Original Article
Ann Liver Transplant 2024;4(1):16-22
https://doi.org/10.52604/alt.24.0004

ALT
Annals of Liver Transplantation

pISSN 2765-5121
eISSN 2765-6098

Carbapenem-resistant gram-negative rod bacteremia in the early postoperative period following liver transplantation

Eun-Ki Min, Deok-Gie Kim, Minyu Kang, Hwa-Hee Koh, Jae Geun Lee, Dong Jin Joo, Myoung Soo Kim

Department of Surgery, The Research Institute for Transplantation, Yonsei University College of Medicine, Seoul, Korea

Background: Carbapenem-resistant gram-negative rod bacteremia (CRGNR-B) is emerging as a formidable challenge, complicating patient management and outcomes in liver transplantation (LT). This study aimed to investigate the incidence, mortality, and risk factors associated with CRGNR-B within 90 days following LT.
Methods: A retrospective nested case-control study was conducted using single centric LT data (n=1,379). CRGNR-B cases were matched 1:5 with control patients for analyzing survival and risk factors for CRGNR-B.
Results: The incidence of CRGNR-B within 90 days post-LT was 6.5% (n=87). The CRGNR-B group showed significantly lower 1-year post-LT survival compared to the control group (37.9% vs. 90.0%, p<0.001). CRGNR-B was significantly correlated with increased mortality after adjustment of covariates (adjusted hazard ratio, 5.66; 95% confidence interval [CI], 3.89–8.24; p<0.001). Key risk factors identified include higher pretransplant model for end-stage liver disease scores (odds ratio [OR], 1.05; 95% CI, 1.01–1.09; p=0.006), encephalopathy prior to transplant (OR, 2.79; 95% CI, 1.48–5.30; p=0.002), retransplantation (OR, 10.4; 95% CI, 2.79–42.1; p<0.001), each 60-minute increase in cold ischemic time (OR, 1.20; 95% CI, 1.01–1.42; p=0.037), and bile duct complications (OR, 6.16; 95% CI, 2.66–14.2; p<0.001).
Conclusion: The occurrence of CRGNR-B within 90 days post-LT poses a significant risk to patient survival, with identifiable pre- and peri-transplant risk factors. These findings underscore the importance of targeted preventive measures, early detection, and effective management strategies to enhance outcomes for LT recipients.

Keywords: Carbapenem resistant; Gram negative; Liver transplantation

Received March 22, 2024
Revised April 19, 2024
Accepted April 19, 2024
Published online May 20, 2024

Corresponding author: Deok-Gie Kim
Department of Surgery, The Research Institute for Transplantation, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
E-mail: mppl01@yuhs.ac
https://orcid.org/0000-0001-9653-926X

INTRODUCTION

Liver transplantation (LT) stands as the definitive therapy for patients grappling with the final stages of liver disease. However, to prevent organ rejection, LT recipients must undergo immunosuppression, inadvertently elevating their susceptibility to infections [1]. This vulnerability is further exacerbated by factors intrinsic to LT patients, such as impaired liver functionality, the presence of sarcopenia, and a higher propensity for hospital admissions, contributing to

the elevated rates of infectious complications and associated morbidity and mortality in the postoperative phase [2-4].

Infections rank prominently among the leading causes of mortality in the initial phase following LT, underscoring the imperative for preemptive measures and swift identification of severe infectious episodes to enhance LT outcomes [5,6]. Notably, the occurrence of infections from drug-resistant pathogens in transplant recipients is estimated to be up to 20%, a figure that surpasses the incidence rates observed in the broader hospital patient cohort [7-9].

Among the pathogens of concern, carbapenem-resistant gram-negative rod (CRGNR) has been identified with increasing frequency in the hospital setting [10]. The prevalence of CRGNR infections has been reported as about 16% in LT recipients, with about 45% of mortality [11,12]. The ability of CRGNR to develop resistance against a multitude of antibacterial agents significantly complicates treatment efforts.

Using a single center LT cohort, we previously assessed the effects and risk factors of carbapenem-resistant *Acinetobacter baumannii* bacteremia, reporting 2.7% incidence within 30 days following transplant and 65.5% of 1-month mortality [13]. Including this pathogen, accurately predicting the risk of CRGNR bacteremia (CRGNR-B) and identifying associated risk factors are critical for improving patient outcomes post-transplantation. This study aims to evaluate consequence and risk factors of CRGNR-B within 90 days after LT.

MATERIALS AND METHODS

Study Population

This investigation utilized a single-center, retrospective case-control design to assess occurrences of CRGNR-B in liver transplant recipients. The cohort comprised patients who underwent LT at Severance Hospital in Korea from September 2005 through December 2022. The study excluded individuals under 18 years of age (n=130), those who succumbed to death or required retransplantation within two days post-LT (n=9), and patients with pre-existing CRGNR-B prior to LT (n=6), resulting in a total of 1,379 eligible participants. Within this cohort, 87 individuals developing CRGNR-B within 90 days post-transplantation (the CRGNR-B group) were identified and compared against a control group of 435 matched patients without CRGNR-B (Fig. 1).

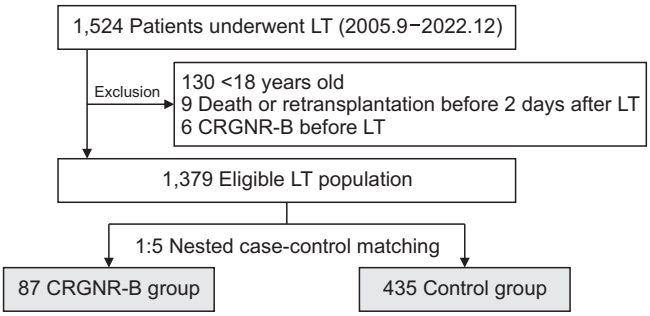

Fig. 1. Study flow for nested case-control study. LT, liver transplantation; CRGNR-B, carbapenem-resistant gram-negative rod bacteremia.

Data Collection

Data concerning recipient and donor demographics were extracted from the institutional liver transplant database, which is prospectively maintained. The accumulation of bacterial culture results was facilitated through the hospital's electronic medical records system. In the perioperative period, cultures of blood, sputum, or urine were conducted based on clinical indications such as fever or signs of infection. Postoperatively, a regimen of surveillance cultures encompassing blood, sputum, urine, and intra-abdominal fluid was implemented daily for the initial week, triweekly during the intensive care unit (ICU) stay, and subsequently on a weekly basis following ICU discharge. Identification of CRGNR-B necessitated the presence of CRGNR in at least two concurrently drawn blood cultures.

Tacrolimus (TAC) administration commenced within a window spanning from one day prior to one day following the operation in the majority of cases. The monitoring of serum trough levels of TAC occurred daily during the first postoperative week, followed by a frequency of two to three times weekly until hospital discharge. Additionally, the study documented the mean and maximum trough levels of TAC, alongside the employment of other immunosuppressive agents up to the index date. The criterion for the usage of these immunosuppressants was defined as a prescription covering over 50% of the days post-transplant until the index date.

Nested Case-Control Matching at the Time of CRGNR-B

Using nested case-control design, a 1:5 matching ratio was employed to pair CRGNR-B patients with controls based on the absence of CRGNR-B at the index postoperative day (POD) of blood culture positivity. Controls were chosen iteratively, allowing for their reuse as potential matches for new CRGNR-B cases, provided they remained

CRGNR-B-free until the next index date. This matching strategy was designed to isolate the index date as a variable, aiming to uncover risk factors specifically associated with CRGNR-B occurrence post-LT, without other matching constraints. This approach enhances the precision of identifying temporal risk factors for CRGNR-B in liver transplant recipients.

Statistical Analysis

Statistical representations for this study involved depicting categorical variables by their counts (and respective percentages) and continuous variables through either median values (along with interquartile ranges [IQRs]) or means and standard deviations. The selection between chi-square, student's t-test, and Wilcoxon rank sum test for group comparisons was made based on the data's distribution and nature. Survival rates at 30 days post-index date were analyzed using Kaplan-Meier survival curves, with differences assessed via the log-rank test. The exploration of potential risk factors for CRGNR-B utilized both univariate and multivariate logistic regression analyses within the matched case-control cohort. Given the CRGNR-B group's size constraints, variables with a p-value less than 0.05 in the univariate analysis were considered for the multivariate model, which was refined through a backward stepwise process to retain only significant predictors. All statistical procedures were conducted through R software, version 4.2.0, on macOS (available at http://cran.r-project.org), adhering to a significance level of $p<0.05$.

Ethical Approval

Conducted in full compliance with the ethical standards set forth by the Declaration of Helsinki and the Declaration of Istanbul, this research received the green light from the Institutional Review Board of Severance Hospital under the Yonsei University Health System (Approval Number: 4-2022-1301). The retrospective nature of this analysis negated the necessity for obtaining informed consent from participants.

RESULTS

Incidence and Time of CRGNR-B

The majority of CRGNR-B cases in the 1,379 eligible population happened in the early post-transplant phase, with cumulative incidences of 4.8%, 6.0%, and 6.5% at 30, 60, and 90 days following LT (Fig. 2). The median period from LT to CRGNR-B was 13 days (IQR, 3–31 days) among the 87 individuals who experienced CRGNR-B within 90 days following LT (Supplementary Fig. 1).

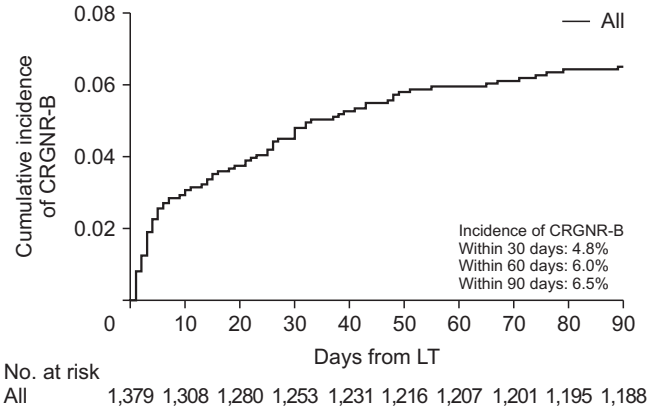

Fig. 2. Cumulative incidence of carbapenem-resistant gram-negative rod bacteremia (CRGNR-B) wihtin 90 days after liver transplantation (LT).

Baseline Characteristics

Table 1 shows baseline characteristics in the CRGNR-B and the matched controls. No significant differences were observed in age (54 years [IQR, 45–60 years] in the CRGNR-B group vs. 54 years [IQR, 48–59 years] in the matched groups, p=0.818), sex (female: 28.7% vs. 29.0%, p>0.999), or body mass index (BMI) (24.1 kg/m^2 [IQR, 21.9–26.5 kg/m^2] vs. 23.9 kg/m^2 [IQR, 22.0–26.3 kg/m^2], p=0.797) between the two groups. Regarding underlying health conditions and liver disease etiologies, no statistically significant differences were found in the prevalence of hypertension (16.1% vs. 20.5%, p=0.431), diabetes mellitus (27.6% vs. 36.6%, p=0.140), cardiovascular disease (10.3% vs. 8.3%, p=0.676), and liver disease cause (viral: 49.4% vs. 56.6%, alcoholic: 23.0% vs. 25.3%, others: 27.6% vs. 18.2%; p=0.130). However, significant differences were noted in the incidence of pretransplant hepatocellular carcinoma (37.9% vs. 48.7%, p=0.084), with a higher model for end-stage liver disease (MELD) score in the CRGNR-B group (30 [IQR, 16–37] vs. 14 [IQR, 9–25], p<0.001). CRGNR-B group had a significantly higher requirement for dialysis prior to transplantation compared to the control group (36.8% vs. 10.1%, p<0.001). The incidence of severe encephalopathy was significantly higher in the CRGNR-B group than in the control group (52.9% vs. 26.0%, p<0.001). Furthermore, patients in the CRGNR-B group were more likely to have undergone deceased donor LT (43.7% vs. 28.0%, p=0.006) and retransplantation (12.6% vs. 1.1%, p<0.001), with donor BMI being significantly lower (22.8 kg/m^2 [IQR, 20.7–25.6 kg/

https://doi.org/10.52604/alt.24.0004

Table 1. Baseline characteristics

Variable	CRGNR-B (n=87)	Control (n=435)	p-value
Age (yr)	54 (45–60)	54 (48–59)	0.818
Sex (female)	25 (28.7)	126 (29.0)	>0.999
BMI (kg/m^2)	24.1 (21.9–26.5)	23.9 (22.0–26.3)	0.797
Hypertension	14 (16.1)	89 (20.5)	0.431
Diabetes mellitus	24 (27.6)	159 (36.6)	0.140
Cardiovascular disease	9 (10.3)	36 (8.3)	0.676
Underlying liver disease			0.130
Viral	43 (49.4)	246 (56.6)	
Alcoholic	20 (23.0)	110 (25.3)	
Others	24 (27.6)	79 (18.2)	
Hepatocellular carcinoma	33 (37.9)	212 (48.7)	0.084
Pretransplant MELD	30 (16–37)	14 (9–25)	<0.001
Pretransplant stay			<0.001
Out-patient day	30 (34.5)	253 (58.2)	
In hospital	57 (65.5)	182 (41.8)	
Pretransplant dialysis	32 (36.8)	44 (10.1)	<0.001
Refractory ascites	16 (18.4)	87 (20.0)	0.844
Encephalopathy	46 (52.9)	113 (26.0)	<0.001
ABO incompatibility	14 (16.1)	66 (15.2)	0.957
Retransplantation	11 (12.6)	5 (1.1)	<0.001
Donor type			0.006
Living	49 (56.3)	313 (72.0)	
Deceased	38 (43.7)	122 (28.0)	
Donor age (yr)	39 (29–49)	35 (26–47)	0.123
Donor sex (female)	30 (34.5)	158 (36.3)	0.838
Donor BMI (kg/m^2)	22.8 (20.7–25.6)	23.3 (21.3–25.3)	0.525
Operation time (min)	588 (495–729)	573 (486–673)	0.144
Cold ischemic time (min)	198 (117–415)	150 (108–270)	0.008
Transfusion of RBC (pack)	10 (5–15)	4 (2–8)	<0.001
Intraoperative CRRT	23 (26.4)	28 (6.4)	<0.001

Values are presented as median (interquartile range) or number (%).
CRGNR-B, carbapenem-resistant gram-negative rod bacteremia; BMI, body mass index; MELD, model for end-stage liver disease; RBC, red blood cell; CRRT, continuous renal replacement therapy.

m^2] vs. 23.3 kg/m^2 [IQR, 21.3–25.3 kg/m^2], p=0.525). Operation times were similar across groups, yet the CRGNR-B group experienced significantly longer cold ischemic times (198 minutes [IQR, 117–415 minutes] vs. 150 minutes [IQR, 108–270 minutes], p=0.008) and required more red blood cell (RBC) transfusion (10 packs [IQR, 5–15 packs] vs. 4 packs [IQR, 2–8 packs], p<0.001).

Preoperative Laboratory Test and Information Before Index POD

As shown in Supplementary Table 1, the CRGNR-B group displayed significantly higher white blood cell, higher neutrophil counts, and lower hemoglobin compared to the control group. Use of immunosuppressants before index POD was similar between groups. Among post-transplant complication, the CRGNR-B group experienced higher bile duct complication before index POD (19.5% vs. 5.3%, p<0.001).

Graft Survival After Index POD

After matched time point (index POD), 1-year patient survival was significantly lower in the CRGNR-B group (50.6%, 39.1%, 37.9%, and 37.9% at 1, 3, 6, and 12 months) than the

controls (97.4%, 94.6%, 92.0%, and 90.0% at 1, 3, 6, and 12 months; p<0.001; Fig. 3). In multivariable Cox regression, CRGNR-B was significantly correlated with LT mortality (adjusted hazard ratio [aHR], 5.66; 95% confidence interval [CI], 3.89–8.24; p<0.001). Other risk factors were age (aHR, 1.02; 95% CI, 1.00–1.04; p=0.017), cardiovascular disease (aHR, 1.83; 95% CI, 1.09–3.08; p=0.022), donor BMI (aHR, 1.05; 95% CI, 1.00–1.10; p=0.039), RBC transfusion (aHR, 1.03; 95% CI, 1.02–1.04; p<0.001; Supplementary Table 2).

Risk Factors for CRGNR-B

In the multivariable logistic regression for risk factors for CRGNR-B (Table 2, Supplementary Table 3), higher pretransplant MELD score was associated with an increased risk of CRGNR-B, with an odds ratio (OR) of 1.05 for each point increase in the MELD score (95% CI, 1.01–1.09; p=0.006). Encephalopathy prior to transplant emerged as a strong independent risk factor, with an OR of 2.79 (95% CI, 1.48–5.30; p=0.002). Retransplantation also presented a markedly elevated risk, with an OR of 10.4 (95% CI, 2.79–42.1; p<0.001). Additionally, for each 60-minute increase in cold ischemic time, there was a 20% increase in the risk of CRGNR-B (OR, 1.20; 95% CI, 1.01–1.42; p=0.037). Notably, bile duct complication was strongly associated with an increased risk of CRGNR-B, showing an OR of 6.16 (95% CI, 2.66–14.2; p<0.001).

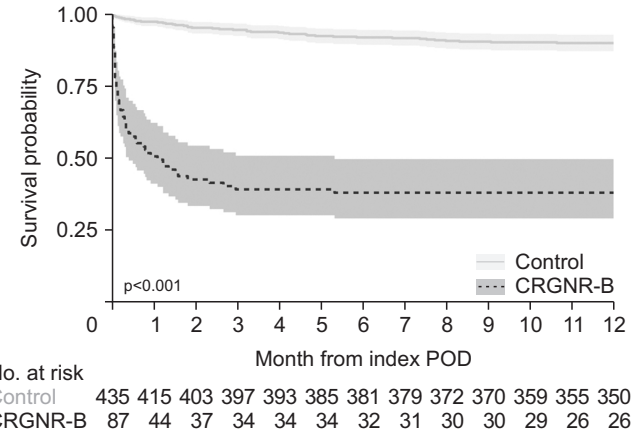

Fig. 3. Kaplan-Meier curves for graft survival after index date. CRGNR-B, carbapenem-resistant gram-negative rod bacteremia; POD, postoperative day.

DISCUSSION

According to the current study, the cumulative incidence of CRGNR-B within 90 days following LT was 6.5%. Even after controlling for other variables, the death rate for LT patients with CRGNR-B was noticeably greater than that of individuals without the condition. During the early post-transplant period following LT, higher pretransplant MELD, encephalopathy, retransplantation, prolonged cold ischemia time, and bile duct complications emerged as major risk factors for CRGNR-B.

The impact of CRGNR-B on LT recipient outcomes cannot be overstated, with our study highlighting a significant correlation between CRGNR-B occurrence and reduced patient survival. This association underlines the critical need for early detection and aggressive management strategies for CRGNR-B to ameliorate its detrimental effects on post-LT survival [14]. It reinforces the importance of vigilant

Table 2. Risk factors for carbapenem-resistant gram-negative rod bacteremia

Variable	Univariable[a]		Multivariable[b]	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Hepatocellular carcinoma	0.64 (0.40–1.03)	0.067	1.79 (0.88–3.73)	0.113
Pretransplant MELD	1.07 (1.05–1.09)	<0.001	1.05 (1.01–1.09)	0.006
Encephalopathy	3.20 (2.00–5.14)	<0.001	2.79 (1.48–5.30)	0.002
Retransplantation	12.45 (4.40–40.44)	<0.001	10.4 (2.79–42.1)	<0.001
Deceased donor	1.99 (1.24–3.19)	0.004	0.36 (0.10–1.29)	0.121
Operation time (per 60 min)	1.08 (1.00–1.17)	0.056	1.12 (0.99–1.26)	0.069
Cold ischemic time (per 60 min)	1.15 (1.07–1.25)	0.001	1.20 (1.01–1.42)	0.037
Intraoperative CRRT	5.22 (2.82–9.63)	<0.001	1.93 (0.83–4.49)	0.124
Bile duct complication	4.35 (2.19–8.53)	<0.001	6.16 (2.66–14.2)	<0.001

OR, odds ratio; CI, confidence interval; MELD, model for end-stage liver disease; CRRT, continuous renal replacement therapy.
[a]Full results for univariable logistic regression are provided in Supplementary Table 3. [b]Model was established by backward step-wise method entering covariates of which p<0.10 in univariable models.

https://doi.org/10.52604/alt.24.0004

monitoring and potentially the development of targeted prophylactic measures for high-risk patients.

Our analysis showed several risk factors for CRGNR-B development, including high MELD scores and prior encephalopathy, aligning with the existing literature that identifies these as markers of increased infection risk, as shown in prior literature [10]. Notably, our study adds to the growing body of evidence that prolonged cold ischemic times and bile duct complications significantly elevate CRGNR-B risk. Cold ischemic time was reported as independent risk factor by Freire et al. [15] highlighting the importance of reducing ischemic time during surgery. Association between bile duct complication and CRGNR-B was novel finding of our study. This might be derived from transmission of pathogens during procedures to treat biliary complications [16]. Our findings suggest that through optimized surgical and postoperative management may be key strategies in reducing CRGNR-B incidence.

Given extremely higher mortality from CRGNR-B after LT, treatment strategy has been widely discussed in lieterature. Doi [17] discussed the antimicrobial resistance threat posed by CRGNR and reviewed several first-line agents used for treatment, including colistin and tigecycline. The study also introduced new agents such as ceftazidime-avibactam, meropenem-vaborbactam, and cefiderocol, which have shown promising results against certain carbapenem-resistant pathogens. In the recent randomized trial, cefiderocol emerged as potential treatment option in addition to previous available therapy [18]. Future directions for treating CRGNR-B would be personalized medicine approaches, informed by genetic and microbial profiling, may offer new avenues for optimizing infection management in LT recipients.

This study consistently demonstrated the incidence, mortality, and risk variables for CRGNR-B within 90 days following LT, despite the limitations of the retrospective, single-centric design. During the first year following LT, CRGNR-B exhibited a considerably greater death rate than controls. The probability of CRGNR-B in LT recipients was elevated by pretransplant MELD, severe encephalopathy, prolonged cold ischemia time, and post-LT biliary problem. Clinicians should concentrate on prophylaxis, early identification, and appropriate therapy for CRGNR-B as soon as LT, while also being cognizant of risk factors.

SUPPLEMENTARY MATERIAL

Supplementary data related to this article can be found online at https://doi.org/10.52604/alt.24.0004.

FUNDING

There was no funding related to this study.

CONFLICT OF INTEREST

All authors have no conflicts of interest to declare.

ORCID

Eun-Ki Min	https://orcid.org/0000-0003-3255-1942
Deok-Gie Kim	https://orcid.org/0000-0001-9653-926X
Minyu Kang	https://orcid.org/0000-0002-6623-2774
Hwa-Hee Koh	https://orcid.org/0000-0001-5944-6136
Jae Geun Lee	https://orcid.org/0000-0002-6722-0257
Dong Jin Joo	https://orcid.org/0000-0001-8405-1531
Myoung Soo Kim	https://orcid.org/0000-0002-8975-8381

AUTHORS' CONTRIBUTIONS

Conceptualization: EKM, DGK. Data curation: EKM, DGK. Formal analysis: EKM, DGK. Investigation: DGK, MK, HHK, JGL, DJJ, MSK. Methodology: EKM, DGK. Project administration: DGK. Resources: DGK. Software: DGK. Supervision: DGK. Validation: DGK. Visualization: DGK. Writing – original draft: EKM, DGK. Writing – review & editing: DGK.

REFERENCES

1. Adam R, Karam V, Delvart V, O'Grady J, Mirza D, Klempnauer J, et al. Evolution of indications and results of liver transplantation in Europe. A report from the European Liver Transplant Registry (ELTR). J Hepatol 2012;57:675-688.
2. Zhang J, He Q, Du L, Ji R, Yuan L, Zhang H, et al. Risk factor for lung infection in recipients after liver transplantation: a meta-analysis. Artif Organs 2021;45:289-296.
3. Kim SI. Bacterial infection after liver transplantation. World J Gastroenterol 2014;20:6211-6220.
4. Krell RW, Kaul DR, Martin AR, Englesbe MJ, Sonnenday CJ, Cai S, et al. Association between sarcopenia and the risk of serious infection among adults undergoing liver transplantation. Liver Transpl 2013;19:1396-1402.
5. Gelson W, Hoare M, Dawwas MF, Vowler S, Gibbs P, Alexander G. The pattern of late mortality in liver transplant recipients in the United Kingdom. Transplantation 2011;91:1240-1244.
6. Neuberger JM, Bechstein WO, Kuypers DR, Burra P, Citterio F,

De Geest S, et al. Practical recommendations for long-term management of modifiable risks in kidney and liver transplant recipients: a guidance report and clinical checklist by the Consensus on Managing Modifiable Risk in Transplantation (COMMIT) group. Transplantation 2017;101(4S Suppl 2):S1-S56.
7. Ye QF, Zhao J, Wan QQ, Qiao BB, Zhou JD. Frequency and clinical outcomes of ESKAPE bacteremia in solid organ transplantation and the risk factors for mortality. Transpl Infect Dis 2014;16:767-774.
8. Bodro M, Sabé N, Tubau F, Lladó L, Baliellas C, Roca J, et al. Risk factors and outcomes of bacteremia caused by drug-resistant ESKAPE pathogens in solid-organ transplant recipients. Transplantation 2013;96:843-849.
9. Zhong L, Men TY, Li H, Peng ZH, Gu Y, Ding X, et al. Multidrug-resistant gram-negative bacterial infections after liver transplantation - spectrum and risk factors. J Infect 2012;64:299-310.
10. Martin-Mateos R, Martínez-Arenas L, Carvalho-Gomes Á, Aceituno L, Cadahía V, Salcedo MM, et al. Multidrug-resistant bacterial infections after liver transplantation: prevalence, impact, and risk factors. J Hepatol 2024. https://doi.org/10.1016/j.jhep.2024.02.023 [Epub ahead of print]
11. Gao S, Huang X, Zhou X, Dai X, Han J, Chen Y, et al. A comprehensive evaluation of risk factors for mortality, infection and colonization associated with CRGNB in adult solid organ transplant recipients: a systematic review and meta-analysis. Ann Med 2024;56:2314236.
12. Freire MP, Oshiro IC, Pierrotti LC, Bonazzi PR, de Oliveira LM, Song AT, et al. Carbapenem-resistant Enterobacteriaceae acquired before liver transplantation: impact on recipient outcomes. Transplantation 2017;101:811-820.
13. Min EK, Yim SH, Choi MC, Lee JG, Joo DJ, Kim MS, et al. Incidence, mortality, and risk factors associated with carbapenem-resistant Acinetobacter baumannii bacteremia within 30 days after liver transplantation. Clin Transplant 2023;37:e14956.
14. Clancy CJ, Chen L, Shields RK, Zhao Y, Cheng S, Chavda KD, et al. Epidemiology and molecular characterization of bacteremia due to carbapenem-resistant Klebsiella pneumoniae in transplant recipients. Am J Transplant 2013;13:2619-2633.
15. Freire MP, Pierrotti LC, Oshiro IC, Bonazzi PR, Oliveira LM, Machado AS, et al. Carbapenem-resistant Acinetobacter baumannii acquired before liver transplantation: impact on recipient outcomes. Liver Transpl 2016;22:615-626.
16. Smith ZL, Oh YS, Saeian K, Edmiston CE Jr, Khan AH, Massey BT, et al. Transmission of carbapenem-resistant Enterobacteriaceae during ERCP: time to revisit the current reprocessing guidelines. Gastrointest Endosc 2015;81:1041-1045.
17. Doi Y. Treatment options for carbapenem-resistant gram-negative bacterial infections. Clin Infect Dis 2019;69(Suppl 7):S565-S575.
18. Bassetti M, Echols R, Matsunaga Y, Ariyasu M, Doi Y, Ferrer R, et al. Efficacy and safety of cefiderocol or best available therapy for the treatment of serious infections caused by carbapenem-resistant Gram-negative bacteria (CREDIBLE-CR): a randomised, open-label, multicentre, pathogen-focused, descriptive, phase 3 trial. Lancet Infect Dis 2021;21:226-240.

https://doi.org/10.52604/alt.24.0004