

Surgical site infection in liver transplant recipients: risk factors and microbial agents from a high volume liver transplant center in Iran

Fereshteh Ghiasvand^{1†}, Zahra Jahani^{2,3†}, Ali Jafarian⁴, Elham Madreseh⁵, Zahra Ahmadinejad¹

¹Department of Infectious Diseases, Liver Transplantation Research Center, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran

²Department of Infectious Diseases, Shariati Hospital, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran

³Clinical Research Development Unit, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran

⁴Department of Liver Transplant and Hepatobiliary Surgery, Liver Transplantation Research Center, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran

⁵Rheumatology Research Center, Tehran University of Medical Sciences, Tehran, Iran

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ABSTRACT

Background and Objectives: Surgical site infection (SSI) is an important complication among liver transplant (LT) recipients. This study aimed to determine the prevalence, risk factors and microbial etiologies of SSI in LT recipients.

Materials and Methods: This retrospective observational study was conducted at a tertiary care hospital, Imam Khomeini Hospital complex, Tehran, Iran, between 2015 and 2020. Clinical data were collected from password-protected database.

Results: A total of 200 patients were included, of whom 121 (60.5%) were men. The mean age was 43.85 ± 14.59 years. Ninety-six patients (48%) developed SSI. broad-spectrum antibiotics use ($p=.005$), preoperative corticosteroids and immunosuppressive therapy ($P = .000$), Prolonged ICU stay ($P=.000$), and higher MELD score before transplantation ($P = .002$) were significantly associated with SSI. Graft rejection and one-year mortality rates were higher among patients with SSI; however, these differences were not statistically significant. SSI was also more common among patient with diabetes mellitus, other non-hepatic comorbidities, moderate-to-severe ascites, and those receiving piperacillin-tazobactam prophylaxis after surgery. The most frequently isolated microorganisms from SSI culture were *Klebsiella pneumoniae* (25%), *Enterococcus* spp. (22.9%) and *Escherichia coli* (16.6%).

Conclusion: SSI remains a common complication among LT in our center and should be suspected in patients presenting with infection during the first postoperative month. Recipients with advanced liver disease, prolonged ICU stay, preoperative immunosuppressive therapy, and post-transplant hemodialysis may require monitoring.

Keywords: Liver transplantation; Surgical wound infection; Risk factors; Drug resistance; Multiple; *Klebsiella pneumoniae*; *Enterococcus*; *Escherichia coli*

*Corresponding author: Zahra Jahani, MD, Department of Infectious Diseases, Shariati Hospital, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran; Clinical Research Development Unit, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-2166581598 Fax: +98-2166581598 Email: Zahra_jahani1992@yahoo.com

†These authors contributed equally to this work.

INTRODUCTION

Liver transplantation (LT) is the standard treatment for end-stage liver disease (1). Patient and graft survival have improved significantly in the last three decades owing to improvements in surgical techniques, perioperative management and better immunosuppressive regimens. However, LT recipients are at increased risk of infections, particularly in the first year after transplantation. The risk of infection is directly related to the intensity of immunosuppressive therapy and graft function (2-6). Multidrug-resistant organisms (MDROs) may also occur after LT (most commonly in the early post-operative phase), affecting both graft and patient survival (7-9). Therefore, appropriate surveillance, prompt diagnosis, and early treatment of infectious complications can significantly improve patient survival. Compared with other major surgical procedures, liver transplantation is associated with a higher risk of infection because of end-stage liver disease, malnutrition, frequent pre-transplant hospitalizations, prolonged operative time, invasive devices and vascular access, and immunosuppressive therapy.

Surgical site infections are common in LT recipients and have been associated with increased risk of allograft loss and death (10, 11). *Escherichia coli* and *Enterococcus* spp. are still the most frequent causes of SSI, as described in the general population (11, 12). The Centers for Disease Control and Prevention (CDC) classify surgical site infections into categories such as superficial, deep incisional, or organ/space infections. These infections must occur within 30 days following surgery or within 1 year after implantation to meet the classification criteria (13).

Despite significant advancements in LT procedures, post-operative infections particularly SSIs remain a major clinical challenge. Given their substantial impact on patient and graft outcomes, there is a growing need to investigate these infections across different clinical settings. Understanding the contributing factors to SSIs is essential for improving post-transplant care, especially in high-volume transplant centers where the burden of such complications is substantial.

This study aimed to evaluate the prevalence, risk factors, and microbial etiologies of SSIs in LT recipients at Imam Khomeini Hospital Complex in Tehran between 2015 and 2020, with the goal of identifying strategies for more effective prevention and management of these infections.

MATERIALS AND METHODS

Study design, setting, and population. This study was designed as a retrospective observational study in Imam Khomeini Hospital complex, one of the largest tertiary care hospitals in the Middle East and the second LT center in Iran, between 2015 -2020. A total of 200 liver transplant recipients who met the eligibility criteria were included. Patients were subsequently classified into two groups according to the presence or absence of SSI (96 with SSI and 104 without SSI).

Inclusion and exclusion criteria. Adult patients who underwent liver transplantation between 2015 and 2020 were eligible for inclusion. Patients were classified according to the presence or absence of SSI based on the CDC criteria. Exclusion criteria were as follows: Incomplete medical data, combined liver-kidney transplantation, death within the first 24 hours after transplant surgery.

Definition of surgical site infection. Surgical site infections (SSIs) were diagnosed and classified according to the Centers for Disease Control and Prevention (CDC) criteria (13). SSIs were categorized as superficial incisional, deep incisional, or organ/space infections. Superficial incisional SSI involved only the skin and subcutaneous tissue, whereas deep incisional SSI involved the fascia and muscle layers. Organ/space SSI included intra-abdominal infections such as liver abscess, perihepatic abscess, peritonitis, and cholangitis.

The diagnosis was based on clinical examination and, when clinically indicated, was supported by imaging studies, including ultrasonography, computed tomography (CT), and, in selected cases, magnetic resonance imaging (MRI), to confirm deep incisional or organ/space infections.

Microbiological procedures. Microbiological specimens were collected according to the type of SSI. For superficial incisional SSIs, sterile wound swabs were obtained. For suspected deep incisional or organ/space SSIs, tissue and/or purulent material obtained during surgical exploration or drainage procedures was submitted for microbiological culture.

Clinical specimens were processed according to standard microbiological procedures described in the Manual of Clinical Microbiology (ASM) (14). Antimicrobial susceptibility testing was performed using the

Kirby–Bauer disk diffusion method, and the results were interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines (15).

Data collection. Clinical data were retrieved from a password-protected database, the liver transplantation clinic records, and the hospital central laboratory information system.

Demographic and preoperative variables, including age, sex, underlying hepatic and non-hepatic diseases, MELD score, parenteral nutrition, renal replacement therapy within one month before transplantation, mechanical ventilation, hospitalization, ICU admission, and the use of corticosteroids and broad-spectrum antibiotics within three months before transplantation, were collected.

Pre-transplant corticosteroid and immunosuppressive therapy were recorded as binary variables (yes/no). Detailed information regarding the specific agents, dosage, duration of treatment, and cumulative corticosteroid exposure was not consistently available in the medical records and therefore was not included in the analysis.

Intraoperative variables included the duration of surgery, the number of packed red blood cell units transfused, type of liver transplantation (deceased donor liver transplantation [DDLT] or living donor liver transplantation [LTLT]), and perioperative antibiotic prophylaxis.

Postoperative variables included the duration of mechanical ventilation, length of hospital stay, graft rejection within the first month after transplantation, acute kidney injury, moderate-to-severe ascites, one-year mortality, and the occurrence of bacterial, fungal, and viral infections, including cytomegalovirus (CMV).

Statistical analysis. Continuous variables were summarized as mean $\pm$ standard deviation, while categorical variables were presented as counts and percentages. Univariate logistic regression analyses were first conducted, and variables with $P < 0.20$ were considered for inclusion in the multivariable model based on clinical relevance. A multiple logistic regression model was then fitted, and a final parsimonious model was selected using a stepwise selection procedure based on the Akaike Information Criterion (AIC), retaining variables that optimized model fit. All statistical analyses were performed using R software (version 4.3.2).

Sample size. The minimum required sample size for patients with SSI was estimated to be 96 based on a previously reported SSI prevalence of 50% (7), using a 95% confidence level and a relative error of 20%.

$$N = (Z_{1-\alpha/2})^2 \times P(1-P)/d^2$$

$$N = (1.96)^2 \times 0.5 \times 0.5 / (0.1)^2 = 96$$

Subsequently, all eligible liver transplant recipients who underwent transplantation between 2015 and 2020 were reviewed. During the study period, 96 patients developed SSI and were included in the SSI group, while 104 patients without SSI served as the comparison group.

Ethical considerations. The study protocol was approved by the institutional Ethics Committee (IR.TUMS.IKHC.REC.1399.195) and it was conducted in accordance with the principles of the Declaration of Helsinki. As the study was retrospective, no informed consent was obtained and Scientific Committee of the hospital granted permission for the use of patient data in accordance with the patient privacy.

RESULTS

Patient population and demographic characteristics. Between March 2015 and March 2020, 480 liver transplantations were performed at our center. After applying the eligibility criteria, 200 patients were included in the study, of whom 96 developed SSI and 104 did not. The mean age was 43.85 ± 14.59 years, and 121 patients (60.5%) were male.

The most common underlying diagnoses were Non-alcoholic steatohepatitis (NASH), autoimmune hepatitis (AIH) and cirrhosis due to hepatitis C virus. The prevalence of hepatocellular carcinoma was 16.6%.

Types of SSIs. Of the 96 SSIs, superficial, deep incisional and organ/space infections occurred in 12 (6.0%), 3 (1.5%), and 81 (40.5%), respectively. Among organ/space SSIs, intra-abdominal infections were the most common. The distribution of organ/space infection is presented in Table 1.

Causative pathogens for SSIs. Positive cultures results were obtained in 78 (81.2%). Eight patients had more than one bacterial or fungal pathogen. Among the isolated microorganisms, 71 (91%) organisms were bacterial. The most frequently 3 iso-

Table 1. Incidence and classification of surgical site infections (SSIs)

SSI type	Subtype	Frequency, n (%)
Superficial incisional SSI	—	12 (6.0)
Deep incisional SSI	Fascia	1 (0.5)
	Abdominal muscle	1 (0.5)
	Fascia and abdominal muscle	1 (0.5)
	Total deep incisional SSI	3 (1.5)
Organ/space SSI	Peritonitis	44 (22.0)
	Hepatic and prehepatic abscess	20 (10.0)
	Cholangitis	8 (4.0)
	Fascia and intra-abdominal infection	8 (4.0)
	Abdominal muscle and intra-abdominal infection	1 (0.5)
	Total organ/space SSI	81 (40.5)
Overall SSI	—	96 (48.0)

lated pathogens were *Klebsiella pneumoniae* (25%), *Enterococcus faecalis* and *faecium* (22.9%), and *Escherichia coli* (16.6%). The causative pathogens and their antimicrobial resistance patterns are presented in Table 2.

Overall, 87.5% of *Klebsiella pneumoniae* isolates were resistant to carbapenems. Vancomycin resistance was detected in 81.8% of *Enterococcus* spp. isolates, while 50% of *Escherichia coli* isolates produced extended-spectrum β -lactamases (ESBLs). The prevalence of fungal infections was 7.2% in our study patients. Fungal Infections included *Candida* species, as the most common pathogens, together with one case of *Mucormycosis*.

Risk factors for SSIs after LT. Table 3 presents the risk factors associated with SSIs in our study population. Among the preoperative variables, the following factors were significantly associated with SSIs: higher MELD score ($P = 0.003$), pre-transplant use of corticosteroids and other immunosuppressive agents ($P < 0.001$), and the presence of moderate to severe ascites ($P < 0.001$).

Postoperative risk factors for SSIs included the type of prophylactic antibiotics administered after surgery ($P = 0.0021$), longer duration of hospitalization ($P < 0.001$), and the need for hemodialysis ($P = 0.022$). Retransplantation, graft rejection, and CMV infection were not significantly associated with SSIs in our study.

SSI management. All patients with SSI received antimicrobial therapy. In 17 patients, antimicrobial

therapy was combined with surgical drainage. Vacuum-assisted wound therapy was used in four patients, as shown in Table 4.

DISCUSSION

In this study, we evaluated the incidence, microbial etiology, and risk factors of SSI among LT recipients at one of the high-volume LT centers in Iran and the middle-east. Organ/space infections, particularly peritonitis and infections caused by multidrug-resistant Gram-negative bacteria were the predominant type of SSI. A higher MELD score, prolonged ICU stay, pre-transplant corticosteroids and immunosuppressive therapy, the need for postoperative hemodialysis, and postoperative of piperacillin-tazobactam prophylaxis were associated with an increased risk of SSIs.

Association between MELD score and risk of SSIs. The severity of liver disease, as reflected by the pre-transplant MELD score, has been recognized as an important risk factor for SSI. Our findings are consistent with those of Merli et al. (16), who examined 150 LT recipients. In contrast, Softness et al. (7) did not report a similar association. Patients with higher MELD scores usually have more advanced liver disease, poorer nutritional status, and impaired immune function, all of which may increase susceptibility to postoperative infections. Furthermore, a high MELD score frequently reflects decompensated liver disease, a condition that often necessitates urgent LT. Patients with advanced liver disease often

Table 2. Microorganisms isolated from surgical site infections and antimicrobial resistance patterns

Pathogen	Frequency n (%)	Antimicrobial resistance pattern, n (%)
Gram-negative organisms		
<i>Klebsiella pneumoniae</i>	24 (25.0)	Susceptible: 2 (8.3); ESBL-E: 1 (4.2); CRE: 21 (87.5); MDR/XDR/PDR: 0
<i>Escherichia coli</i>	16 (16.6)	Susceptible: 5 (31.2); ESBL-E: 8 (50.0); CRE: 0; MDR/ XDR/PDR: 3 (18.7)
<i>Acinetobacter baumannii</i>	6 (6.3)	Susceptible: 1 (16.7); Carbapenem-susceptible: 1 (16.7); CRAB: 4 (66.7); MDR/XDR/PDR: 0; DTR-A: 0
<i>Stenotrophomonas maltophilia</i>	2 (2.1)	—
<i>Pseudomonas aeruginosa</i>	1 (1.0)	Susceptible: 0; ESBL: 0; CR-PA: 0; DTR-P: 1 (100)
<i>Morganella morganii</i>	1 (1.0)	—
<i>Salmonella</i> spp.	1 (1.0)	—
<i>Sphingomonas</i> spp.	1 (1.0)	—
Gram-positive organisms		
<i>Enterococcus faecalis/faecium</i>	22 (22.9)	VSE: 4 (18.2); VRE: 18 (81.8)
<i>Coagulase-negative staphylococci</i>	8 (8.3)	MSSE: 0; MRSE: 8 (100)
<i>Staphylococcus aureus</i>	5 (5.2)	MSSA: 2 (40.0); MRSA: 3 (60.0)
<i>Viridans group streptococci</i>	2 (2.1)	VSE: 2 (100)
Fungal organisms		
<i>Candida</i> spp.	6 (6.3)	No antifungal resistance data available
<i>Mucor</i>	1 (1.0)	No antifungal resistance data available

ESBL-E: extended-spectrum beta-lactamase-producing Enterobacterales; CRE: carbapenem-resistant Enterobacterales; CRAB: carbapenem-resistant *Acinetobacter baumannii*; CR-PA: carbapenem-resistant *Pseudomonas aeruginosa*; DTR-P: difficult-to-treat resistance in *Pseudomonas aeruginosa*; DTR-A: difficult-to-treat resistance in *Acinetobacter baumannii*; MDR: multidrug-resistant; XDR: extensively drug-resistant; PDR: pandrug-resistant; MRSA: methicillin-resistant *Staphylococcus aureus*; MRSE: methicillin-resistant *Staphylococcus epidermidis*; VRE: vancomycin-resistant enterococci; VSE: vancomycin-susceptible enterococci.

require urgent transplantation and experience greater physiological impairment, which may contribute to an increased risk of postoperative infections.

The overall incidence of SSI in our cohort (48%) was higher than that reported in several previous studies and recent meta-analyses. This difference may be explained by variations in patient characteristics, disease severity, referral patterns to our tertiary transplant center, and differences in surveillance methods and SSI definitions across studies.

Our finding should also be interpreted in the context of other Iranian transplant centers. A prospective study from the Shiraz Organ Transplant Center (17), the largest liver transplant center in Iran, evaluated early bacterial infections after liver transplantation and similarly emphasized the substantial burden of postoperative infectious complications, although it was not specifically focused on surgical site infections. Differences in study design, infection defini-

tions, patient characteristics, and surveillance protocols may account for the variation in the reported incidence across centers.

Relationship between ICU stays duration and SSIs. In our study, prolonged ICU stay after liver transplantation was independently associated with an increased risk of SSIs, consistent with previous studies (11, 18-21). Prolonged ICU stay may reflect greater illness severity and increased exposure to invasive procedures and the hospital environment, all of which may contribute to the development of postoperative infections. As a high-volume tertiary referral transplant center, our institution frequently manages critically ill patients with advanced liver disease, which may partly explain the higher incidence of SSI observed in our cohort compared with previous reports. In addition, prolonged ICU hospitalization has been associated with an increased risk

Table 3. Univariate and multivariable logistic regression analysis of risk factors associated with surgical site infections after liver transplantation

Variable	SSI group (n=96)	Non-SSI group (n=104)	Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	Adjusted P-value
Demographic and clinical factors						
Age (years, mean $\pm$ SD)	43.09 $\pm$ 14.5	44.55 $\pm$ 14.7	0.99 (0.97-1.01)	0.480	—	—
Female gender (n, %)	38 (39.6)	41 (39.4)	1.01 (0.57-1.78)	0.982	—	—
Comorbidity (n, %)	32 (33.3)	21 (20.2)	1.98 (1.05-3.79)	0.037	—	—
Liver transplant etiology						
Metabolic/ Cryptogenic (n, %)	22 (22.9)	26 (25.0)	0.89 (0.46-1.71)	0.730	—	—
Autoimmune (n, %)	16 (16.7)	21 (20.2)	0.79 (0.38-1.62)	0.522	—	—
Cholestatic/ Biliary (n, %)	14 (14.6)	11 (10.6)	1.44 (0.62-3.42)	0.394	—	—
Malignancy (n, %)	5 (5.2)	14 (13.5)	0.35 (0.11-0.97)	0.055	—	—
Severity of liver disease						
MELD score (mean $\pm$ SD)	23.27 $\pm$ 9.1	19.38 $\pm$ 8.5	1.05 (1.02-1.09)	0.003	—	—
Severe-to-moderate ascites (n, %)	60 (62.5)	34 (32.7)	3.38 (1.89-6.13)	<0.001	3.72 (1.46- 10.03)	0.007
Perioperative factors						
Broad-spectrum antibiotics before transplantation (n, %)	14 (14.6)	8 (7.7)	2.05 (0.83-5.36)	0.125	—	—
Corticosteroid use (n, %)	25 (26.0)	8 (7.7)	4.23 (1.87-10.52)	0.001	5.24 (1.24-25.56)	0.030
Immunosuppressive drugs (n, %)	50 (52.1)	18 (17.3)	5.13 (2.73-10.01)	<0.001	3.80 (1.34-11.33)	0.013
Intraoperative factors						
Duration of surgery (min, mean $\pm$ SD)	321.36 $\pm$ 96.9	322.65 $\pm$ 70.4	1.00 (0.99-1.01)	0.915	—	—
Packed cells transfused (mean $\pm$ SD)	2.08 $\pm$ 1.8	1.71 $\pm$ 1.7	1.13 (0.96-1.35)	0.142	1.27(0.94-1.74)	0.121
Post-transplant factors						
ICU stay (days, mean $\pm$ SD)	7.59 $\pm$ 7.5	2.19 $\pm$ 1.5	1.84 (1.54-2.28)	<0.001	1.88 (1.49-2.52)	<0.001
Piperacillin–tazobactam prophylaxis (n, %)	77 (80.2)	64 (61.5)	2.15 (1.13-4.19)	0.021	2.71 (0.91-8.97)	0.085
CMV infection (n, %)	17 (17.7)	16 (15.4)	1.34 (0.63-2.86)	0.446	—	—
Hemodialysis (n, %)	14 (14.6)	5 (4.8)	3.46 (1.27-11.09)	0.022	—	—
Rejection (n, %)	20 (20.8)	12 (11.5)	2.02 (0.94-4.51)	0.076	—	—
Re-transplantation (n, %)	10 (10.4)	10 (9.6)	1.11 (0.43-2.83)	0.829	—	—
One-year mortality (n, %)	21 (21.9)	15 (14.4)	1.66 (0.8-3.5)	0.173	—	—

SSI: surgical site infection; OR: odds ratio; CI: confidence interval; MELD: Model for End-stage Liver Disease; ICU: intensive care unit; CMV: cytomegalovirus; SD: standard deviation.

Table 4. Management strategies for surgical site infections

Management method	Frequency (n)	Percentage (%)
Antimicrobial therapy alone	51	53.1
Antimicrobial therapy + surgical drainage	41	42.7
Antimicrobial therapy + surgical drainage + vacuum therapy	4	4.2

of other healthcare-associated infections, including ventilator-associated pneumonia, catheter-associated urinary tract infections, and bloodstream infections.

Prognostic role of pre-transplant corticosteroids and immunosuppressive drugs.

The use of

pre-transplant corticosteroids and immunosuppressive agents was identified as one of the factors associated with an increased risk of SSI in the present study (22, 23). These medications are commonly prescribed for patients with autoimmune hepatitis, primary biliary cholangitis, and primary sclerosing cholangitis.

To further contextualize our findings, we conducted a PubMed search and identified only one study that evaluated the prognostic impact of pre-transplant anti-CD20 therapy in recipients of ABO-incompatible living-donor liver transplantation (24). The limited number of available studies highlights the need for further research on the prognostic role of pre-transplant immunosuppressive therapy in LT recipients. Because of the retrospective design of our study, detailed information regarding the specific immunosuppressive agents, corticosteroid dosage, duration of therapy, and cumulative exposure was not consistently available and therefore could not be evaluated. Future prospective studies should investigate the impact of different immunosuppressive regimens on the risk of SSI after liver transplantation.

Impact of pre-transplant broad spectrum antibiotic use on SSIs in LT patients. Another aspect examined in this study was the effect of broad-spectrum antibiotic exposure within three to six months prior to LT on the incidence of SSIs. In our analysis, this association was not statistically significant ($P > 0.05$). However, the use of broad-spectrum antibiotics in the pre-transplant period may serve as an indicator of previous hospitalization, severe infection, or sepsis rather than a direct causal factor for SSIs development.

Reddy et al. (25) reported that among 136 LT candidates who experienced bacterial infections within six months before transplantation, 42% either died or were removed from the transplant list due to infection, 35% underwent LT, and only 24% survived six months post-transplant, highlighting the poor prognosis associated with pre-transplant infections. Subsequent studies have confirmed that recent infections or antibiotic exposure before LT are strongly linked to increased mortality and graft failure, although not necessarily to a higher SSIs rate (11, 26).

Furthermore, prior antibiotic exposure has been associated with colonization by multidrug-resistant organisms (MDROs), particularly gram-negative pathogens, which may increase the risk of post-transplant nosocomial infections (27, 28). Therefore, while the absence of a direct statistical correlation between pre-transplant antibiotic use and SSI incidence in our study suggests no independent effect, these findings should be interpreted with caution.

Association between the duration of surgery and the incidence of SSIs. In our study, the association

between the duration of surgery and the incidence of SSIs was evaluated. Unlike several previous studies (29-31), we did not observe a statistically significant relationship between operative time or the number of packed red blood cell transfusions and SSIs occurrence.

Given that these studies were based on larger or multicenter cohorts, the absence of a significant association in our findings may be attributed to differences in surgical complexity, perioperative management, and sample size. Further multicenter investigations with larger populations are warranted to clarify the precise impact of surgical duration and intraoperative transfusion requirements on the development of SSIs after LT.

Impact of SSIs on graft rejection and re-transplantation. Our findings are consistent with those reported by Hellinger et al. (32), indicating that SSIs may not be an independent predictor of graft-related outcomes after LT. Similarly, in our cohort, no significant difference in SSI incidence was observed between patients undergoing re-transplantation and those receiving a primary graft.

Previous studies have reported mixed results. While some, such as Schreiber et al. (11) and Hellinger et al. (32), found an association between SSIs and poorer graft outcomes, others, including Aydin Aktas et al. (33) and Carugati et al. (30), did not identify SSIs as an independent predictor of graft-related outcomes. Overall, although SSIs contribute to postoperative morbidity, their impact on graft survival remains uncertain.

Our results suggest that SSIs, while clinically important, may not independently influence graft survival or the likelihood of re-transplantation, highlighting the multifactorial nature of post-transplant outcomes.

Impact of prophylactic antibiotics on SSIs in LT. In evaluating the type of prophylactic antibiotic therapy administered, our results indicated that patients who received ampicillin-sulbactam experienced a lower incidence of SSIs. However, since piperacillin-tazobactam is typically prescribed for patients with a recent history of hospitalization or prior therapeutic or prophylactic antibiotic use before transplantation, this observed difference may be partially influenced by these confounding factors. Furthermore, among the total cohort of 200 cases and controls, only 50 patients received ampicillin-sul-

bactam, and no adjustment was performed for other potentially influential variables such as MELD score, age, etiology of chronic liver disease, or other clinical parameters.

Relationship between CMV infection and the occurrence of SSIs. In our study, no significant correlation was observed between CMV infection and the development of SSIs. However, Freire et al. (34), reported CMV infection as a significant contributor to SSI in a cohort of 543 LT recipients, of whom 141 developed SSIs. In that study, CMV infection was assessed according to the standardized definitions provided by Ljungman et al. (35).

CONCLUSION

Surgical site infections (SSIs), particularly deep infections, remain a frequent complication among liver transplant recipients in our center, especially during the first postoperative month. Gram-negative multidrug-resistant organisms were the predominant causative pathogens. Higher MELD score, prolonged ICU stay, pre-transplant corticosteroid and immunosuppressive therapy, diabetes mellitus, and post-transplant hemodialysis were associated with an increased risk of SSI. These findings highlight the importance of identifying high-risk patients and strengthening perioperative infection prevention strategies. Further multicenter studies with larger sample sizes are needed to validate these findings and evaluate additional risk factors.

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REFERENCES

- Kim YJ, Yoon JH, Kim SI, Choi HJ, Choi JY, Yoon SK, et al. Impact of pretransplant infections on clinical course in liver transplant recipients. *Transplant Proc* 2018; 50: 1153-1156.
- Shinde AS, Kapoor D. Infections after liver transplant: timeline, management and prevention. *J Clin Exp Hepatol* 2024; 14: 101316.
- Chelala L, Kovacs CS, Taege AJ, Hanouneh IA. Common infectious complications of liver transplant. *Cleve Clin J Med* 2015; 82: 773-784.
- Ferrarese A, Zanetto A, Becchetti C, Sciarrone SS, Shalaby S, Germani G, et al. Management of bacterial infection in the liver transplant candidate. *World J Hepatol* 2018; 10: 222-230.
- Idossa DW, Simonetto DA. Infectious complications and malignancies arising after liver transplantation. *Anesthesiol Clin* 2017; 35: 381-393.
- Patel G, Huprikar S. Infectious complications after orthotopic liver transplantation. *Semin Respir Crit Care Med* 2012; 33: 111-124.
- Ferrarese A, Senzolo M, Sasset L, Bassi D, Cillo U, Burra P. Multidrug-resistant bacterial infections in the liver transplant setting. *Updates Surg* 2024; 76: 2521-2529.
- Martin-Mateos R, Martínez-Arenas L, Carvalho-Gomes Á, Aceituno L, Cadahía V, Salcedo M, et al. Multidrug-resistant bacterial infections after liver transplantation: prevalence, impact, and risk factors. *J Hepatol* 2024; 80: 904-912.
- Friedrich K, Kreml J, Schamoni S, Hippchen T, Pfeiffenberger J, Rupp C, et al. Multidrug-resistant bacteria and disease progression in patients with end-stage liver disease and after liver transplantation. *J Gastrointest Liver Dis* 2019; 28: 303-310.
- Rolak SC, Yetmar ZA, Lahr BD, Beam E, Razi S, Watt K et al. Risk factors for surgical site infections after liver transplant: does perioperative antibiotic regimen matter? *Transplantation* 2024; 108: 1179-1188.
- Schreiber PW, Hoessly LD, Boggian K, Neofytos D, van Delden C, Egli A, et al. Surgical site infections, risk factors, and outcomes after liver transplant. *JAMA Netw Open* 2025; 8(3): e251333.
- Chea N, Sapiano MRP, Zhou L, Epstein L, Guh A, Edwards JR, et al. Rates and causative pathogens of surgical site infections attributed to liver transplant procedures and other hepatic, biliary, or pancreatic procedures, 2015-2018. *Transpl Infect Dis* 2021; 23(4): e13589.
- Centers for Disease Control and Prevention. National Healthcare Safety Network (NHSN) patient safety component manual: Chapter 9. Surgical site infection (SSI) event. Atlanta, GA: CDC; 2025 [cited 2026 Aug 7]. Available from: <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscscscurrent.pdf>
- Baron EJ (2015). Specimen collection, transport, and processing: bacteriology. In: *Manual of Clinical Microbiology*. Eds, JH Jorgensen, KC Carroll, G Funke, MA Pfaller, ML Landry, SS Richter, et al. 11th ed. ASM

- Press. Washington, DC, pp. 270-315.
15. CLSI (2020). Performance Standards for Antimicrobial Susceptibility Testing. 30th ed. CLSI supplement M100. Wayne, PA. Clinical and Laboratory Standards Institute.
 16. Merli M, Lucidi C, Giannelli V, Giusto M, Riggio O, Falcone M, et al. Cirrhotic patients are at risk for health care-associated bacterial infections. *Clin Gastroenterol Hepatol* 2010; 8: 979-985.
 17. Jafarpour Z, Pouladfar G, Malek Hosseini SA, Firoozifar M, Jafari P. Bacterial infections in the early period after liver transplantation in adults: A prospective single-center cohort study. *Microbiol Immunol* 2020; 64: 407-415.
 18. Freire MP, Oshiro ICVS, Bonazzi PR, Guimarães T, Figueira ER, Bacchella T, et al. Surgical site infections in liver transplant recipients in the model for end-stage liver disease era: an analysis of the epidemiology, risk factors, and outcomes. *Liver Transpl* 2013; 19: 1011-1019.
 19. Bruns T, Zimmermann HW, Stallmach A. Risk factors and outcome of bacterial infections in cirrhosis. *World J Gastroenterol* 2014; 20: 2542-2554.
 20. Galbois A, Aegerter P, Martel-Samb P, Housset C, Thabut D, Offenstadt G, et al. Improved prognosis of septic shock in patients with cirrhosis: a multicenter study. *Crit Care Med* 2014; 42: 1666-1675.
 21. Pita A, Nguyen B, Rios D, Maalouf N, Lo M, Genyk Y, et al. Variability in intensive care unit length of stay after liver transplant: determinants and potential opportunities for improvement. *J Crit Care* 2019; 50: 296-302.
 22. Panackel CF, Mathew JF, Fawas NM, Jacob M. Immunosuppressive drugs in liver transplant: an insight. *J Clin Exp Hepatol* 2022; 12: 1557-1571.
 23. Hisanaga T, Hidaka I, Sakaida I, Nakayama N, Ido A, Kato N, et al. Analysis of the safety of pretransplant corticosteroid therapy in patients with acute liver failure and late-onset hepatic failure in Japan. *JGH Open* 2021; 5: 428-433.
 24. Hsu SC, Thorat A, Jeng LB, Li PC, Chen TH, Yang HR, et al. ABO-incompatible living donor liver transplantation with reduced rituximab dose: a retrospective analysis of 65 patients—can we fast-track liver transplant surgery and improve long-term survival? *Ann Transplant* 2020; 25: e923502.
 25. Reddy KR, O'Leary JG, Kamath PS, Fallon MB, Biggins SW, Wong F, et al. High risk of delisting or death in liver transplant candidates following infections: results from the North American Consortium for the Study of End-Stage Liver Disease. *Liver Transpl* 2015; 21: 881-888.
 26. Incicco S, Tonon M, Zeni N, Gambino C, Gagliardi R, Calvino V, et al. Impact of bacterial infections prior to liver transplantation on post-transplant outcomes in patients with cirrhosis. *JHEP Rep* 2023; 5: 100808.
 27. Phichaphop C, Apiwattanakul N, Techasaensiri C, Le-rtudomphonwanit C, Treepongkaruna S, Thirapattaraphan C, et al. High prevalence of multidrug-resistant gram-negative bacterial infection following pediatric liver transplantation. *Medicine (Baltimore)* 2020; 99(45): e23169.
 28. Taddei R, Riccardi N, Tiseo G, Galfo V, Biancofiore G. Early intra-abdominal bacterial infections after orthotopic liver transplantation: a narrative review for clinicians. *Antibiotics (Basel)* 2023; 12: 1316.
 29. Oliveira RA, Turrini RNT, Poveda VB. Risk factors for development of surgical site infections among liver transplantation recipients: an integrative literature review. *Am J Infect Control* 2018; 46: 88-93.
 30. Carugati M, Arif S, Yarrington ME, King LY, Harris M, Evans K, et al. Risk factors for invasive surgical site infections among adult single liver transplant recipients at Duke University Hospital in the period 2015-2020. *Transplant Direct* 2024; 10(12): e1719.
 31. Oliveira RA, Mancero JMP, Faria DF, Poveda VB. A retrospective cohort study of risk factors for surgical site infection following liver transplantation. *Prog Transplant* 2019; 29: 144-149.
 32. Hellinger WC, Heckman MG, Crook JE, Taner CB, Willingham DL, Diehl NN, et al. Association of surgeon with surgical site infection after liver transplantation. *Am J Transplant* 2011; 11: 1877-1884.
 33. Aktas A, Kayaalp C, Gunes O, Gokler C, Uylas U, Cicek E, et al. Surgical site infection and risk factors following right lobe living donor liver transplantation in adults: a single-center prospective cohort study. *Transpl Infect Dis* 2019; 21(6): e13176.
 34. Freire MP, Song ATW, Oshiro ICV, Andraus W, D'Albuquerque LAC, Abdala E. Surgical site infection after liver transplantation in the era of multidrug-resistant bacteria: what new risks should be considered? *Diagn Microbiol Infect Dis* 2021; 99: 115220.
 35. Ljungman P, Boeckh M, Hirsch HH, Josephson F, Lundgren J, Nichols G, et al. Definitions of cytomegalovirus infection and disease in transplant patients for use in clinical trials. *Clin Infect Dis* 2017; 64: 87-91.