Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

The Utilization of Vasopressor Infusions During Pediatric Liver Transplantation and Association with Post-operative Outcomes: A Retrospective Cohort Study

Jordan Moraczewski
Lurie Children's Hospital
Ashley Bartels
Emory University School of Medicine
Katie Liu
Emory University School of Medicine
Matthew A. Goldstein
matthew.goldstein2@nyulangone.org
New York University Grossman School of Medicine
Pradip P. Kamat
Emory University School of Medicine
Laura E. Gilbertson
Emory University School of Medicine
Joelle Karlik
Emory University School of Medicine

Research Article

Keywords: Pediatric liver transplant, Pediatric anesthesia, Vasopressor, Re-do transplantation

Posted Date: November 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11544182/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

The Utilization of Vasopressor Infusions During Pediatric Liver Transplantation and Association with Post-operative Outcomes: A Retrospective Cohort Study

Running title: Vasopressor Infusions During Pediatric Liver Transplant and Associations with Post-Operative Outcomes

Article type: Original Article

Jordan Moraczewski[1], Ashley Bartels[2], Katie Liu[3], Matthew A. Goldstein[4], Pradip P. Kamat[5], Laura E. Gilbertson[2], Joelle Karlik[2*]

[1]Department of Anesthesiology, Lurie Children's Hospital, Chicago, IL, USA

[2]Division of Pediatric Anesthesiology, Department of Anesthesiology, Children's Healthcare of Atlanta, Emory University School of Medicine, Atlanta, GA, USA

[3]Pediatric Biostatistics Core, Department of Pediatrics, Children's Healthcare of Atlanta, Emory University School of Medicine, Atlanta, GA, USA

[4]Department of Pediatrics, Division of Pediatric Critical Care Medicine, New York University Grossman School of Medicine, New York, NY, USA

[5]Department of Pediatrics, Children's Healthcare of Atlanta, Emory University School of Medicine, Atlanta, GA, USA

Author degrees: Jordan Moraczewski, MD; Ashley Bartels, MD; Katie Liu, MSPH; Matthew A. Goldstein, DO; Pradip P. Kamat, MD; Laura E. Gilbertson, MD; Joelle Karlik, MD

*Corresponding author: Matthew A. Goldstein, DO, Department of Pediatrics, Division of Pediatric Critical Care Medicine, New York University Grossman School of Medicine, 424 East 34th Street, New York, NY 10016, USA. Email: Matthew.goldstein2@nyulangone.org

ORCID iDs:

Jordan Moraczewski:

Ashley Bartels:

Katie Liu:

Matthew A. Goldstein: 0000-0002-1483-8950

Pradip P. Kamat: 0000-0002-9633-0973

Laura E. Gilbertson: 0000-0001-5501-8943

Joelle Karlik: 0000-0002-6625-069X

Acknowledgements: None.

Assistance with the study: None.

Previous presentation: Preliminary data were presented as a poster at the Society for Pediatric Anesthesia meeting, 2024.

Permissions: None.

Word counts: Abstract, 250 words; main text (Introduction to Discussion), 2,621 words; Tables, 6; Figures, 0; References, 24

Abstract

Purpose: Pediatric patients undergoing liver transplantation frequently require vasopressor infusions. In this retrospective study, we aimed to evaluate intraoperative vasopressor utilization and its association with postoperative outcomes.

Methods: All patients who underwent a liver transplant at Children's Healthcare of Atlanta from 2014 to 2021 were evaluated. Associations between vasopressor use and postoperative outcomes were examined using Firth logistic regression for binary outcomes and gamma generalized linear models.

Results: A total of 173 patients were analyzed, with 136 patients (78.6%) meeting criteria for the vasopressor infusion group. 36% of patients received one vasopressor infusion, 32% received two vasopressor infusions, 10% received 3 vasopressor infusions, and 0.6% received 4 vasopressor infusions. Baseline patient characteristics were similar between groups except for age, pre-transplant location, and baseline INR. The no vasopressor infusion group was noted to have a significantly shorter length of stay and higher rates of immediate post-operative extubation. Outcomes for re-exploration, immediate re-transplantation, postoperative infection, and mortality were similar. No association was found between the number of different vasopressors used and adverse post-operative outcomes. Therefore, once a patient received at least 1 vasopressor, the difference between using 1 and multiple infusions had no association on LOS or graft dysfunction.

Conclusion: Utilizing a vasopressor infusion is associated with increased length of stay and longer duration of mechanical ventilation in pediatric liver transplantation. However, no association was found between vasopressor infusion use and re-exploration, immediate re-

transplantation, postoperative infection, and mortality. The number of distinct vasopressors used does not appear to have cumulative detrimental effects.

Keywords: Pediatric liver transplant · Pediatric anesthesia · Vasopressor · Re-do transplantation

What is Known:

- Vasopressor infusions are frequently required during pediatric liver transplantation, but their association with postoperative outcomes is unclear.

What is New:

- Intraoperative vasopressor infusion was associated with increased length of stay and mechanical ventilation days but not with re-exploration, re-transplantation, infection, or mortality.
- Using more than one vasopressor infusion was not associated with worse outcomes than using a single infusion.

List of Abbreviations

AKI	Acute kidney injury
CI	Confidence interval
ESLD	End-stage liver disease
ICU	Intensive care unit
INR	International normalized ratio
IQR	Interquartile range
IRB	Institutional Review Board
LOS	Length of stay

MELD Model for End-Stage Liver Disease

OR Odds ratio

PELD Pediatric End-Stage Liver Disease

PICU Pediatric intensive care unit

PRS Post-reperfusion syndrome

SD Standard deviation

VIF Variance inflation factor

Introduction

Pediatric patients undergoing liver transplantation frequently require vasopressor infusions intraoperatively to temporarily mitigate hypotension [1, 2]. The hypotension that develops during liver transplantation is induced by both surgical and physiologic changes related to the state of end-stage liver disease (ESLD) [3]. During the anhepatic phase, hypotension is preferentially treated with vasopressors instead of intravenous fluids to avoid right ventricular dysfunction, volume overload, and graft over-congestion [4]. Vasopressors may also be used to temporize during periods of massive blood loss, post-reperfusion arrhythmias, and post-reperfusion syndrome (PRS). However, prolonged vasopressor use is not without risk and can affect end-organ and graft perfusion as well as vasospasm of implanted vessels. There are a variety of vasopressor agents that can be administered during liver transplantation. Norepinephrine, epinephrine, dopamine, phenylephrine, vasopressin, and methylene blue dye have all been used to treat hypotension and vasoplegia during pediatric liver transplantation [4].

While vasopressors may have a detrimental effect, there is limited data on the association between post-operative outcomes and the utilization of intraoperative vasopressor infusions [5–7]. In an analysis of over 4000 pediatric liver transplants, vasopressor use was not found to be a significant variable that affected patient or post-transplant graft loss [8]. Certain vasopressors have been investigated to measure effects on specific post-operative outcomes, but findings have not been clear [9–11]. Examined specific outcomes include acute kidney injury (AKI) [12], bleeding [13], biliary complications [14], and graft failure [14]. A recent systematic review concluded that vasopressors had no significant effect on post-operative outcomes including AKI [15].

Many pediatric practices prefer norepinephrine as the first-line vasopressor of choice for pediatric liver transplantation [16, 17]. Despite norepinephrine often being selected as a first-line vasopressor, a study in 2020 demonstrated a 169% increase in probability of mortality in living donor pediatric liver transplantation when comparing patients who required norepinephrine infusion versus those who did not [10]. In addition, a meta-analysis found that norepinephrine may be associated with a higher rate of blood loss when compared to phenylephrine and terlipressin [15]. However, there is an overall paucity of evidence regarding comparisons between different types of vasopressor infusions and patient outcomes. Furthermore, there is scarce literature regarding the use of multiple vasopressor infusions for a single patient during pediatric liver transplantation and the association with post-operative graft function and mortality.

To address this, we conducted a retrospective cohort study comparing pediatric liver transplant recipients who received at least one intra-operative vasopressor infusion with those who received none. We hypothesized that perioperative vasopressors result in untoward postoperative outcomes such as increased length of stay (LOS), infection, and graft dysfunction in pediatric patients undergoing liver transplantation. We secondarily aimed to evaluate the association between different vasopressor agents and outcomes to discern if there was a significant difference based on type of infusion or number of infusions utilized.

Materials and methods

The investigation was approved by the Children's Healthcare of Atlanta Institutional Review Board (STUDY00001442). Procedures were followed in accordance with the ethical standards of our IRB, the Helsinki Declaration of 2013, and the Istanbul Declaration of 2018.

The requirement for written informed consent was waived. The authors identified all patients who underwent a liver transplant at our institution from January 1, 2014 to June 1, 2021.

Demographic data including weight, age, and sex were obtained. In addition, MELD (Model for End-stage Liver Disease) classification/PELD (Pediatric End-Stage Liver Disease) score, graft type (whole-organ or split-organ), diagnosis for transplantation (biliary atresia, hepatoblastoma, acute liver failure, autoimmune hepatitis or other), combined organ transplantation status (liver transplant or combined liver/kidney transplant), pre-operative transplant location (home, pediatric intensive care unit (PICU), or floor bed), and pre-operative International Normalized Ratio (INR) were reviewed.

The intraoperative data that was obtained included: duration of surgery, duration of anesthesia, intraoperative use of a vasopressor infusion for a minimal duration of 15 consecutive minutes, anhepatic time, type of abdominal closure (primary or temporary), last pH on arterial blood gas prior to transfer, and extubation status in the operating room. The amount of intravenous crystalloids (including sodium chloride, lactated ringers, and plasmalyte) and blood products received intraoperatively was also gathered.

The postoperative data that was collected included: rates of postoperative infection, re-exploration, and immediate re-transplantation. Postoperative infection was defined as infection requiring additional antibiotic coverage and/or fever of unknown origin. Re-exploration was defined as any patient who required a subsequent surgical procedure during the hospitalization to evaluate for arterial or venous thrombosis, decreased arterial or venous flow, elevated liver enzymes, or other concerning symptoms. Immediate re-transplantation was defined as graft failure with re-transplantation within one week of the initial transplantation. Additionally, PICU LOS, hospital LOS, and mortality data was obtained.

We compared liver transplant patients based on whether they required the use of an intraoperative vasopressor infusion for a minimal duration of 15 consecutive minutes (defined as "vasopressor infusion group") versus those who did not. As this was a retrospective review, there was no specific protocol used to decide if a patient would require a vasopressor infusion. However, multidisciplinary care among the surgeon and anesthesiologist is an essential component for all transplant surgeries at our institution.

Descriptive statistics were used to summarize patient demographic characteristics, intraoperative factors, and postoperative outcomes. For continuous variables, medians with interquartile ranges (IQRs) or means with standard deviations (SDs) were reported, as appropriate. For categorical variables, frequencies with percentages were reported. To compare patients who received vasopressor infusion during liver transplant to those who did not, hypothesis tests were conducted. Normally distributed continuous variables were assessed using unpaired two-sample t-test, while Wilcoxon rank-sum test was utilized for nonparametric variables. Pearson's Chi-square test or Fisher's exact test was utilized to compare categorical variables. We compared intraoperative and postoperative data with the same approach.

To assess the relationship between vasopressor infusion requirement and post-operative outcomes of re-transplantation, re-exploration, or postoperative infection, Firth logistic regression was performed due to the limited number of events in each outcome. Multivariable models for re-transplantation and postoperative infection were adjusted for age at transplantation, pre-transplant location, total blood products received during transplantation, and abdominal closure. A multivariable model for immediate re-transplantation was not performed due to limited number of events (n=8).

To evaluate the association between vasopressor infusion requirement and PICU LOS or hospital LOS, generalized linear regression models with a gamma distribution were performed to account for the right-skew distributions of LOS variables, as most patients had 0-5 days in the PICU and 0-10 days in the hospital. Both univariable and multivariable models were fitted, with the same covariates adjusted for in the multivariable models described above.

Among patients who received vasopressor infusion, we further examined the association between 1) number of vasopressor infusion administered, and 2) the type(s) of vasopressors used, with all five postoperative outcomes (re-transplantation, re-exploration, postoperative infection, PICU LOS, Hospital LOS), using the same modeling approach. As patients can receive any combination of vasopressor infusions, multivariable models included all four types of agents (epinephrine, norepinephrine, dopamine, and vasopressin) as independent variables. Variance inflation factors (VIFs) were calculated to assess collinearity among the different vasopressor agents used. An alpha level of 0.05 was used to determine statistical significance for all p-values. All analyses were performed using R (version 4.4.2) via RStudio.

Results

A total of 173 patients were analyzed, with 136 patients (78.6%) meeting criteria for the vasopressor infusion group. 36% of patients received one vasopressor infusion, 32% received two vasopressor infusions, 10% received 3 vasopressor infusions, and 0.6% received 4 vasopressor infusions. Epinephrine was the most common vasopressor infusion used. Compared to those without vasopressor infusion (median age at transplant [IQR]: 5 [2, 12] years), those who received vasopressor were significantly younger (median [IQR]: 2 [0.5, 10.3] years, p = 0.046; Table 1). Pre-op INR was significantly higher in the vasopressor group (median [IQR]:

1.4 [1.2, 1.8] vs 1.2 [1.1, 1.4], p=0.033). Not surprisingly, another notable difference in baseline characteristics between the two groups was pre-transplant location, with the no vasopressor group having a significantly increased proportion of patients presenting from home (92% vs. 57% respectively, $p < 0.001$).

Intraoperatively, there was a significant increase in the rate of immediate extubation between the no vasopressor infusion group and the vasopressor infusion group (89% vs. 65%, $p = 0.004$; Table 2). There was also a significant increase in the rate of primary abdominal closure in the no vasopressor group when compared to the vasopressor group (89% versus 63%, $p = 0.003$). The duration of surgery, duration of anesthesia, amount of crystalloid received, anhepatic time, and pH prior to end of surgery were similar between the two groups.

There was a significant decrease in PICU LOS between the no vasopressor infusion group and the vasopressor infusion group (median [IQR]: 3 days [2, 4] vs. 4 days [3, 7.3] respectively, $p < 0.001$) and hospital LOS (median [IQR]: 10 days [8, 12] vs. 14 days [10, 21], $p < 0.001$) (Table 3).

The utilization of vasopressor infusion was not significantly associated with re-exploration, immediate re-transplantation, or post-operative infection (Table 4). Similarly, in multivariable logistic regression models which adjusted for age, pre-transplant location, total blood product administration and abdominal closure, those receiving a vasopressor infusion were not associated with an increased incidence of re-exploration or post-operative infection. Interestingly, older age at transplant was associated with lower odds of post-operative infection (OR 0.87), while failure to extubate in operating room was associated with higher odds of post-operative infection (OR 3.46).

Using generalized linear regression with a gamma distribution, the use of vasopressor was significantly associated with a 123% increase in PICU LOS ($p<0.001$) and a 62% increase in hospital LOS ($p < 0.001$) (Table 4). Notably, older patients had significantly shorter PICU LOS while pre-transplant ICU admission was associated with increased PICU LOS and extubation failure in the operating room (OR 1.57). Hospital LOS was noted to be associated with younger age as well as need to remain intubated postoperatively.

In patients who received a vasopressor infusion (n=136), there was no significant association between number of vasopressor infusion (one, two, three, or four) and re-exploration, re-transplantation, post-operative infection, PICU LOS, or hospital LOS (Table 5). Similar findings were found in multivariable models.

Analysis by the type of vasopressor infusion used showed that epinephrine, norepinephrine, dopamine, and vasopressin were not significantly associated with re-exploration, re-transplantation, post-operative infection, PICU LOS, or hospital LOS (Table 6). Similar findings were found in multivariable models that included all four types of vasopressors simultaneously, allowing for all possible combinations of vasopressor used. No collinearity was observed among the type(s) of vasopressor infusion administered.

Discussion

This study demonstrates that not requiring an intraoperative vasopressor infusion during a pediatric liver transplant was associated with improved outcomes, such as higher immediate postoperative extubation rates, primary abdominal closure at time of transplant, and shorter LOS. However, the data shows that the majority of patients (78.7%) required at least one vasopressor infusion intraoperatively, and the use of a vasopressor infusion was not associated with

complications such as graft dysfunction, infection, and postoperative mortality. These findings persisted despite controlling for patient's preoperative location, a variable we found to highly correlate with PELD/MELD scores and signifying patient severity.

With regards to length of stay, our data demonstrated that the vasopressor group had a longer PICU and hospital LOS. Our findings are relatively concordant with a previous study that demonstrated an association between longer ICU and hospital LOS with increased dopamine and vasopressin infusion volume in pediatric liver transplant patients [18]. Given the average LOS of a pediatric liver transplant recipient is 13-19 days, these findings can represent a significant decrease in associated hospitalization costs and resource use as well [18].

Our analysis demonstrated that there was no difference between the vasopressor and no vasopressor group in both univariable and multivariable analysis with regards to rates of adverse post-operative events (re-exploration, immediate re-transplantation, post-operative infection, and post-operative mortality). This finding is consistent with previous studies that have shown that intraoperative vasopressor use is not associated with graft failure after pediatric liver transplantation [15, 19, 20]. In addition, there was no difference in the rates of these adverse postoperative events between any of the vasopressors evaluated in this study (norepinephrine, dopamine, epinephrine, and vasopressin). This finding suggests that despite varying mechanisms of action, any of these four vasopressor infusions may carry the same risk of graft dysfunction as each other.

Interestingly, we found that after initiating one vasopressor infusion, there was no subsequent increase in adverse events when utilizing additional vasopressor infusions. Based off our analysis, the difference between using one or four infusions had no correlation with an increase in adverse outcomes. As our group is very adept at pediatric liver transplantation, we

hypothesize that this may be due to the anesthesiologists' goal of utilizing multiple infusions at relatively lower rates to achieve pharmaceutical synergy through multiple physiologic mechanisms as opposed to maximizing the infusion rate of one vasopressor. A more in-depth look into this finding would be beneficial to better decipher these correlations and guide clinical management.

To better understand the differences between the groups of patients who received vasopressor infusions and those who did not, analysis of the preoperative patient characteristics and intraoperative factors was performed. Evaluating pre-transplant factors, our data demonstrated that the vasopressor group was more likely to have an inpatient pre-transplant location (PICU/floor) compared to the no vasopressor group (Table 1). This finding is intuitive as patients presenting from home are more likely to have a greater degree of physiologic stability and fewer active medical needs compared to patients presenting from an inpatient setting. Another significant finding, lower baseline INR, also supports that the patients who did not receive vasopressors had overall better baseline health status. Also not unexpectedly, we found that younger children, particularly infants, required vasopressors more frequently, likely due to their more delicate physiological balance.

When evaluating intraoperative factors, our data demonstrated that the vasopressor group had higher rates of blood transfusion, were less likely to be extubated in the operating room or have primary abdominal closure compared with the no vasopressor group. This finding supports a previous study that demonstrates that use of vasopressor infusions is associated with lower rates of immediate extubation after pediatric liver transplant [21]. Moreover, usual criteria for extubation often involves hemodynamic stability with minimal or no vasopressor support [22].

303 At our institution, a temporarily closed abdomen does not exclude immediate post-operative
304 extubation, but this practice may differ between institutions.

305 Due to this study being retrospective in design, there are limitations in interpreting its
306 data. The decision to initiate a single or multiple vasopressors remained a subjective clinical
307 decision in this study population. Although multivariable analyses were performed for the
308 generalized linear/logistic regression models in an attempt to control for confounding variables,
309 there are likely other components that were not accounted for. The patient population described
310 in this study is from one institution and so our findings external validity may be limited.
311 Fortunately, our patient population had a very low rate of complications (8 re-transplantations, 4
312 mortality) which also limited data analysis.

313 In addition to vasopressors, prolonged hypotension and PRS have been associated with
314 adverse post-operative outcomes including renal dysfunction, early allograft dysfunction,
315 primary nonfunction, and increased LOS [23, 24]. Further research should focus on the clarifying
316 between injury from hypotension versus vasopressors and what specific mechanisms of injury
317 are specific to PRS.

318 Overall, our data demonstrates that a majority of pediatric liver transplant patients receive
319 vasopressor infusions intraoperatively. Patients who receive a vasopressor infusion
320 intraoperatively have a longer hospital LOS but are not at increased risk for adverse post-
321 operative events (re-exploration, immediate re-transplantation, post-operative infection, and
322 post-operative mortality). The use of one vasopressor infusion confers the same risk of adverse
323 post-operative events as more than one vasopressor infusion. Given these findings, we endeavor
324 to continue more in-depth research to develop specific intraoperative vasopressor protocols and
325 blood pressure goals for pediatric liver transplantation.

326

327

References

1. Goldstein M, Jergel A, Karpen S, et al (2024) Trends in sedation-analgesia practices in pediatric liver transplant patients admitted postoperatively to the pediatric intensive care unit: an analysis of data from the Pediatric Health Information System (PHIS) database. Pediatr Transplant 28(1):e14660
2. Çekmen N, Uslu A. (2024) Anesthesia management for pediatric liver transplantation: narrative review. Transl Perioper Pain Med; 11(1):574–591
3. Coelho ADR, da Luz RO, Basto TS, et al (2023) Prolonged anhepatic state as a bridge to retransplantation: a challenging case of a 35-year-old male liver transplant patient with a temporary portacaval shunt. Am J Case Rep 24: e941933.
4. Ballard HA, Jones E, Malavazzi Clemente MM, Damian D, Kovatsis PG (2022) Educational review: error traps in anesthesia for pediatric liver transplantation. Paediatr Anaesth 32(12):1285–1291
5. Alnagar A, Bessa S, Karam M, Shawky A, Attia M (2021) Outcomes of pediatrics liver transplantation: comparison between cadaveric and live donor grafts. Egypt J Surg 40(4):1125–1136
6. Thongprayoon C, Kaewput W, Thamcharoen N, et al (2019) Incidence and impact of acute kidney injury after liver transplantation: a meta-analysis. J Clin Med 8(3):372
7. Karapanagiotou A, Dimitriadis C, Papadopoulos S, et al (2014) Comparison of RIFLE and AKIN criteria in the evaluation of the frequency of acute kidney injury in post-liver transplantation patients. Transplant Proc 46(9):3222–3227
8. McDiarmid SV, Anand R, Martz K, Millis MJ, Mazariegos G (2011) A multivariate analysis of pre-, peri-, and post-transplant factors affecting outcome after pediatric liver

transplantation. Ann Surg 254(1):145–154. https://doi.org/10.1097/SLA.0b013e31821ad86a

9. Reddy SM, Kaliamoorthy I, Rajakumar A, et al (2017) Double-blind randomized controlled trial of the routine perioperative use of terlipressin in adult living donor liver transplantation. Liver Transpl 23(8):1007–1014

10. Chen LJ, Chen YL, Qi B, et al (2020) Impact of intraoperative norepinephrine support on living donor liver transplantation outcomes: a retrospective cohort study of 430 children. Front Pharmacol 11:1254

11. Vitin AA, Martay K, Vater Y, Dembo G, Maziarz M (2010) Effects of vasoactive agents on blood loss and transfusion requirements during pre-reperfusion stages of the orthotopic liver transplantation. J Anesth Clin Res 1:104

12. Kulkarni AV, Kumar K, Candia R, Arab JP, Tevethia HV, Premkumar M, Sharma M, Menon B, Rao GV, Reddy ND, et al (2022) Prophylactic perioperative terlipressin therapy for preventing acute kidney injury in living donor liver transplant recipients: a systematic review and meta-analysis. J Clin Exp Hepatol 12(2):417–427. https://doi.org/10.1016/j.jceh.2021.06.019

13. Hong SH, Park CS, Jung HS, Choi H, Lee SR, Lee J, Choi JH (2012) A comparison of intra-operative blood loss and acid-base balance between vasopressor and inotrope strategy during living donor liver transplantation: a randomised, controlled study. Anaesthesia 67(10):1091–1100. https://doi.org/10.1111/j.1365-2044.2012.07198.x

14. Larivière J, Giard JM, Zuo RM, Massicotte L, Chassé M, Carrier FM (2021) Association between intraoperative fluid balance, vasopressors and graft complications in liver

transplantation: a cohort study. PLoS One 16(7):e0254455. https://doi.org/10.1371/journal.pone.0254455

15. Carrier FM, Girard M, Zuo RM, Ziegler D, Trottier H, Chassé M (2024) Intraoperative vasoactive medications and perioperative outcomes in liver transplantation: a systematic review and network meta-analyses. Transplantation 108(4):854–873. https://doi.org/10.1097/TP.0000000000004744

16. Liu W, Dai X, Guo H, You C, Du M, Li Q (2024) Acute kidney injury after living-related liver transplantation in infants with biliary atresia: a retrospective study. Pediatr Discov 2(2):e37

17. Efune NP, Hoyt JM, Saynhalath R, et al (2023) Intraoperative fluid administration volumes during pediatric liver transplantation and postoperative outcomes: a multicenter analysis. Paediatr Anaesth 33(9):754–764

18. Covarrubias K, Luo X, Massie A, et al (2020) Determinants of length of stay after pediatric liver transplantation. Pediatr Transplant 24(4):e13702

19. Jung S, Park K, Ihn K, et al (2022) Predicting graft failure in pediatric liver transplantation based on early biomarkers using machine learning models. Sci Rep 12(1):22411

20. Rogers EM, Delman A, Campbell K, et al (2022) Children undergoing early liver re-transplantation for primary non-function have improved survival. Pediatr Transplant 26(7):e14347

21. Goldstein AM, Karlik J, Kamat PP, et al (2024) Utilization of immediate extubation in a multidisciplinary pathway for pediatric liver transplantation associated with improved postoperative outcomes. Pediatr Transplant 28(3):e14722

22. Ibrahim GD, Zaki GF, Aboseif EM, Elfawy DM, Abdou AM (2022) Predictors of success of immediate tracheal extubation in living donor liver transplantation recipients. Braz J Anesthesiol 72(2):274–279

23. Caragata R, Emerson S, Santema ML, Selzner N, Sapisochin G, Wang S, Huszti E, Van Klei W, McCluskey SA (2023) Intraoperative hypotension and the risk of acute kidney injury following liver transplantation. Clin Transplant 37(10):e15053. https://doi.org/10.1111/ctr.15053

24. Zhang L, Tian M, Xue F, Zhu Z (2018) Diagnosis, incidence, predictors and management of postreperfusion syndrome in pediatric deceased donor liver transplantation: a single-center study. Ann Transplant 23:334–344. https://doi.org/10.12659/AOT.909050

Statements and Declarations

Funding: No funding was received for conducting this study.

Competing interests: The authors have no relevant financial or non-financial interests to disclose.

Author contributions: JM and JK conceived and designed the study. JM, AB, and LEG collected the data. KL performed the statistical analysis. JM, MAG, PPK, LEG and JK drafted and critically revised the manuscript. All authors read and approved the final manuscript.

Ethics approval: This retrospective study was approved by the Children's Healthcare of Atlanta Institutional Review Board (STUDY00001442). Procedures were performed in accordance with the ethical standards of the institutional research committee, the 1964 Declaration of Helsinki and its later amendments (2013), and the Declaration of Istanbul (2018).

Consent to participate: The requirement for written informed consent was waived by the Children's Healthcare of Atlanta Institutional Review Board owing to the retrospective design of the study.

Consent to publish: Not applicable; no individual identifiable data are reported.

Data availability: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Table 1. Pediatric Liver Transplantation Patient Baseline Characteristics Comparison by Utilization of Vasopressor Infusion

Characteristic	**Overall**, N = 173	**Vasopressor Infusion**, N = 136[b]	**No Vasopressor Infusion**, N = 37	**p-value**[a]
Weight (kg), Median (IQR)	14.4 (8.1, 40.6)	12.7 (7.7, 37.9)	17.8 (12.8, 52.8)	0.050
Sex, n (%)				0.074
Female	85 (49%)	62 (46%)	23 (62%)	
Male	88 (51%)	74 (54%)	14 (38%)	
Age at transplant (Years), Median (IQR)	3.0 (0.8, 11.0)	2.0 (0.6, 10.3)	5.0 (2.0, 12.0)	**0.046**
Diagnosis, n (%)				0.554
Acute Liver Failure	17 (9.8%)	15 (11%)	2 (5.4%)	
Autoimmune Hepatitis	10 (5.8%)	9 (6.6%)	1 (2.7%)	
Biliary Atresia	68 (39%)	55 (40%)	13 (35%)	
Hepatoblastoma	7 (4.0%)	5 (3.7%)	2 (5.4%)	
Other	71 (41%)	52 (38%)	19 (51%)	
PELD/MELD, n (%)				0.332
Status 1A	22 (13%)	20 (15%)	2 (5.4%)	
Status 1B	21 (12%)	15 (11%)	6 (16%)	
≥25	80 (46%)	64 (47%)	16 (43%)	
<25	50 (29%)	37 (27%)	13 (35%)	
Graft Type, n (%)				0.054
Split	27 (16%)	25 (18%)	2 (5.4%)	
Whole	146 (84%)	111 (82%)	35 (95%)	
Combined Liver/Kidney, n (%)				0.290
Yes	5 (2.9%)	3 (2.2%)	2 (5.4%)	
No	168 (97%)	133 (98%)	35 (95%)	
Pre-treatment Location, n (%)				**<0.001**
Floor	29 (17%)	29 (21%)	0 (0%)	
Home	112 (65%)	78 (57%)	34 (92%)	
ICU	32 (18%)	29 (21%)	3 (8.1%)	
Pre-op INR, Median (IQR)	1.4 (1.1, 1.8)	1.4 (1.2, 1.8)	1.2 (1.1, 1.4)	**0.033**

IQR = Interquartile Range; 25th and 75th percentiles, respectively

[a]Wilcoxon rank sum test for continuous variables; Pearson's Chi-squared test or Fisher's exact test for categorical variables

[b]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes

Table 2. Pediatric Liver Transplantation Patient Intra-Operative Factors Comparison by Utilization of Vasopressor Infusion

Characteristic	**Overall**, N = 173	**Vasopressor Infusion**, N = 136[b]	**No Vasopressor Infusion**, N = 37	**p-value**[a]
Surgery Duration (Mins), Median (IQR)	331 (293, 389)	334 (293, 404)	323 (294, 371)	0.362
Anesthesia Duration (Mins), Median (IQR)	484 (435, 547)	477 (433, 565)	498 (467, 533)	0.750
Anhepatic Time (Mins), Median (IQR)	57 (51, 64)	57 (51, 64)	55 (51, 62)	0.372
Total Blood Products (ml/kg), Median (IQR)	18 (0, 38)	19 (9, 45)	0 (0, 18)	**<0.001**
Total Crystalloids (mL/kg), Median (IQR)	31 (17, 58)	31 (15, 56)	43 (26, 68)	0.055
Last pH Prior to End of Surgery, Median (IQR)	7.36 (7.32, 7.40)	7.36 (7.32, 7.40)	7.36 (7.34, 7.38)	0.794
Abdominal Closure, n (%)				**0.003**
Primary	119 (69%)	86 (63%)	33 (89%)	
Temporary	54 (31%)	50 (37%)	4 (11%)	
Extubated in OR, n (%)				**0.004**
Yes	121 (70%)	88 (65%)	33 (89%)	
No	52 (30%)	48 (35%)	4 (11%)	
Number of Vasopressors used, n (%)				-
0	37 (21%)	0 (0%)	37 (100%)	
1	62 (36%)	62 (46%)	0 (0%)	
2	55 (32%)	55 (40%)	0 (0%)	
3	18 (10%)	18 (13%)	0 (0%)	
4	1 (0.6%)	1 (0.7%)	0 (0%)	
Type of Vasopressor				
Epinephrine, n (%)	103 (60%)	103 (76%)	0 (0%)	
Norepinephrine, n (%)	63 (36%)	63 (46%)	0 (0%)	
Dopamine, n (%)	40 (23%)	40 (29%)	0 (0%)	
Vasopressin, n (%)	24 (14%)	24 (18%)	0 (0%)	

IQR = Interquartile Range; 25th and 75th percentiles, respectively

[a]Wilcoxon rank sum test for continuous variables; Pearson's Chi-squared test for categorical variables

[b]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes

Table 3. Pediatric Liver Transplantation Patient Post-Operative Outcomes Comparison by Utilization of Vasopressor Infusion

Characteristic	**Overall**, N = 173	**Vasopressor Infusion**, N = 136[b]	**No Vasopressor Infusion**, N = 37	**p-value**[a]
Re-exploration, n (%)[c]				0.462
Yes	39 (23%)	29 (21%)	10 (27%)	
No	134 (77%)	107 (79%)	27 (73%)	
Immediate Re-transplantation, n (%)				0.680
Yes	8 (4.6%)	6 (4.4%)	2 (5.4%)	
No	165 (95%)	130 (96%)	35 (95%)	
Post-op Infection, n (%)[d]				0.184
Yes	26 (15%)	23 (17%)	3 (8.1%)	
No	147 (85%)	113 (83%)	34 (92%)	
Post-op Death, n (%)				0.579
Yes	4 (2.3%)	4 (2.9%)	0 (0%)	
No	169 (98%)	132 (97%)	37 (100%)	
PICU LOS (Days), Median (IQR)	4.0 (3.0, 7.0)	4.0 (3.0, 7.3)	3.0 (2.0, 4.0)	**<0.001**
Hospital LOS (Days), Median (IQR)	12 (9, 18)	14 (10, 21)	10 (8, 12)	**<0.001**

IQR = Interquartile Range; 25th and 75th percentiles, respectively

[a]Wilcoxon rank sum test for continuous variables; Pearson's Chi-squared test or Fisher's exact test for categorical variables

[b]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes

[c]Re-exploration is classified as any patient who required a subsequent surgical procedure to evaluate for arterial or venous thrombosis, elevated liver enzymes, or other concerning symptoms

[d]Post-operative infection is classified as any patient requiring additional antibiotic coverage and/or fever of unknown origin

444 **Table 4.** Associations between **use of vasopressor infusion** and post-op outcomes in pediatric liver transplant
445 patients, N=173

Risk factor	Univariable OR (95% CI)	p-value	Multivariable OR (95% CI)	p-value
Outcome = Re-exploration[a,f]				
Vasopressor Infusion[e]				
Yes	0.72 (0.32, 1.68)	0.436	0.62 (0.25, 1.56)	0.301
No	Reference		Reference	
Age at Transplant (Years)	0.95 (0.89, 1.01)	0.127	0.96 (0.90, 1.02)	0.208
Pre-transplant Location				
Floor	1.09 (0.41, 2.68)	0.860	0.81 (0.27, 2.23)	0.690
ICU	0.80 (0.29, 2.01)	0.646	0.74 (0.25, 1.99)	0.566
Home	Reference		Reference	
Pre-op INR[c]	1.23 (0.98, 1.54)	0.074	-	
Total blood products (per 10 mL/kg)	1.07 (1.01, 1.13)	**0.015**	1.08 (1.01, 1.16)	**0.016**
Abdominal closure				
Primary	0.75 (0.36, 1.61)	0.458	1.19 (0.49, 3.07)	0.701
Temporary	Reference		Reference	
Extubated in OR[c]			-	
No	1.64 (0.78, 3.43)	0.191		
Yes	Reference			
Outcome = Re-transplant [a,d]				
Vasopressor Infusion			-	
Yes	0.71 (0.17, 3.98)	0.660		
No	Reference			
Age at Transplant (Years)	0.94 (0.79, 1.05)	0.288	-	
Pre-transplant Location			-	
Floor	2.84 (0.45, 15.4)	0.241		
ICU	3.71 (0.75, 18.4)	0.103		
Home	Reference			
Pre-op INR	1.33 (0.93, 1.79)	0.102	-	
Total blood products (per 10 mL/kg)	1.03 (0.89, 1.10)	0.602	-	
Abdominal closure			-	
Primary	2.38 (0.50, 23.0)	0.301		
Temporary	Reference			
Extubated in OR			-	
No	0.44 (0.05, 2.11)	0.336		
Yes	Reference			
Outcome = Post-op Infection[a,g]				
Vasopressor Infusion				
Yes	2.04 (0.70, 7.98)	0.208	1.39 (0.40, 5.96)	0.617
No	Reference		Reference	
Age at Transplant (Years)	0.85 (0.73, 0.93)	**<0.001**	0.87 (0.77, 0.96)	**0.003**
Pre-transplant Location				
Floor	3.42 (1.29, 8.88)	**0.014**	1.60 (0.53, 4.67)	0.395
ICU	1.16 (0.33, 3.45)	0.797	0.92 (0.23, 3.12)	0.898
Home	Reference		Reference	
Pre-op INR	1.22 (0.95, 1.55)	0.109	-	

Total blood products (per 10 mL/kg)	1.08 (1.02, 1.15)	**0.005**	1.08 (1.01, 1.17)	**0.028**
Abdominal closure				
Primary	0.68 (0.29, 1.62)	0.371	1.74 (0.61, 5.51)	0.310
Temporary	Reference		Reference	
Extubated in OR			-	
No	3.30 (1.42, 7.76)	**0.006**		
Yes	Reference			
Outcome = PICU LOS Days[b]				
Vasopressor Infusion				
Yes	2.13 (1.35, 3.24)	**<0.001**	1.73 (1.12, 2.60)	**0.012**
No	Reference		Reference	
Age at Transplant (Years)	0.96 (0.93, 1.00)	**0.043**	0.96 (0.93, 0.99)	**0.003**
Pre-transplant Location				
Floor	1.42 (0.90, 2.33)	0.148	0.93 (0.59, 1.52)	0.771
ICU	2.21 (1.43, 3.55)	**<0.001**	2.00 (1.30, 3.17)	**0.002**
Home	Reference		Reference	
Pre-op INR	1.18 (1.03, 1.39)	**0.030**	-	
Total blood products (per 10 mL/kg)	1.06 (1.02, 1.12)	**<0.001**	1.04 (1.01, 1.08)	**0.007**
Abdominal closure				
Primary	0.72 (0.45, 1.13)	0.164	1.33 (0.88, 1.96)	0.173
Temporary	Reference		Reference	
Extubated in OR			-	
No	2.41 (1.76, 3.35)	**<0.001**		
Yes	Reference			
Outcome = Hospital LOS Days[b]				
Vasopressor Infusion				
Yes	1.62 (1.27, 2.04)	**<0.001**	1.35 (1.08, 1.69)	**0.009**
No	Reference		Reference	
Age at Transplant (Years)	0.98 (0.96, 1.00)	**0.015**	0.98 (0.97, 1.00)	**0.023**
Pre-transplant Location				
Floor	1.32 (1.01, 1.75)	**0.047**	1.05 (0.82, 1.36)	0.689
ICU	1.48 (1.15, 1.94)	**0.004**	1.28 (1.02, 1.63)	**0.041**
Home	Reference		Reference	
Pre-op INR	1.12 (1.04, 1.21)	**0.003**	-	
Total blood products (per 10 mL/kg)	1.05 (1.03, 1.07)	**<0.001**	1.04 (1.02, 1.06)	**<0.001**
Abdominal closure				
Primary	0.73 (0.58, 0.92)	**0.008**	1.08 (0.87, 1.33)	0.487
Temporary	Reference		Reference	
Extubated in OR			-	
No	1.74 (1.45, 2.10)	**<0.001**		
Yes	Reference			

OR = Odds Ratio; CI = Confidence Interval; PELD/MELD = Pediatric End-Stage Liver Disease/Model for End Stage Liver Disease; OR = Operation Room

[a]Outcomes of Re-exploration, re-transplant, and post-op infection were assessed using firth logistic regression

[b]Outcomes of PICU LOS days, and hospital LOS days were assessed using generalized linear regression with Gamma distribution

[c]Pre-op INR is not included in multivariable models due its collinearity with total blood products; extubated in OR is not included in multivariable model due to its collinearity with abdominal closure

[d]Given the limited number of re-transplant events (n=8), a multivariable model was not performed

[e]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes

[f]Re-exploration is classified as any patient who required a subsequent surgical procedure to evaluate for arterial or venous thrombosis, elevated liver enzymes, or other concerning symptoms

[g]Post-operative infection is classified as any patient requiring additional antibiotic coverage and/or fever of unknown origin

Table 5. Associations between **number of vasopressor infusion** and post-op outcomes in pediatric liver transplant patients with vasopressor infusion, N=136[e]

Risk factor	Univariable OR (95% CI)	p-value	Multivariable OR (95% CI)	p-value
Outcome = Re-exploration[a,f]				
Number of Vasopressor Infusion				
1	Reference		Reference	
2	1.06 (0.45, 2.49)	0.889	0.97 (0.39, 2.37)	0.949
3	0.51 (0.09, 1.90)	0.334	0.27 (0.04, 1.26)	0.101
4	1.11 (0.01, 22.1)	0.948	0.46 (0.00, 10.7)	0.638
Age at Transplant (Years)	0.96 (0.89, 1.03)	0.234	0.98 (0.90, 1.05)	0.523
Pre-transplant Location				
Floor	1.17 (0.42, 3.06)	0.754	0.91 (0.29, 2.57)	0.861
ICU	0.79 (0.25, 2.19)	0.659	0.67 (0.19, 2.00)	0.485
Home	Reference		Reference	
Pre-op INR[c]	1.27 (0.99, 1.62)	0.056	-	
Total blood products (per 10 mL/kg)	1.07 (1.01, 1.14)	**0.017**	1.07 (1.01, 1.16)	**0.029**
Abdominal closure				
Primary	0.55 (0.24, 1.25)	0.149	0.69 (0.26, 1.87)	0.455
Temporary	Reference		Reference	
Extubated in OR[c]				
No	1.99 (0.87, 4.56)	0.102	-	
Yes	Reference			
Outcome = Re-transplant [a,d]				
Number of Vasopressor Infusion			-	
1	Reference			
2	1.61 (0.30, 10.0)	0.570		
3	2.07 (0.18, 16.7)	0.509		
4	8.07 (0.05, 203)	0.310		
Age at Transplant (Years)	0.96 (0.80, 1.08)	0.508	-	
Pre-transplant Location			-	
Floor	2.78 (0.41, 18.8)	0.275		
ICU	2.78 (0.41, 18.8)	0.275		
Home	Reference			
Pre-op INR	1.29 (0.84, 1.77)	0.206	-	
Total blood products (per 10 mL/kg)	1.03 (0.89, 1.11)	0.574	-	
Abdominal closure			-	
Primary	2.23 (0.43, 22.2)	0.364		
Temporary	Reference			
Extubated in OR			-	
No	0.48 (0.05, 2.50)	0.406		
Yes	Reference			
Outcome = Post-op Infection[a,g]				
Number of Vasopressor Infusion				
1	Reference		Reference	
2	1.46 (0.56, 3.83)	0.436	1.32 (0.47, 3.80)	0.594
3	1.27 (0.29, 4.62)	0.730	1.00 (0.18, 4.55)	0.998
4	1.88 (0.01, 38.0)	0.720	0.62 (0.00, 15.2)	0.778
Age at Transplant (Years)	0.87 (0.76, 0.96)	**0.003**	0.89 (0.79, 0.98)	**0.018**

Floor	3.02 (1.09, 8.36)	**0.033**	1.76 (0.58, 5.17)	0.312
ICU	1.15 (0.32, 3.63)	0.818	0.90 (0.21, 3.18)	0.872
Home	Reference		Reference	
Pre-op INR	1.25 (0.96, 1.60)	0.090	-	
Total blood products (per 10 mL/kg)	1.08 (1.02, 1.15)	**0.009**	1.08 (1.01, 1.16)	**0.029**
Abdominal closure				
Primary	0.71 (0.29, 1.76)	0.452	1.50 (0.49, 5.12)	0.490
Temporary	Reference		Reference	
Extubated in OR				
No	3.52 (1.43, 9.01)	**0.006**	-	
Yes	Reference			
Outcome = PICU LOS Days[b]				
Number of Vasopressor Infusion				
1	Reference		Reference	
2	1.05 (0.65, 1.70)	0.856	0.83 (0.54, 1.28)	0.381
3	1.09 (0.56, 2.30)	0.813	0.73 (0.39, 1.44)	0.338
4	1.36 (0.21, 109)	0.819	1.11 (0.19, 35.2)	0.932
Age at Transplant (Years)	0.97 (0.93, 1.01)	0.099	0.96 (0.93, 0.99)	**0.014**
Pre-transplant Location				
Floor	1.22 (0.76, 2.03)	0.421	0.97 (0.59, 1.66)	0.918
ICU	1.99 (1.24, 3.30)	**0.006**	2.06 (1.27, 3.47)	**0.005**
Home	Reference		Reference	
Pre-op INR	1.15 (1.00, 1.36)	0.077	-	
Total blood products (per 10 mL/kg)	1.05 (1.01, 1.10)	**0.007**	1.05 (1.01, 1.09)	**0.010**
Abdominal closure				
Primary	0.79 (0.49, 1.27)	0.341	1.24 (0.77, 1.95)	0.365
Temporary	Reference		Reference	
Extubated in OR				
No	2.37 (1.68, 3.37)	**<0.001**	-	
Yes	Reference			
Outcome = Hospital LOS Days[b]				
Number of Vasopressor Infusion				
1	Reference		Reference	
2	1.03 (0.80, 1.33)	0.816	0.90 (0.72, 1.13)	0.347
3	1.14 (0.80, 1.67)	0.471	0.81 (0.58, 1.15)	0.225
4	0.77 (0.25, 4.52)	0.708	0.54 (0.19, 2.40)	0.321
Age at Transplant (Years)	0.98 (0.96, 1.00)	**0.045**	0.98 (0.97, 1.00)	**0.037**
Pre-transplant Location				
Floor	1.19 (0.90, 1.60)	0.230	1.09 (0.84, 1.42)	0.555
ICU	1.38 (1.05, 1.85)	**0.028**	1.32 (1.02, 1.74)	**0.043**
Home	Reference		Reference	
Pre-op INR	1.11 (1.03, 1.20)	**0.012**	-	
Total blood products (per 10 mL/kg)	1.04 (1.02, 1.06)	**<0.001**	1.04 (1.02, 1.06)	**<0.001**
Abdominal closure				
Primary	0.78 (0.61, 1.00)	0.052	1.06 (0.83, 1.35)	0.647
Temporary	Reference		-	
Extubated in OR				
No	1.67 (1.37, 2.05)	**<0.001**	-	
Yes	Reference			

OR = Odds Ratio; CI = Confidence Interval; PELD/MELD = Pediatric End-Stage Liver Disease/Model for End Stage Liver Disease; OR = Operation Room

[a]Outcomes of Re-exploration, re-transplant, and post-op infection were assessed using firth logistic regression

[b]Outcomes of PICU LOS days, and hospital LOS days were assessed using generalized linear regression with Gamma distribution
[c]Pre-op INR is not included in multivariable models due its collinearity with total blood products; extubated in OR is not included in multivariable model due to its collinearity with abdominal closure
[d]Given the limited number of re-transplant events (n=8), a multivariable model was not performed
[e]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes
[f]Re-exploration is classified as any patient who required a subsequent surgical procedure to evaluate for arterial or venous thrombosis, elevated liver enzymes, or other concerning symptoms
[g]Post-operative infection is classified as any patient requiring additional antibiotic coverage and/or fever of unknown origin

Table 6. Associations between **type of vasopressor infusion** and post-op outcomes in pediatric liver transplant patients with vasopressor infusion, N=136[e]

Risk factor	Univariable OR (95% CI)	p-value	Multivariable OR (95% CI)	p-value
Outcome = Re-exploration[a,f]				
Epinephrine Infusion				
Yes	0.63 (0.26, 1.59)	0.322	0.59 (0.24, 1.53)	0.273
No	Reference		Reference	
Norepinephrine infusion				
Yes	1.31 (0.58, 2.97)	0.512	1.15 (0.49, 2.66)	0.741
No	Reference		Reference	
Dopamine infusion				
Yes	0.74 (0.28, 1.80)	0.518	0.66 (0.24, 1.68)	0.394
No	Reference		Reference	
Vasopressin infusion				
Yes	0.75 (0.22, 2.13)	0.610	0.68 (0.19, 1.96)	0.487
No	Reference		Reference	
Outcome = Re-transplant [a,d]				
Epinephrine Infusion			-	
Yes	1.21 (0.23, 12.1)	0.837		
No	Reference			
Norepinephrine infusion			-	
Yes	0.63 (0.11, 2.94)	0.558		
No	Reference			
Dopamine infusion			-	
Yes	1.33 (0.22, 6.30)	0.726		
No	Reference			
Vasopressin infusion			-	
Yes	2.68 (0.44, 12.9)	0.255		
No	Reference			
Outcome = Post-op Infection[a,g]				
Epinephrine Infusion				
Yes	0.67 (0.26, 1.83)	0.418	0.71 (0.27, 1.97)	0.497
No	Reference		Reference	
Norepinephrine infusion				
Yes	1.99 (0.82, 5.03)	0.129	1.88 (0.76, 4.80)	0.170
No	Reference		Reference	
Dopamine infusion				
Yes	0.86 (0.30, 2.21)	0.755	0.91 (0.31, 2.46)	0.864
No	Reference		Reference	
Vasopressin infusion				
Yes	1.05 (0.30, 3.06)	0.930	1.05 (0.30, 3.13)	0.931
No	Reference		Reference	
Outcome = PICU LOS Days[b]				
Epinephrine Infusion				
Yes	0.76 (0.47, 1.21)	0.267	0.68 (0.45, 1.01)	0.059
No	Reference		Reference	
Norepinephrine infusion				
Yes	1.33 (0.88, 2.04)	0.181	1.26 (0.90, 1.79)	0.182

No	Reference		Reference	
Dopamine infusion				
Yes	0.98 (0.62, 1.61)	0.942	0.70 (0.47, 1.04)	0.070
No	Reference		Reference	
Vasopressin infusion				
Yes	1.07 (0.62, 1.98)	0.812	0.87 (0.56, 1.41)	0.559
No	Reference		Reference	
Age at Transplant (Years)	0.97 (0.93, 1.01)	0.099	0.95 (0.92, 0.98)	**<0.001**
Pre-transplant Location				
Floor	1.22 (0.76, 2.03)	0.421	0.95 (0.61, 1.50)	0.811
ICU	1.99 (1.24, 3.30)	**0.006**	2.01 (1.32, 3.12)	**0.002**
Home	Reference		Reference	
Pre-op INR[c]	1.15 (1.00, 1.36)	0.077	-	
Total blood products (per 10 mL/kg)	1.05 (1.01, 1.10)	**0.007**	1.05 (1.02, 1.08)	**0.002**
Abdominal closure				
Primary	0.79 (0.49, 1.27)	0.341	1.27 (0.86, 1.86)	0.231
Temporary	Reference		Reference	
Extubated in OR[c]			-	
No	2.37 (1.68, 3.37)	**<0.001**		
Yes	Reference			
Outcome = Hospital LOS Days[b]				
Epinephrine Infusion				
Yes	0.81 (0.62, 1.05)	0.122	0.73 (0.58, 0.90)	**0.004**
No	Reference		Reference	
Norepinephrine infusion				
Yes	1.26 (1.00, 1.58)	0.050	1.16 (0.96, 1.40)	0.134
No	Reference		Reference	
Dopamine infusion				
Yes	1.00 (0.77, 1.29)	0.980	0.81 (0.65, 1.00)	**0.050**
No	Reference		Reference	
Vasopressin infusion				
Yes	1.06 (0.79, 1.45)	0.710	0.84 (0.66, 1.09)	0.173
No	Reference		Reference	
Age at Transplant (Years)	0.98 (0.96, 1.00)	**0.045**	0.97 (0.96, 0.99)	**0.001**
Pre-transplant Location				
Floor	1.19 (0.90, 1.60)	0.230	1.07 (0.85, 1.36)	0.568
ICU	1.38 (1.05, 1.85)	**0.028**	1.34 (1.06, 1.70)	**0.015**
Home	Reference		Reference	
Pre-op INR	1.11 (1.03, 1.20)	**0.012**	-	
Total blood products (per 10 mL/kg)	1.04 (1.02, 1.06)	**<0.001**	1.04 (1.02, 1.06)	**<0.001**
Abdominal closure				
Primary	0.78 (0.61, 1.00)	0.052	1.10 (0.89, 1.35)	0.391
Temporary	Reference		Reference	
Extubated in OR				
No	1.67 (1.37, 2.05)	**<0.001**	-	
Yes	Reference			

OR = Odds Ratio; CI = Confidence Interval; PELD/MELD = Pediatric End-Stage Liver Disease/Model for End Stage Liver Disease; OR = Operation Room

[a]Outcomes of Re-exploration, re-transplant, and post-op infection were assessed using firth logistic regression

[b]Outcomes of PICU LOS days, and hospital LOS days were assessed using generalized linear regression with Gamma distribution

[c]Pre-op INR is not included in multivariable models due its collinearity with total blood products; extubated in OR is not included in multivariable model due to its collinearity with abdominal closure

[d]Given the limited number of re-transplant events (n=8), a multivariable model was not performed

[e]Vasopressor Infusion is classified as any patient who had a vasopressor infusion utilized intraoperatively for at least 15 consecutive minutes

[f]Re-exploration is classified as any patient who required a subsequent surgical procedure to evaluate for arterial or venous thrombosis, elevated liver enzymes, or other concerning symptoms

[g]Post-operative infection is classified as any patient requiring additional antibiotic coverage and/or fever of unknown origin