Adult Liver Transplant Anesthesiology Practice Patterns and Resource Utilization in the United States: Survey Results from the Society for the Advancement of Transplant Anesthesia

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ABSTRACT

INTRODUCTION: Liver transplant anesthesiology is an evolving and expanding subspecialty, and programs have, in the past, exhibited significant variations of practice at transplant centers across the United States. In order to explore current practice patterns, the Quality & Standards Committee from the Society for the Advancement of Transplant Anesthesia (SATA) undertook a survey of liver transplant anesthesiology program directors.

METHODS: Program directors were invited to participate in an online questionnaire. A total of 110 program directors were identified from the 2018 Scientific Registry of Transplant Recipients (SRTR) database. Replies were received from 65 programs (response rate of 59%).

RESULTS: Our results indicate an increase in transplant anesthesia fellowship training and advanced training in transesophageal echocardiography (TEE). We also find that the use of intraoperative TEE and viscoelastic testing is more common. However, there has been a reduction in the use of veno-venous bypass, routine placement of pulmonary artery catheters and the intraoperative use of anti-fibrinolytics when compared to prior surveys.

CONCLUSION: The results show considerable heterogeneity in practice patterns across the country that continues to evolve. However, there appears to be a movement towards the adoption of specific structural and clinical practices.

Keywords: Survey, risk assessment/risk stratification, patient safety

INTRODUCTION

The field of liver transplantation has progressed substantially since the first successful liver transplant in 1967.[1] This expansion of the specialty has prompted the need for oversight and the development of policy and regulations aimed at assisting in the organization of the multidisciplinary teams responsible for the care of liver transplant patients. This process has been undertaken primarily by the United Network for Organ Sharing (UNOS)/Organ Procurement and Transplantation Network (OPTN) whose bylaws describe, in great detail, the requirements for the various transplant specialty teams. The notable specialty missing from these comprehensive policies is transplant anesthesiology. There remains no guidance for how transplant anesthesia care should be organized and delivered.

There is one UNOS/OPTN bylaw [Appendix F.5] that requires programs to designate a Director of Liver Transplant Anesthesia (DLTA) and details the expected clinical responsibilities of this individual.[2] The Transplant Anesthesia Committee of the American Society of Anesthesiologists (ASA) has also published a single guideline regarding the training and experience required to serve as a program DLTA.[3] However, there are no guidelines regarding the organization or experience required of other members of the transplant anesthesiology team, in spite of evidence that the existence of a dedicated liver transplant anesthesiology team is associated with improved patient outcomes.[4]

Investigations of specific perioperative practice patterns and team organization have been published previously but there has not been a specific review in the United States since 2013.[5,6] Furthermore, these reviews focused on programs at academic centers and excluded those in private practice. Given that there may be differences in practice at academic and private practice programs, as well as significant variations in case volume across all programs, the goal of this survey is to gain a more comprehensive overview of perioperative adult liver transplant anesthesiology practice.

METHODS

SATA Quality & Standards Committee

This project was designed and undertaken by the Quality & Standards Committee of the Society for the Advancement of Transplant Anesthesia (SATA), an international association which aims to advance the field of transplant anesthesiology. The committee consists of fifteen liver transplant anesthesiologists, all currently active in the subspecialty, who represent programs at various academic centers across the United States and Canada. All committee members satisfy the UNOS requirements to serve as the DLTA and there are eight current and former DLTAs on the committee.

Study Population

Using publicly available information from the 2018 Scientific Registry of Transplant Recipients (SRTR), a database of all liver transplant programs (147 programs) active at the time of the project was created.[7] Primary pediatric transplant centers (27 programs) and any program that was unable to provide the contact information for their DLTA (7 programs) were excluded from this survey. Although OPTN/UNOS require for each transplant program to designate a DLTA, there is no available database containing this contact information. The DLTAs were identified through each program's website or by contacting program administrative staff directly. Despite this requirement, some programs could not identify or provide contact details for the DLTA.

A contact list of all identified DLTAs was created and used as the distribution list for the questionnaire. Three DLTAs represented two separate institutions, resulting in a total of 110 program directors who were contacted representing a total of 113 programs. Of the 110 directors contacted, 45 represented programs classified as "low" volume transplant centers (performing < 50 liver transplants per year), 31 represented programs classified as "medium" volume transplant centers (performing between 50-100 liver transplants per year), and 34 represented programs classified "high" volume transplant centers (>100 liver transplants per year).

Survey process

The project proposal was reviewed by the Colorado Multidisciplinary Review Board (IRB 20-2567) and classified as "not human subject research" and exempt from further review. Ideas for questions were developed by the committee after identifying four areas of interest that warranted further investigation: the organization and structure of the liver transplant anesthesiology team, the focused preoperative evaluation of potential liver transplant candidates, the utilization of specific

intraoperative monitoring and treatment modalities, and decisions regarding immediate postoperative disposition. Questions were subject to multiple revisions during survey development before being reviewed by all members of the committee for face validity prior to final acceptance. Questions were both dichotomous (yes/no) and multiple-choice and some responses allowed free text entry to capture unique practices and/or explanations of practice.

The questionnaire was created using Qualtrics EX Platform software (Qualtrics, Provo, UT) and all response data was managed by the same. All directors were sent a cover letter before the questionnaire was made accessible. This letter contained a personal invitation to participate along with a description of the project and the consent process; the cover letter was approved by the SATA Executive Council. A link to the web-based questionnaire was then sent via email. Responses were collected over three months, ending in January 2021. Reminder emails were sent bi-weekly to non-responders in an attempt to increase the response rate. Survey results were de-identified and stratified according to 2018 SRTR program volume data.

Analysis

The complete results were reviewed by the SATA Quality and Standards Committee. The numerical results were described as a percentage (n/total n). Pearson's chi square test or Fisher exact test was used to compare the results among the three groups (high, medium and low volume centers). A p value less than 0.05 was considered statistically significant. VassarStats (www.vassarstats.net) was used for statistical analysis.

RESULTS

Sixty-five responses were received from the 110 invitations (response rate of 59%). Program responses were stratified based on transplant volume utilizing 2018 data from the SRTR database (available at the time of project design). Response rates stratified by program size were roughly equivalent in both high and medium volume centers, 65% high volume centers (22/34) and 65% medium volume centers (20/31), respectively. The response rate from low volume centers was 51% (23/45). Survey questions and responses stratified by program size are shown in Appendix (Table 1). Not all questions were answered by all respondents resulting in some variation in the total number of responses throughout the survey.

Liver Transplant Anesthesia Team Structure and Function

Almost all responding centers, 98% (63/64), report having a "dedicated" liver transplant anesthesia team (LTAT). The most common team size consists of 6-10 members, 68% (43/63), followed by 1-5 members, 24% (15/63), 11-15 members, 5% (3/63), 16-20 members, 2% (1/63) and greater than 20 members, 2% (1/63) (Figure 1). The designation of a liver transplant anesthesia team along with team size is similar across all program sizes.

Most programs report substantial variation in additional fellowship training undertaken by the team members (Figure 2). Fellowships in cardiothoracic anesthesia (55%, 36/65), critical care (46%, 30/65), and transplant anesthesia (29%, 19/65) were most commonly reported. Forty-three programs (66%) also described an additional requirement for institutional training prior to someone joining the LTAT. Additional TEE training by at least half of team members appeared more common in medium and high-volume centers when compared to low volume centers, 64% and 70% vs 35% (χ^2 = 14.67, p=0.023) (Figure 2). Only a small number of programs, 23% (15/64) offer a fellowship

training program in transplant anesthesia at their institution (Figure 1). Team members with fellowship training in transplant anesthesia were more common in high volume programs, 45% (10/22) than in medium or low volume programs, 20% (4/20) and 22% (5/23), respectively (Figure 2). High volume programs were more likely to offer fellowship training specific to liver transplant anesthesia than low volume programs, 36% vs 9% respectively (Figure 1).

Living Donor Liver Transplantation Program

Most responding centers have a formal living donor liver transplant (LDLT) program, 59% (38/64). High volume centers were more likely to have an LDLT program (86%, 19/22) while low volume centers were much less likely to offer LDLT (30%, 7/23). Medium volume programs remained in the middle with 63% (12/20) of responding programs performing LDLT (χ^2 = 14.74, p=0.0006) (Figure 1).

Multidisciplinary Team Participation

The majority of responding programs (75%, 47/63) reported attendance by the DLTA or the DLTA and/or team members at selection committee meetings greater than 50% of the time. Most responding programs (64%, 41/64) reported participation more than 50% of the time in multidisciplinary morbidity and mortality conferences and quality improvement meetings. Only 8% (5/64), reported no involvement in these activities by the DLTA and/or team members (Figure 1).

Pre-operative Management

A large majority of responding programs, 92% (59/64), reported the utilization of a standardized approach to pre-operative cardiovascular testing for potential liver transplant candidates.

Respondents were allowed to choose more than one response to this question if appropriate. When asked if there was a routine pre-operative evaluation method, 75% (48/64) of programs reported utilizing dobutamine stress echocardiography, 39% (25/64) programs employed left heart catheterization while 23% (15/64) of programs reported using CT coronary angiography. Fifteen programs (23%) utilized different methods than those listed, among which were baseline resting echocardiograms, stress echocardiograms, nuclear perfusion scans and right heart catheterizations. Programs of all sizes favored a pre-operative cardiovascular testing protocol for transplant candidates, 95% (21/22) vs 89% (17/20) vs 91% (21/23) for high, medium and low volume centers, respectively.

Intraoperative Management Techniques

Less than half of programs, 42% (27/65) reported that they use veno-veno bypass (VV-bypass) for liver transplantation. Of those who reported its use, 22% (6/27) reported that VV-bypass is utilized in more than half of all cases. The remainder of programs that utilize VV-bypass, 78% (21/27), reported only using this sparingly, 0-25% of the time. The use of VV-bypass appeared to be more common among lower volume programs than higher volume programs, 48% vs 32% respectively (Figure 3).

The majority of programs, 82% (53/65) reported utilizing a form of intraoperative renal replacement therapy (RRT). Of the programs that utilize intraoperative RRT, 77% (41/53) only used this in 0-25% of cases, 19% (10/53) used it in 26-50% of cases, 2% (1/53) used it in 51-75% of cases and 2% (1/53) used it in the bulk of their transplant cases. Of those programs that utilize intraoperative RRT, 91% (48/53) utilize a form of continuous veno-venous hemodialysis (CVVHD) while a small amount, 4% (2/53) utilize a form of intermittent hemodialysis (HD) or sustained low-efficiency dialysis (SLED). Programs reported the most common reasons for using intraoperative RRT as hepatorenal

syndrome, hyponatremia, hyperkalemia, acidosis, volume overload, end-stage renal disease and simultaneous liver-kidney transplantation. The use of intraoperative RRT was slightly more common among low volume programs when compared to high volume programs, 83% vs 77% (Figure 3).

The vast majority of programs, 95% (62/65) reported using point of care (POC) viscoelastic testing (Thromboelastography (TEG) or Rotational Thromboelastometry (ROTEM)) to guide transfusion decisions, with only 3 responding programs not utilizing this technology. Of the programs using these testing modalities, 59% (36/61) utilize TEG, a smaller proportion, 36% (22/61) reported using ROTEM, while the remainder of programs utilized a combination of the two. Routine use of POC viscoelastic testing appeared to be common practice among programs of all sizes (Figure 3).

Intraoperative transesophageal echocardiography (TEE) was used by 49% of programs (32/65) in 76-100% of cases, 9% of programs (6/65) used this in 51-75% of cases, 9% (6/65) used this in 25-50% of cases and 32% (21/65) reported minimal use, 0-25% of the time. A similar distribution was seen among pulmonary artery catheter (PAC) use, with 46% (30/65) of programs reporting placement of PACs in 76-100% of cases, 5% (3/65) placing PACs in 51-75% of cases, 11% (7/65) placing PACs in 26-50% of cases and 38% (25/65) placing PACs in 0-25% of cases. The routine use (in more than half of cases) of intraoperative transesophageal echocardiography appeared to be slightly more common in high volume programs compared to low volume programs, 64% vs 43% (Figure 3). However, the use of pulmonary artery catheters appeared similar among programs of all sizes.

For pharmacological treatment of intraoperative coagulopathy, the most commonly used pharmacologic agents were anti-fibrinolytics (24.9% $\pm$ 26.5%) followed by fibrinogen concentrate (7.1% $\pm$ 16.5%) and prothrombin complex concentrates (5.8% $\pm$ 11.8%) with recombinant factor VII

used sparingly (1.7% ± 4.7%). Lower volume programs appeared to utilize pharmacologic pro-coagulant medications more frequently than high volume centers, particularly prothrombin complex concentrates (mean use of 7.35% vs 5.18%), recombinant factor VII (mean use of 2.94% vs 1.14%) and antifibrinolytics (mean use 30.95% vs 25.14%).

Post-operative Management

Only 20% (13/64) of programs reported routinely extubating patients at the end of the case. Similarly, almost all programs routinely admit patients to the ICU post-operatively with 95% (61/64) of programs reporting ICU admission more than half of the time. Post-operative management, including extubation at the end of the case and ICU admission appeared similar across centers of all sizes (Figure 4).

DISCUSSION

We chose to evaluate all adult liver transplant programs as represented in the 2018 SRTR database to obtain a larger, more comprehensive picture of current program practice compared to data obtained from previous surveys which had excluded private-practice groups.[5,6] Given that some directors serve at multiple institutions, which may be both academic and private practice based, we were unable to accurately separate practice affiliation in the analysis. However, our results once more demonstrate considerable heterogeneity in practice across transplant programs in the United States. These differences must be understood prior to the development of recommendations for any change in practice or suggesting restrictive practice guidelines.

Liver Transplant Anesthesia Team Structure and Function

The consistent use of a formal liver transplant anesthesia team to provide anesthesiology services to liver transplant patients appears to be standard practice across transplant programs in the United States. As expected, these teams vary in size and training given the wide variety of training that has historically been required for participation in the care of these patients. However, there are a growing number of transplant anesthesia specific fellowships, as reflected by survey responses which indicate that this pathway is increasingly being utilized to join the LTAT. Not surprisingly, prior training in cardiothoracic anesthesiology and critical care remain the two most common forms of fellowship training seen amongst team members; this has been the historical standard prior to the introduction of liver transplant specific fellowship training programs. Additional training in transesophageal echocardiography appears to be becoming increasingly common, with 43% of respondents reporting additional training (either testamur or diplomate certification by the National Board of Echocardiography) in at least half of team members compared to only 7% of programs reporting similar certification previously.[5]

Multidisciplinary Team Participation

The majority of programs report regular attendance at selection committee meetings as well as other multidisciplinary meetings (e.g., morbidity and mortality conferences and quality improvement meetings) which is an increase from prior published results. Our results indicate that 75% of responding programs had LTAT members present at more than 50% of selection committee meetings compared to only 18% of programs previously reported.[6] One confounding factor that should be noted is that this survey was conducted during the COVID-19 pandemic in which almost all meetings transitioned to virtual platforms, which may have resulted in higher than usual participation reporting given the relative ease of attending virtual meetings compared to in-person meetings that are often held remote from the operating room and at inopportune times for clinical anesthesiologists.

Pre-operative Management

The pre-operative evaluation of liver transplant candidates is a complex topic that involves multidisciplinary decision making at a program level based on risk tolerance. Patients are evaluated for both their ability to survive liver transplant surgery and their risks of possible peri-operative cardiac complications. We found a wide variation in pre-operative cardiac evaluation methods. Dobutamine stress echocardiography appears to be the most popular form of pre-operative cardiac screening, with other modalities used as needed.

Intraoperative Management Techniques

The routine use of VV bypass is decreasing. Prior studies reported the "routine" use of VVB in 51% of responding programs, while we find that only 42% of responding programs report use of this surgical technique and of this group, less than a quarter (22%) did so in the majority of their cases.[5]

The necessity of intraoperative RRT is regularly debated among the liver transplant community. Patients undergoing liver transplantation often have profound renal dysfunction and/or renal failure. The utility of intraoperative dialysis has been previously described, and is used to treat acidosis, electrolyte abnormalities and fluid shifts that frequently complicate the management of patients undergoing liver transplantation.[8] In contrast, some centers refrain from the use of intraoperative renal replacement yet report good outcomes, including surgery for patients undergoing simultaneous liver and kidney transplant.[9] Most centers that use intraoperative RRT employ some form of CVVHD/CRRT with a much smaller group using HD/SLED. This variation may be related to the reduced size and complexities of the CRRT machine when compared to the full-sized hemodialysis

and reverse osmosis machines as well as the additional need for extra support staff to operate the equipment.

The use of intraoperative TEE use during liver transplantation is well established. The significant hemodynamic fluctuations and intraoperative challenges associated with liver transplantation surgery necessitate close monitoring.[10] Intraoperative TEE use is becoming more commonplace with more than 58% of programs using this monitoring modality in more than half of their cases. Previous surveys reported TEE use in 48% of large-volume programs and 47% in mid-volume programs with lesser use in low-volume programs.[5] Despite this increased use of TEE, there are still a large number of programs that routinely place PACs though this practice appears less common than previously reported.[5] Schumann et al found that 94% of responding programs reported regularly placing a PAC whereas in our survey, we found that just over half of programs reported using PACs regularly in their cases.

The almost universal use of point of care viscoelastic testing in respondents reflects the complex manifestations and rebalance of anti- and pro-coagulation changes seen in patients presenting for liver transplantation.[11] Dynamic hemostatic changes during this operation are not well measured by isolated, standardized plasma-based laboratory coagulation assays.[12] Use of either the TEG or ROTEM systems in patients undergoing transplantation are well described, initially in non-randomized reports, with fewer prospective level 1 data. Meta-analyses are dominated by reports in cardiac surgery and include patients with liver disease undergoing non-transplant procedures. Two small prospective studies support the finding of reproducible decreases in administration of blood products in viscoelastic testing guided management, without significant impact of long-term outcomes.[13,14] This is reflected in the increased utilization of this technology, as reported by 95% of

respondents in our results, compared with 62% of programs less than a decade ago.[5] The advantages of viscoelastic whole blood coagulation assessment include the point-of-care accessibility and the acquisition of rapid results which is immensely valuable to transplant anesthesiologists. Increasing numbers of studies report the success of this technology in standardized approaches in the management of operative bleeding and support the widespread use of this technology in this context.[15,16]

Pharmacologic based treatment of coagulopathy remains rare, with the exception of anti-fibrinolytic medication use, however, even these are used less commonly now. Previous reports indicated that 50-60% of programs routinely administered anti-fibrinolytics during liver transplantation[5] whereas our results demonstrated average use a quarter of cases. Although, the safety of both prothrombin complex concentrates and fibrinogen concentrates has been previously described[17,18] there is insufficient robust prospective data to support the utility of these agents to reduce transfusion of blood products.[19,20]

Post-operative Management

There is prior evidence of the safety and benefits of early extubation in liver transplant patients.[21,22] Despite this, most programs opt to continue with mechanical ventilation postoperatively which necessitates post-op ICU admission. Although not investigated further in this survey, we speculate that this may be dependent on center specific policies regarding post-operative care and less influenced by anesthetic team practice.

Variations in Practice by Program Size

Some areas of practice that did not differ with relation to program size. The existence of a designated LTAT at programs and the use of pre-operative cardiovascular testing protocols for transplant candidate evaluation were not surprising as these appear to be standard practice across the country. The finding that fellowship programs are more likely to be offered and high-volume centers is also not surprising. The presence of an LDLT program was the primary statistically significant result when program size was taken into account. Once again, this is not surprising given that high volume centers are more likely to have appropriately trained surgeons with the technical expertise to perform this complex procedure.

The more frequent use of VVB at lower-volume centers is interesting and we suspect this may be based on surgeon experience and preference. We speculate that increased resources available at higher volume centers may reduce the need for intraoperative RRT (blood washing, medication availability, etc). The widespread use of point-of-care viscoelastic testing (TEG and/or ROTEM) appeared to be common across programs of all sizes.

The increase in TEE training and in its intraoperative use speaks to the growing application of the technology in general. Higher volume centers were more likely to have team members with additional training in TEE and were therefore more likely to use TEE in the majority of their cases. This is not unexpected given that high volume programs are more likely to have access to formalized advanced training in TEE.

The increased use of pharmacologic pro-coagulant agents at low volume centers could be due to lesser availability of other resources (i.e., increased response time from blood bank). However, the reasons behind these choices were not investigated in this survey.

Limitations of study

The strength of this study lies in the representation of the full spectrum of transplant programs along with the broad nature of questions asked to fully evaluate the current state of practice in the United States. However, there are several limitations related to the methodology of the study design. Invitations were sent out to all identified program directors and despite multiple follow-up requests, only 59% responded in a meaningful manner. However, this constitutes an acceptable response rate for a survey of this nature.[23] There are intrinsic limitations associated with survey research, including oversimplification from multiple choice questions, and introducing recall bias when asking generalized questions. Respondents were encouraged to provide additional explanations for their answers, but many program directors did not utilize this opportunity. Some respondents did not answer one or more questions, we do not know why this occurred, but are aware that this may have impacted the results. Answers often relied on recall of grouped data rather than actual, verifiable numbers and this too may lead to a misrepresentation of actual practice. The accuracy of respondent's answers cannot be verified. Every attempt was made to include as many programs as possible in the survey, however, we encountered substantial difficulty identifying either the DLTA or an appropriate substitute at many programs despite attempts to personally contact these programs. Three DLTAs represented more than one center (each represented their primary center as well as a low volume center). Their answers were presumed to represent responses from their higher volume center though this was not explicitly stated. This study was conducted during the COVID-19 pandemic, which may have skewed results. These extenuating circumstances may have resulted in potential practice changes; in particular, most academic institutions transitioned to virtual meetings which may have increased attendance.

CONCLUSION

This study represents the largest evaluation of transplant anesthesia practice in the last two decades. It confirms that significant variation in practice continues across transplant centers in the United States. The results showed less variation in practice based on program size than expected, which may indicate movement toward a more generally accepted pattern of practice. Further study into the differences across programs is therefore needed to improve our understanding of the reasons why such variation persists and to identify what can be done to support the drive toward "best" practice. Additionally, more evidence is needed to identify and assess the risks and benefits of choosing certain intraoperative management techniques and how these choices effect overall patient outcomes.

However, it appears that certain practices are becoming more uniform across programs of all sizes and designations which may lend themselves to being accepted as standard of care. Team membership requiring fellowship training, the training of team members in the intraoperative use of TEE, viscoelastic testing for coagulation management and access to intraoperative renal support have been adopted by many programs who already view these as their "standard of care."

We recommend that future studies continue to be performed to monitor our subspecialty's progress toward more standardized practice. While not advocating a "single practice fits all" approach, we posit that more work should be done to explore the concepts of "best" practice in liver transplant anesthesia to achieve the goal of excellent and comprehensive perioperative care for all liver transplant recipients.

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Table 1. Summary of survey questions and responses stratified by program size.

	Survey Question	High Volume Center (>100 transplants/year) n = 22	Medium Volume Center (50-100 transplants/year) n = 20	Low Volume Center (<50 transplants/year) n = 23
1	Do you have a dedicated liver transplant anesthesia team (LTAT)? A "dedicated" LTAT is a defined group with members that take liver transplant call or perform liver transplant cases.	Yes: 21 No: 1	Yes: 20 No: 0	Yes: 22 No: 0
	If Yes: How many people are on the LTAT?	1 – 5: 2 6 – 10: 17 11 – 15: 2 16 – 20: 0 More than 20: 0	1 – 5: 5 6 – 10: 12 11 – 15: 1 16 – 20: 1 More than 20: 1	1 – 5: 8 6 – 10: 14 11 – 15: 0 16 – 20: 0 More than 20: 0
	If Yes: What is the training of most team members? Please select all that apply	Cardiothoracic Anesthesia: 12 Critical Care: 9 Transplant Anesthesia: 10 Institutional Training: 12 Other: 4	Cardiothoracic Anesthesia: 9 Critical Care: 9 Transplant Anesthesia: 4 Institutional Training: 16 Other: 5	Cardiothoracic Anesthesia: 15 Critical Care: 12 Transplant Anesthesia: 5 Institutional Training: 15 Other: 1
2	Do team members regularly attend patient selection committee meetings?	DLTA Only (76 – 100%): 4 DLTA Only (51 – 75%): 4 DLTA Only (26 – 50%): 0 DLTA Only (0 – 25%): 0 DLTA and/or LTAT (76 – 100%): 8 DLTA and/or LTAT (51 – 75%): 2 DLTA and/or LTAT	DLTA Only (76 – 100%): 6 DLTA Only (51 – 75%): 3 DLTA Only (26 – 50%): 1 DLTA Only (0 – 25%): 2 DLTA and/or LTAT (76 – 100%): 2 DLTA and/or LTAT (51 – 75%): 1 DLTA and/or LTAT	DLTA Only (76 – 100%): 8 DLTA Only (51 – 75%): 4 DLTA Only (26 – 50%): 0 DLTA Only (0 – 25%): 4 DLTA and/or LTAT (76 – 100%): 5 DLTA and/or LTAT (51 – 75%): 0 DLTA and/or LTAT

		(26 – 50%): 1 DLTA and/or LTAT (0 – 25%): 3	(26 – 50%): 2 DLTA and/or LTAT (0 – 25%): 1	(26 – 50%): 1 DLTA and/or LTAT (0 – 25%): 1
3	Do team members regularly participate in M&M and/or quality improvement (QI) meetings within the transplant program?	Yes (76 – 100%): 10 Yes (51 – 75%): 7 Yes (26 – 50%): 4 Yes (0 – 25%): 0 No: 1	Yes (76 – 100%): 7 Yes (51 – 75%): 4 Yes (26 – 50%): 4 Yes (0 – 25%): 2 No: 2	Yes (76 – 100%): 9 Yes (51 – 75%): 4 Yes (26 – 50%): 4 Yes (0 – 25%): 4 No: 2
4	Does you program offer advanced training in liver transplant anesthesia?	Fellowship: 8 Additional Training: 3 None: 11	Fellowship: 5 Additional Training: 3 None: 11	Fellowship: 2 Additional Training: 2 None: 19
5	Who manages pediatric liver transplantations at your institution?	Pediatric LT team: 11 Pediatric general team: 1 Adult LT team: 0 Other/combination: 2	Pediatric LT team: 6 Pediatric general team: 2 Adult LT team: 0 Other/combination: 2	Pediatric LT team: 4 Pediatric general team: 1 Adult LT team: 0 Other/combination: 6
6	Do you have a living donor transplant program at your institution?	Yes: 19 No: 3	Yes: 12 No: 7	Yes: 7 No: 16
7	Do you have a standardized approach to preoperative cardiac testing for LT candidates?	Yes: 21 No: 1	Yes; 17 No: 2	Yes: 21 No: 2
	If yes: What is the preferred preoperative evaluation method? Please select all that apply	Dobutamine Stress Echo: 17 CT Coronary Angiogram: 7 Left Heart Catheterization: 7 Other: 5	Dobutamine Stress Echo: 15 CT Coronary Angiogram: 4 Left Heart Catheterization: 9 Other: 4	Dobutamine Stress Echo: 16 CT Coronary Angiogram: 4 Left Heart Catheterization: 9 Other: 6
8	Do you utilize VV-bypass for liver transplantation?	Yes: 7 No: 15	Yes: 9 No: 11	Yes: 11 No: 12
	If Yes: What is the approximate percentage of cases done on VV-bypass?	0 – 25: 5 26 – 50%: 0 51 – 75%: 0	0 – 25: 7 26 – 50%: 0 51 – 75%: 1	0 – 25: 9 26 – 50%: 0 51 – 75%: 2

		76 – 100%: 2	76 – 100%: 1	76 – 100%: 0
9	Do you utilize intraoperative renal replacement therapy?	Yes: 17 No: 5	Yes: 17 No: 3	Yes: 19 No: 4
	If Yes: What is the approximate percentage of cases that utilize renal replacement therapy?	0 – 25: 13 26 – 50%: 4 51 – 75%: 0 76 – 100%: 0	0 – 25: 14 26 – 50%: 2 51 – 75%: 1 76 – 100%: 0	0 – 25: 14 26 – 50%: 4 51 – 75%: 0 76 – 100%: 1
	If Yes: What type of renal replacement therapy do you utilize intraoperatively?	CVVHD: 15 HD (or SLED): 1 Other: 1	CVVHD: 16 HD (or SLED): 0 Other: 1	CVVHD: 17 HD (or SLED): 1 Other: 1
10	What is the approximate percentage of cases that utilize transesophageal echocardiography (TEE)?	0 – 25: 5 26 – 50%: 3 51 – 75%: 2 76 – 100%: 12	0 – 25: 6 26 – 50%: 0 51 – 75%: 2 76 – 100%: 12	0 – 25: 10 26 – 50%: 3 51 – 75%: 2 76 – 100%: 8
11	What percentage of team members are trained (either Testamur or Diplomate status in Basic and/or Advanced TEE) in TEE use?	0 – 25: 9 26 – 50%: 3 51 – 75%: 1 76 – 100%: 9	0 – 25: 8 26 – 50%: 2 51 – 75%: 6 76 – 100%: 4	0 – 25: 5 26 – 50%: 10 51 – 75%: 3 76 – 100%: 5
12	What is the approximate percentage of cases utilizing pulmonary artery catheters (PACs)?	0 – 25%: 9 26 – 50%: 3 51 – 75%: 0 76 – 100%: 10	0 – 25%: 8 26 – 50%: 2 51 – 75%: 1 76 – 100%: 9	0 – 25%: 8 26 – 50%: 2 51 – 75%: 2 76 – 100%: 11
13	Do you utilize ROTEM or TEG to guide transfusion decisions?	Yes: 20 No: 2	Yes: 20 No: 0	Yes: 22 No: 1
	If Yes: Which technology is used?	TEG: 12 ROTEM: 6 Other/Combination: 2	TEG: 10 ROTEM: 9 Other/Combination: 1	TEG: 14 ROTEM: 7 Other/Combination: 0
14	What is the approximate percentage of cases involving the use of the following pharmacologic agents: Prothrombin Complex Concentrates (PCCs)?	Mean: 5.18% Std Dev: 8.84%	Mean: 5.00% Std Dev: 7.35%	Mean: 7.35% Std Dev: 17.18%
15	What is the approximate percentage of cases involving the use of the following	Mean: 1.14%	Mean: 1.26%	Mean: 2.94%

	pharmacologic agents: Recombinant Factor VII?	Std Dev: 2.03%	Std Dev: 1.76%	Std Dev: 7.95%
16	What is the approximate percentage of cases involving the use of the following pharmacologic agents: Anti-fibrinolytics (TXA or EACA)?	Mean: 25.14% Std Dev: 20.07%	Mean: 18.21% Std Dev: 21.02%	Mean: 30.95% Std Dev: 35.73%
17	What is the approximate percentage of cases involving the use of the following pharmacologic agents: Fibrinogen concentrate?	Mean: 7.41% Std Dev: 19.87%	Mean: 4.79% Std Dev: 8.36%	Mean: 8.79% Std Dev: 18.65%
18	What is the approximate percentage of cases extubated at the end of the case?	0 – 25%: 12 26 – 50%: 2 51 – 75%: 6 76 – 100%: 2	0 – 25%: 13 26 – 50%: 3 51 – 75%: 4 76 – 100%: 0	0 – 25%: 19 26 – 50%: 2 51 – 75%: 0 76 – 100%: 1
19	What is the approximate percentage of cases admitted to the ICU post-operatively?	0 – 25%: 0 26 – 50%: 2 51 – 75%: 0 76 – 100%: 20	0 – 25%: 0 26 – 50%: 1 51 – 75%: 1 76 – 100%: 18	0 – 25%: 0 26 – 50%: 0 51 – 75%: 1 76 – 100%: 21

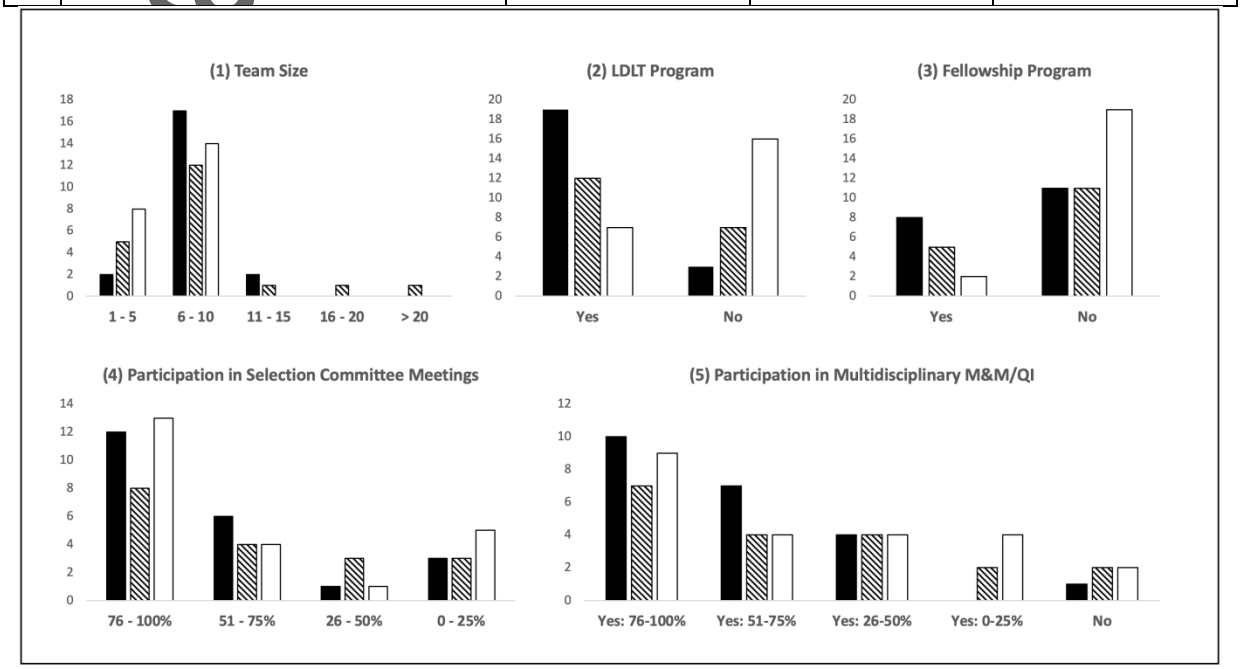

Figure 1. Demographic and logistical information about liver transplant anesthesia teams. (1) Reported LT
team size at responding centers. (2) Number of responding programs with LDLT programs and (3) transplant anesthesia fellowship programs, respectively. (4) Participation in selection committee meetings
and (5) multidisciplinary M&M/QI meetings, responses indicate average percentage of meetings attended.
High volume centers – black, medium volume centers – striped, low volume centers – white.

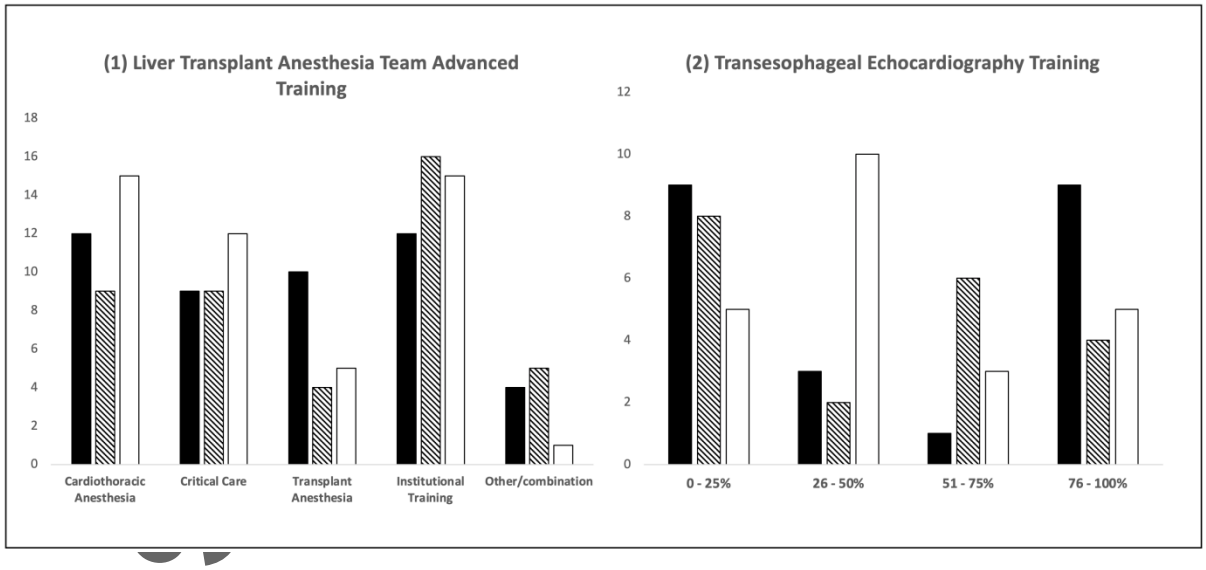

Figure 2. Advanced training by liver transplant anesthesia team members. (1) Advanced/fellowship training
by team members among responding programs, programs could choose more than one option in order to
fully represent their teams typical training. (2) Average percentage of team members that have advanced
transesophageal echocardiography (TEE) training, in either Basic or Advanced Perioperative Echocardiography including Testamur and Diplomate status by the National Board of Echocardiography.
High volume centers – black, medium volume centers – striped, low volume centers – white.

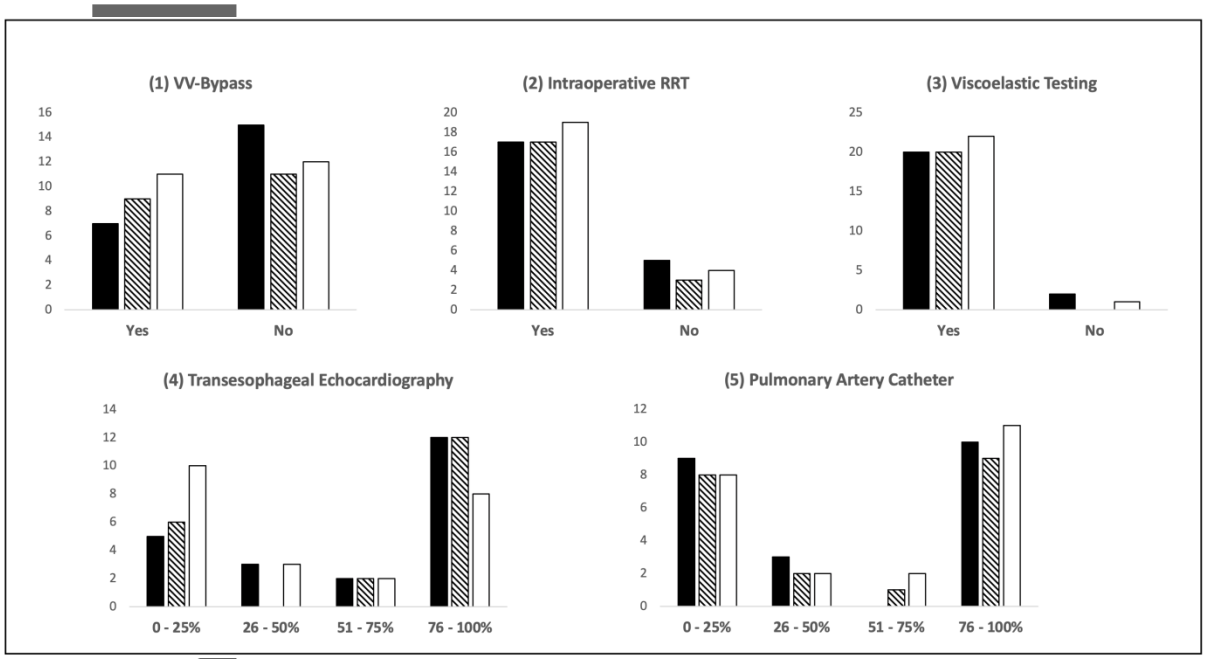

Figure 3. Intraoperative management of liver transplant patients. (1) Number of responding programs that
utilize veno-veno bypass, (2) intraoperative renal replacement and (3) viscoelastic testing. (4) Number of
responding programs that use transesophageal echocardiography (TEE) or (5) pulmonary artery catheters
(PAC) and average percentage of cases used.
High volume centers – black, medium volume centers – striped, low volume centers – white.

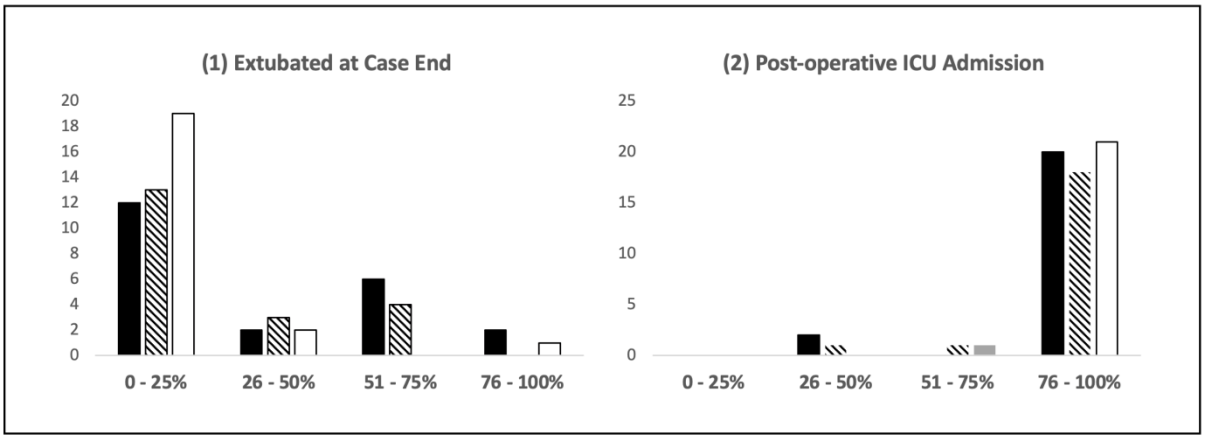

Figure 4. Post-operative care among responding centers; (1) average percentage of cases extubated in the
operating room at case end and (2) average percentage of cases admitted to the ICU post-operatively. High volume centers – black, medium volume centers – striped, low volume centers – white.