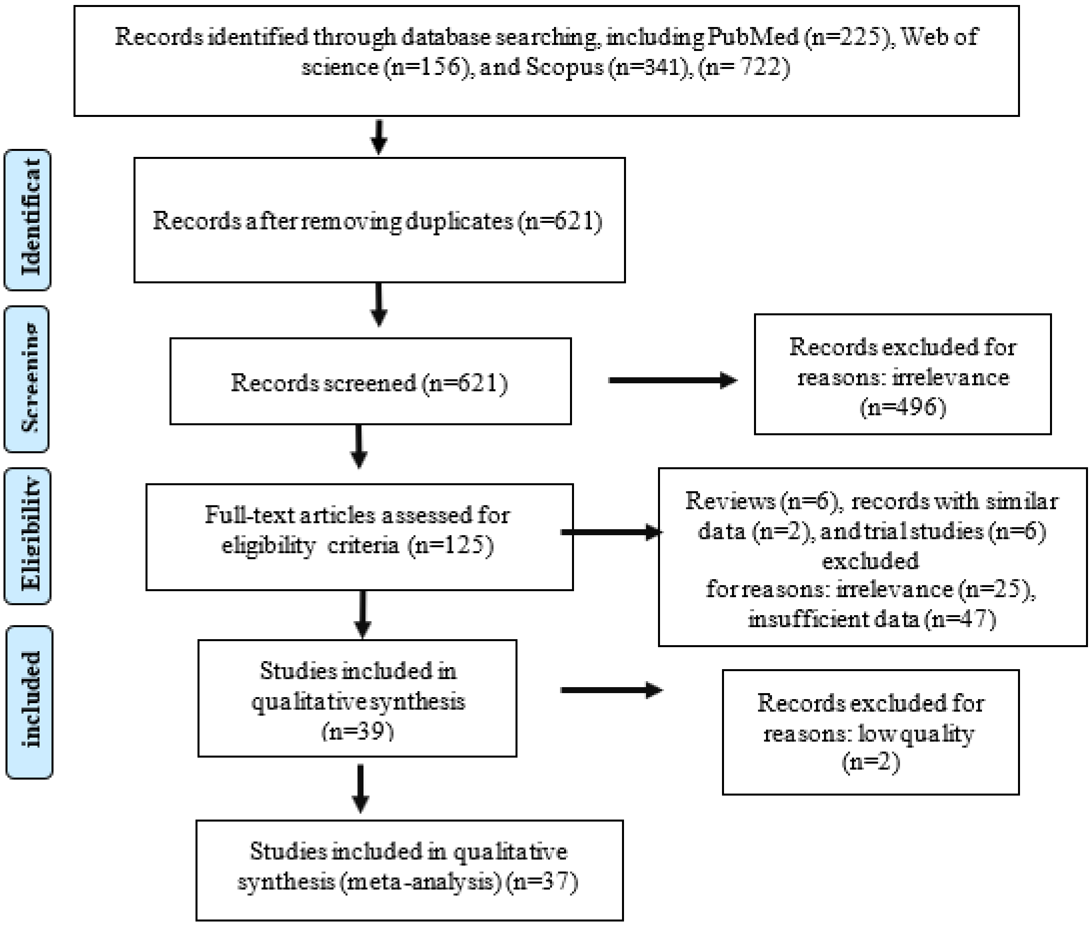

Figure 1) PRISMA flow chart summarising study selection process

Table 1) Characteristics of the included studies

	Author (Year)	Follow-up	Country	Type of Study	Age-Group	Population	SSIs
1	Aktas et al. (2019) [15]	>30	Turkey	Prospective	Adult	101	24
2	Asensio et al. (2008) [16]	>30	Spain	Prospective	Adult	1222	81
3	Avkan-Oguz et al. (2015) [17]	30	Turkey	Retrospective	Adult	412	71
4	Ayvazoglu Soy et al. (2018) [18]	30	Turkey	Retrospective	Both	561	67
5	Banach et al. (2022) [19]	30	USA	Retrospective	Pediatric	88	8
6	Bandali et al. (2020) [20]	30	USA	Retrospective	Adult	44	3
7	Barchiesi et al. (2016) [21]	30	Italy	Retrospective	Adult	330	40
8	Brigati et al. (2023) [22]	30	Italy	Retrospective	Adult	241	61
9	Bruns et al. (2024) [23]	30	Germany	Retrospective	Pediatric	119	23
10	Drapeau et al. (2009) [24]	30	Italy	Prospective	Adult	305	29
11	Freire et al. (2013) [7]	>30	Brazil	Retrospective	NR	597	141
12	Freire et al. (2021) [25]	30	Brazi	Retrospective	Adult	762	229
13	García Prado et al. (2008) [26]	>30	Spain	Prospective	Adult	167	56
14	Hellinger et al. (2011) [27]	30	USA	Retrospective	Adult	1036	166
15	Hollenbeak and colleagues (2001) [28]	>30	USA	Prospective	Both	777	292
16	Hollenbeak et al. (2003) [29]	>30	USA	Prospective	Pediatric	77	25
17	Hrenczuk et al. (2020) [30]	30	Poland	Retrospective	Adult	60	16
18	Iinuma et al. (2004) [31]	>30	Japan	Prospective	Both	111	42
19	Jafarpour et al. (2020) [32]	30	Iran	Prospective	Adult	389	28
20	Leibovici-Weissman et al. (2021) [33]	30	Israel	Retrospective	Adult	317	33
21	Mowrer et al. (2022) [34]	30	USA	Retrospective	Adult	175	18
22	Nafady-Hego et al. (2011) [35]	>30	Japan	Retrospective	Pediatric	345	93

	Author (Year)	Follow-up	Country	Type of Study	Age-Group	Population	SSIs
23	Natori et al. (2017) [4]	30	Canada	Prospective	Adult	250	43
24	Oliveira et al. (2019) [36]	30	Brazil	Retrospective	Adult	156	42
25	Parekh et al. (2019) [37]	30	USA	Prospective	NR	1048	101
26	Park et al. (2009) [38]	30	USA	Retrospective	Adult	680	76
27	Pouladfar et al. (2019) [39]	30	Iran	Prospective	Pediatric	94	35
28	Rolak et al. (2024) [40]	30	USA	Retrospective	Adult	557	40
29	Schaeffer et al. (2009) [41]	>30	Canada	Retrospective	Adult	167	10
30	Schnickel et al. (2021) [42]	30	USA	Retrospective	Adult	1731	169
31	Schreiber et al. (2025) [43]	>30	Switzerland	Prospective	Adult	1158	70
32	Shah et al.(2014) [44]	30	USA	Retrospective	Adult	152	31
33	Statlender et al. (2019) [45]	30	Israel	Retrospective	Adult	113	24
34	Tun et al. (2024) [46]	30	Australia	Retrospective	Adult	375	31
35	Vazin et al. (2022) [47]	30	Iran	Retrospective	Pediatric	80	16
36	Viehman et al. (2016)[48]	>30	USA	Retrospective	NR	331	60
37	Yamamoto et al. (2015) [49]	30	Japan	Prospective	Both	201	66

calculated simply by dividing the number of SSI events during postoperative follow-up by the number of patients who received liver transplants.

Quality assessment: Two authors (FJ and SH) independently assessed the methodological quality and standard of outcome reporting in the included studies using the Newcastle-Ottawa scale (NOS) developed for assessing the quality of nonrandomized studies in meta-analyses [14] (Appendix 2). Disagreements were solved with discussion.

Statistical procedures and data analysis: Data were categorized based on the income level of the countries where the study was conducted and the WHO regions of those countries. Studies were categorized based on the age of their participants into adult, pediatric, and NR (not reported) (a group for which data were insufficient) groups.

Meta-analysis was performed to synthesize data on SSIs by aggregating the findings of studies that reported SSI incidence to produce a pooled SSI incidence worldwide. R software Version 4.2.0 was used for data analysis. A random-effects model was used to calculate the pooled incidence of SSIs among liver transplant patients, and the results were shown using a forest plot. The I-squared test (I^2 statistics) assessed heterogeneity among the included publications. Univariate regression analysis was used to further explore heterogeneity. A sensitivity analysis

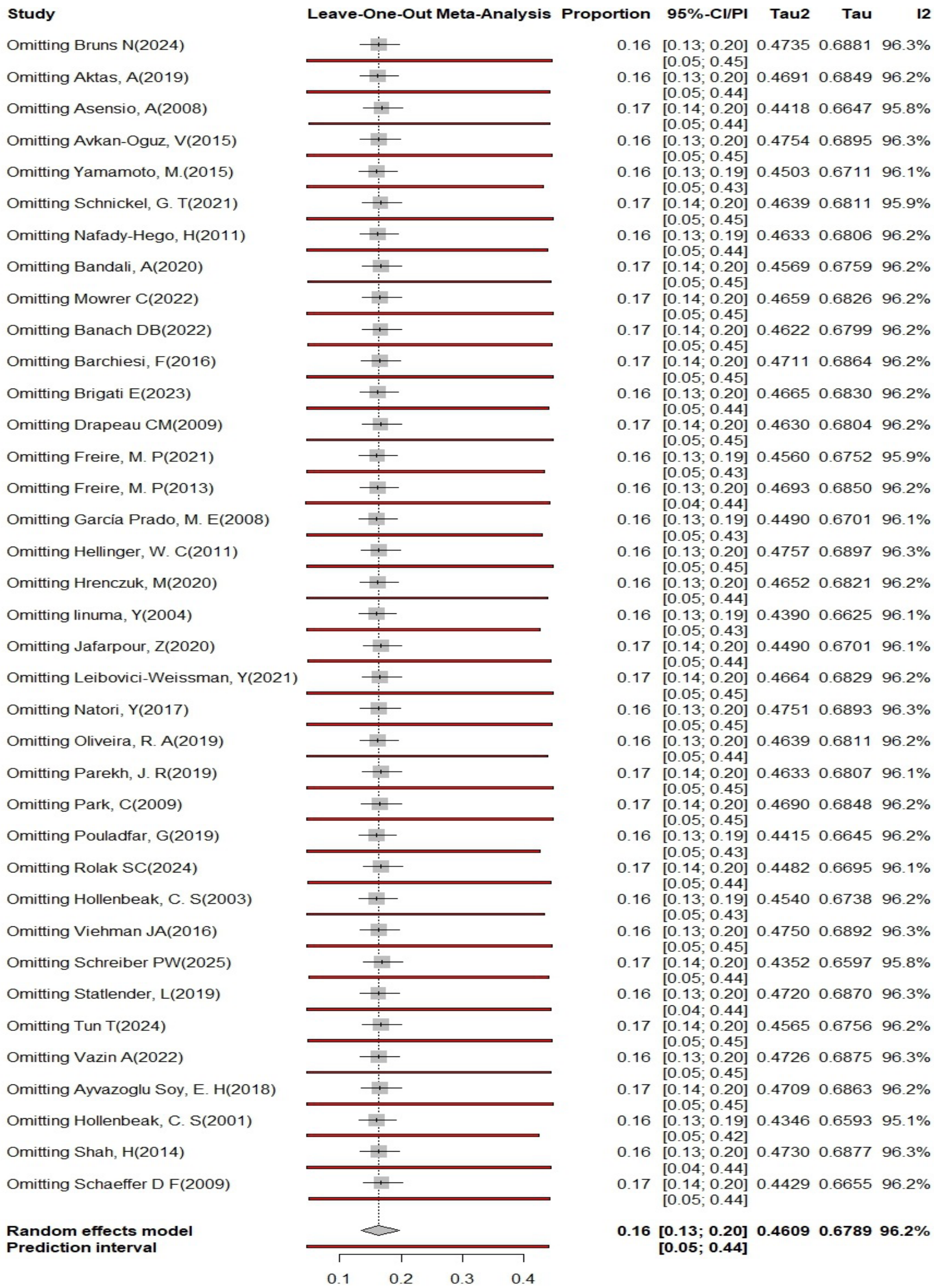

Figure 2) Summary of incidence proportions, leave-one-out meta-analysis

was performed to identify variations in pooled effects by excluding studies that were shown to impact the summary estimates.

Findings

Overview of search: A total of 722 studies were found during the literature search. After removing 101 duplicates, 621 papers were evaluated based on their titles and abstracts. Of these, 125 full-text papers were assessed for inclusion requirements. After eliminating 73 articles, 39 papers were selected for qualitative synthesis. Figure 1 shows the literature research strategy using PRISMA guidelines.

Descriptive: All studies were observational

Table 2) Subgroup analysis of SSI incidence in liver transplant patients

Subgroup Category		No. of Studies	Incidence per 100 Persons	T2	I2(%)	Test for Subgroup Differences
Total		39	16.37(13.48;19.73)	.461	96.2	X^2=935.17 , *df*= 36 (*p*< .001)
Age group	Adult	24	13.60(10.81;16.98)	.387	95.2	X^2=11.34, *df*= 3 (*p*= .010)*
	Pediatric	6	23.21(16.44;31.71)	.228	78.8	
	Adult/Pediatric	4	28.16(17.47;42.06)	.375	97.1	
	NR	3	16.18(10.38;24.34)	.19	96.5	
Study design	Prospective	13	18.81(12.54;27.25)	.749	97.9	X^2= .87, *df*= 1 (*p*= .3505)
	Retrospective	24	15.26(12.59;18.38)	.270	93.3	
Income group	High-income	28	15.21(12.06-19.00)	.482	96.4	X^2=2.19 , *df*= 1 (*p*= .139)
	Upper-middle-income	9	20.32(14.83-27.19)	.309	93.6	
Follow up	>30 d	11	19.73(12.93;28.93)	.697	97.8	X^2=1.32, *df*= 1 (*p*= .251)
	30 d	26	15.08(12.34;18.30)	.324	93.9	
WHO region	European Region	13	15.18(11.25;20.16)	.366	94.5	X^2=2.10, *df*= 3 (*p*= .552)
	Western Pacific	4	23.91(13.21;39.35)	.520	95.4	
	Region of the Americas	17	15.487(11.71;20.19)	.418	96.8	
	Eastern Mediterranean Region	3	18.12(7.78;36.72)	.672	96	
Type of **SSI	Superficial	14	2.60(16.2;2.16)	.631	89.8	X^2=127.29 , *df*= 13 (*p*< .0001)
	Deep incisional	16	1.94(1.06;2.52)	1.222	92.6	X^2=202.82 , *df*= 15 (*p*< .0001)
	Organ/space	18	10.61(7.06;15.63)	.869	96.1	X^2=436.60 , *df*= 17 (*p*< .0001)

*significant at *p*< .05, **SSI:Surgical site infection

studies published between 2001 and 2025 and included data on 15329 adult and pediatric surgery patients with 2360 SSIs cases. Three studies were conducted in each of the countries Brazil, Iran, Italy, Japan, and Turkey; two studies were conducted in each of the countries Canada, Israel, and Spain; 12 studies were conducted in the USA; and one study was conducted in each of the countries Australia, Germany, Poland, and Switzerland. Table 1 shows the characteristics of the included studies.

SSI incidence: The pooled incidence rate of SSIs in these studies was 16.37% (95% CI: 13.48-19.73%).

In terms of infection type, the highest incidence rate was for organ/space infection 10.61% (95% CI: 7.06-15.63%), followed by superficial infection 2.60% (95% CI: 16.2-2.16%), and finally deep infection 1.94% (95% CI:1.06-2.52).

Of the total 37 studies, 24 were retrospective, and 13 were prospective, with surgical site infection incidence rates of 15.26% (95% CI: 12.59-18.38%) and 18.81% (95% CI: 12.54-27.25%), respectively.

Table 3) Univariate meta-regression analysis of SSI incidence in liver transplant patients by subgroups category

Subgroup Category		No. of Studies	Estimate	Se	Z Value	*P*-Value	Test for Moderator
Age group	Adult	24	Ref				QM(df =3)=10.83, p=.013*
	Pediatric	6	0.639	0.289	2.21	.027	
	Adult/Pediatric	4	0.910	0.328	2.77	.005	
	NR	3	0.203	0.368	0.551	.582	
Study design	Prospective	13					QM(*df* = 1) = 1.15, *p*= .283
	Retrospective	24	-0.257	0.239	-1.07	.283	
Income group	High-income	28	Ref				QM(*df* = 1) = 1.77, *p*= .183
	Upper-middle-income	9	0.351	0.264	1.33	.183	
Follow up	>30 d	11	Ref				QM(*df* = 1) = 1.78, *p*= .182
	30 d	26	-0.329	0.247	-1.34	.182	
WHO region	Eastern Mediterranean Region	13	Ref				QM(*df* = 3) = 2.43, *p*= .488
	Western Pacific	4	0.354	0.525	0.673	.501	
	Region of the Americas	17	-0.187	0.435	-0.430	.667	
	European Region	3	-0.207	0.444	-0.467	.640	
The year the data collection ended		39	-0.0351	0.018	-1.884	.059	QM(*df* = 1) = 3.55, *p*= .059

*significant at *p*<.05,

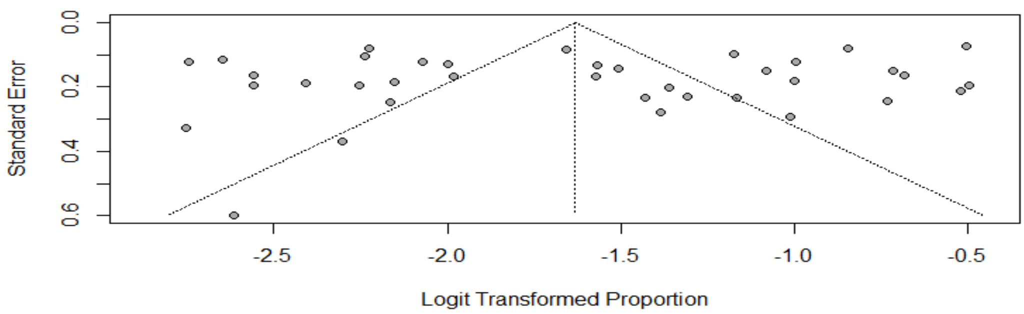

Figure 3) Funnel Plot of the meta-analysis of the included studies

Surgical site infections incidence by age-group: Articles were categorized based on the age of their subjects as pediatric, adult, pediatric/adult, and NR (not reported) (a group that couldn't be categorized based on the reported age of the study population) groups. Subgroup analysis revealed that studies differed in terms of patient age group ($\chi^2(3)$ =11.34, *p*= .010), and the incidence rate was higher in pediatric patients

23.21% (95% CI: 16.44-31.71%) than in adult patients 13.60% (95% CI: 10.81-16.98%).

Univariate meta-regression: Univariate meta-regression was done to explore the source of high heterogeneity observed across studies. The results indicated that study design, income group, follow-up duration, and WHO region could not explain the heterogeneity between studies. The amount of heterogeneity explained by the covariate was defined as the reduction in the residual heterogeneity variance (tau-squared, τ^2) when including the covariate in the model, which was 25% for the patients' age group.

Sensitivity analysis: The leave-one-out method was used to assess potential changes in the pooled incidence rate if each study was excluded from the analysis once. In the current study, the exclusion of any of the studies did not affect the pooled incidence rate, demonstrating the robustness of the meta-analysis results (Figure 2).

Publication bias: Funnel plots are a visual tool for detecting publication and other biases in meta-analysis. Egger's linear regression test revealed that there was no statistically significant evidence of funnel plot asymmetry (i.e., no publication bias) (t = -0.85, df = 35, p= .403).

Discussion

The present systematic review showed that the overall incidence rate of surgical site infections (SSIs) in liver transplantation was 16.37% (95% CI: 13.48-19.73%). So far, three review studies have attempted to report the incidence of surgical site infection in liver transplant patients. Two of these studies [13, 51] included a small number of articles in the meta-analysis, and in one study [11], the primary aim was not to estimate and calculate the incidence of SSIs in a real-world setting. In these reviews, the incidence of SSIs was reported as 9.6-35.5% by Oliveira et al. (2018) [50], 11.8% by McElroy (2014) [12], and finally 17.3% by Jin et al. (2025) [10], respectively.

The SSI incidence in liver transplant surgery is higher compared to other types of surgery. Our previous scoping review revealed that the pooled incidence of SSIs in abdominal surgery was 10.6% [51]. A recent meta-analysis by Mentor et al. (2020) reported an SSI risk of 10.4% for liver resection [52], and the Bhangu et al. (2018) [53] reported an incidence rate of 12.3% in gastrointestinal surgery. The higher incidence of surgical site infections in liver transplant surgery compared to other types of surgery may be due to longer hospital stays and longer surgery times. Jin et al. (2025) revealed that re-transplantation, preoperative hemodialysis, biliary complications, and prior surgical history were significant risk factors for SSIs after liver transplantation [10]. Organ/space infections were found to be the predominant type of infection in liver transplantation, with an incidence rate of 10.61% (95% CI: 7.06-15.63%). Azharuddin and Sharma (2022) also found that organ/space infections were more common in liver transplant patients [54]. Organ/space SSI is a more severe condition than superficial or deep SSI, which is associated with increased mortality, prolonged hospital stay, and increased medical costs [55, 56]. This type of infection may have different risk factors in terms of magnitude and significance compared to superficial infection [57]; thus, SSI prevention strategies to decrease SSIs in liver transplant patients should consider these differences.

The prevalence of surgical site infections in pediatric patients 23.21% (95% CI: 16.44-31.71%) was higher than in adult patients 13.60% (95% CI: 10.81-16.98%). Children, especially neonates, may be more susceptible to SSIs due to their underdeveloped immune systems. In pediatric patients, gestational age, birth weight, age at the time of surgery, length of surgical procedure, number of procedures per patient, length of preoperative hospital stay, and preoperative sepsis are related to the incidence of surgical site infections [58].

Strengths of the study: The current study meta-analysis included a relatively adequate number of studies (39 studies), which allows for examining some sources of heterogeneity across studies, making the results more trustworthy. This review included prospective and retrospective research studies, representing real-world settings, but excluded experimental studies and clinical trials, representing manipulated settings. Heterogeneity was assessed at all stages of the meta-analysis.

Weaknesses of the study: First, this meta-analysis presented findings from papers published in electronic databases. Many dissertations, theses, and unpublished works not published in standard print journals were excluded from the meta-analysis. The meta-analysis was based on data from published studies; the outcomes of unpublished research may differ from our findings.

Conclusions

The findings revealed that the overall incidence of surgical site infection following liver transplantation was around 20%. As a result, reducing the burden of surgical site infections is both morally and economically necessary to enhance patient safety. Healthcare organizations seeking to reduce the incidence of surgical site infections across general surgical subspecialties may benefit from investigating various surgical site infection categories, considering appropriare therapies for each type of surgical site infection.

There was high heterogeneity among the studies included in the meta-analysis. The findings indicated that age group was one source of heterogeneity. However, a large amount of heterogeneity remained undefined, which may be a result of differences in the patient population studied. Thus, in future studies, it is recommended to collect standardized data, diagnose SSIs, and report incidence rates on a global scale considering the total cases in the study population.

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