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Perioperative Pleural Drainage in Liver Transplantation: A Retrospective Analysis from a High-Volume Liver Transplant Center

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Background: Pleural effusions represent a common complication after liver transplantation (LT) and chest drain (CD) placement is frequently necessary.

Material/Methods: In this retrospective cohort study, adult LT recipients between 2009 and 2016 were analyzed for pleural effusion formation and its treatment within the first 10 postoperative days. The aim of the study was to compare different settings of CD placement with regard to intervention-related complications.

Results: Overall, 597 patients met the inclusion criteria, of which 361 patients (60.5%) received at least 1 CD within the study period. Patients with a MELD >25 were more frequently affected (75.7% versus 56.0%, *P*<0.001). Typically, CDs were placed in the intensive care unit (ICU) (66.8%) or in the operating room (14.1% during LT, 11.5% in the context of reoperations). In total, 97.0% of the patients received a right-sided CD, presumably caused by local irritations. Approximately one-third (35.4%) of ICU-patients required pre-interventional optimization of coagulation. Of the 361 patients receiving a CD, 15 patients (4.2%) suffered a post-interventional hemorrhage and 6 patients (1.4%) had a pneumothorax requiring further treatment. Less complications were observed when the CD was performed in the operating room compared to the ICU: 1 out 127 patients (0.8%) versus 20 out of 332 patients (6.0%); *P*=0.016.

Conclusions: CD placement occurring in the operating room was associated with fewer complications in contrast to placement occurring in the ICU. Planned CD placement in the course of surgery might be favorable in high-risk patients.

MeSH Keywords: **Chest Tubes • Liver Transplantation • Pleural Effusion • Postoperative Complications**

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Background

Liver transplantation (LT) remains the only curative therapy for end-stage liver disease; LT was first performed more than 50 years ago. Due to increasing clinical experience, as well as improvements in immunosuppression, survival rates have improved in the intervening years [1,2]. In order to further improve the prognosis of liver transplant recipients, the management of postoperative complications has gained priority, considering that the rate of postoperative complications remains high [3].

The most common postoperative pulmonary complication following LT is a pleural effusion, with a reported incidence between 32% and 47% [4], and an association with a significantly decreased short-term survival [5]. Effusions are most commonly identified unilaterally on the right side, are occasionally bilateral and only rarely left-sided in isolation [5–7]. The necessity of chest drain (CD) placement varies between 22.0% and 52.0% among these patients [5,6,8]. Amongst others, the improvement of oxygenation [9,10] and pneumonia prophylaxis [11,12] are the fundamental intentions of treating pleural effusions. However, the benefits of this intervention must be weighed against possible complications of CD insertion. Predominant problems after CD are pneumothorax and hemorrhage. Varying incidences have been reported, mostly for thoracentesis only, without tube insertion. Pneumothoraxes are reported in 0% to 3% of patients and are associated with higher costs and longer hospital stays [13–15]. A study analyzing cirrhotic patients only – and therefore emphasizing a high-risk population – reported an incidence of 8.4% for pneumothorax after therapeutic thoracentesis in this population [16]. Hemorrhagic complication rates range from 0% to 2% [13]. Although the majority of recent studies in general populations do not recommend optimizing coagulation prior to pleural drainage placement, current guidelines recommend that non-urgent CD insertion should be avoided if the international normalization ratio (INR) is >1.5 [17,18]. In addition, in clinical practice expensive fresh frozen plasma and platelet concentrates are frequently administered to patients at higher risk of bleeding when interventions are required.

Although pleural effusion is a well-documented complication in the early phase following LT, data regarding the frequency of interventions and incidence of post-interventional complications remain scarce.

Thus, the aim of this study was to investigate the incidence of post-LT pleural effusions requiring drainage and to analyze the post-interventional complications in a high-volume transplant center to help inform future improvements in the management of one of the most common complications following LT.

Material and Methods

Study design

This retrospective cohort study was conducted at the transplantation center of the Charité University Hospital, Berlin, Germany. Patients receiving single liver or combined (multivisceral or liver-kidney) transplantation between January 2009 and December 2016 were included. Donor organs were derived from deceased (full size and split grafts) as well as living donors. The observation period ended at postoperative day 10, as the focus of this study was on the early postoperative phase. If patients required retransplantation during the initial 10 days, this was accounted as a reoperation and the observation period ended at postoperative day 10 after retransplantation. If patients required a retransplantation after the initial 10 days, this was treated as a separate case. Patients under the age of 18 years old were excluded, as were recipients receiving combined liver-lung and/or liver-heart transplantation, due to the routine necessity of chest drains following intrathoracic surgery.

Definitions

Each patient received a chest x-ray directly prior to LT as part of the routine preparation at our center, which was the baseline for this study. In the postoperative phase experienced surgeons and/or intensive care specialists on our specialized LT intensive care unit (ICU) indicated the necessity for CD placement using thoracic ultrasound. There is currently no published guideline for stating the precise indications for CD in pleural effusion (e.g., specific volume of the effusion), especially not in this group of postoperative patients. Therefore, the indication was determined using clinical experience and depending on respiratory limitations, which corresponds with the recommendations of the Spanish Society for Pulmonology and Thoracic Surgery [17,19,20]. Different types of CDs were used: Pleuracan© (B. Braun Melsungen AG, Melsungen, Germany) or Thal-Quick Chest Tube Set from Cook Medical© (COOK MEDICAL LLC, Bloomington, IN, USA) via needle puncture, surgical suction drainage (Bülau drain) and thoracentesis without tube insertion. The cutoff values for correction of bleeding risks were thrombocytes <50 000/µL and partial thromboplastin time >50 seconds. In line with the guidelines for pneumonia, published by the Centers for Disease Control and Prevention, pneumonia was defined as a new lung infiltrate plus leukocytosis or leukopenia and/or new onset of fever plus clinical evidence for pulmonary infection and/or a positive sputum culture [21].

Data collection

For data collection, electronic records of all patients who met the study criteria were used. This included ICU records, surgical

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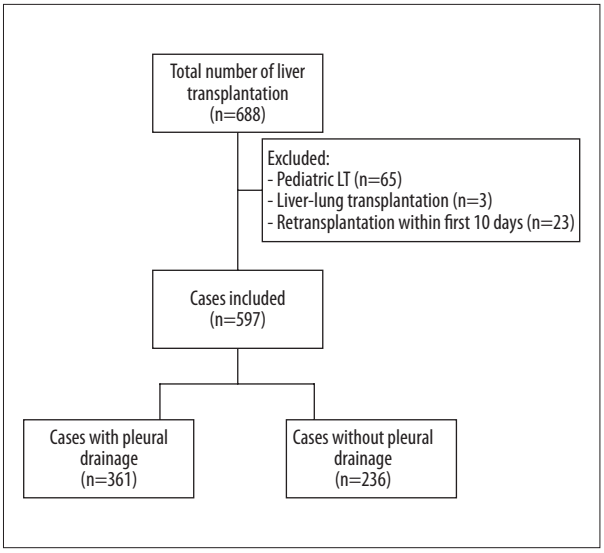

Figure 1. Flowchart of the study population. LT – liver transplantation.

records, and radiological reports. Donor, recipient, and transplantation characteristics were included to identify risk factors for pleural effusions. The primary endpoint of the study was the rate of required interventions due to pleural effusions during surgery or within 10 days following LT. Secondary outcome measurements included the number of administered blood products for pre-interventional correction of bleeding risks, post-interventional complications, short-term patient survival, and the development of pneumonia.

Statistical analyses

Categorical data are presented as frequencies and percentages and were compared using Pearson chi-squared tests. Continuous data are presented as either mean and standard deviation and was compared by independent 2 sample t-tests if parametric or as median and interquartile range and compared by Mann-Whitney U tests if non-parametric. Logistic regression was carried out to identify risk factors for necessitating thoracic drainage. Variables significant in univariate analysis were then studied in multivariate regression models using both forward and backward procedures with a significance level of 0.05 for model entry and 0.10 for exclusion. For all variables considered for multivariable regression missing data was maximum 3.7% and therefore no procedures to impute missing data were used. All statistical analyses were carried out using IBM SPSS Statistics (IBM Corporation, Armonk, NY, USA, version 24) and a *P*-value of <0.05 was considered significant. The study was approved by the local ethic commission (Charité's Ethics Committee and approval number EA1/369/16).

Results

During the study period, 688 LTs were performed, of which 597 patients fulfilled all the inclusion criteria; 65 patients were excluded because they were pediatric recipients and 3 patients received combined liver-lung transplantation. There were 23 retransplantations performed within the first 10 days following LT, which were, therefore, not categorized as separated cases (Figure 1).

Of these 597 patients, 361 patients (60.5%) received at least 1 CD within the first 10 days after LT, during LT, or already had a CD prior to LT, with a total amount of 497 drainages. Patients who received a CD had a significantly lower body mass index (BMI) (26.2 versus 28.0; $P<0.001$) and a higher Model for End-stage Liver Disease (MELD) score [22] preoperatively ($P<0.001$). In a high-risk patient cohort with a laboratory MELD > 25 prior to LT a total of 119 patients (75.7%) required CD compared to 232 patients (56.0%) with a pre-transplant laboratory MELD ≤25 ($P<0.001$) (Table 1).

Calculated mean laboratory MELD score was 17.7 in the group of patients without pleural drainage and 22.0 in the group of patients with pleural drainage ($P<0.001$; median laboratory MELD 16 versus 22, $P<0.001$). Mean match MELD score (used for allocation by Eurotransplant) which includes MELD score exceptions (e.g., for patients with a diagnosis of hepatocellular carcinoma) was 23.8 for patients without chest drain and 26.9 for patients with chest drain ($P<0.001$; median match MELD 24 versus 28, $P<0.001$). Furthermore, existing survival-outcome scores like balance of risk score (BAR) [23] and D-MELD score [24] were significantly elevated in the drainage-requiring cohort ($P<0.001$ and $P=0.002$). Patients dependent on life support prior to LT – defined as dialysis ($P=0.009$), mechanical ventilation ($P<0.001$) and catecholamine therapy ($P<0.001$) – were prone to receive a CD. Regarding intraoperative risk factors these patients received a greater number of packed red blood cells and fresh frozen plasma (both $P<0.001$), underwent multi-organ transplantation more often and operation time was longer ($P=0.001$). Concerning donor characteristics, donors of patients who received a CD were younger and had a lower BMI ($P=0.048$ and $P<0.001$), but donor risk index [25] was comparable ($P=0.133$). After LT, recipients of the drainage-group showed twice as long ICU stays (14 days versus 7 days $P < 0.001$) and longer total hospital stays (38 days versus 29 days $P<0.001$).

Using univariable logistic regression the following risk factors were found significant for CD placement: retransplantation, recipient BMI, laboratory MELD, INR, creatinine (md/dL), total bilirubin (mg/dL), urea (mg/dL), hospitalization status before LT (home, hospital, ICU), need for hemodialysis, catecholamine therapy, ventilation, surgery duration, transfusions of red blood cells and fresh frozen plasma, BAR score, Model

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Table 1. Patient, donor and perioperative characteristics by necessity of pleural drainage (n=597).

	Patients with pleural drainage (n=361)		Patients without pleural drainage (n=236)		p-Value
Recipient age*	52.9	(11.4)	53.5	(10.8)	0.548
Gender: male sex***	228	(63.2%)	156	(66.1%)	0.463
Recipient BMI*	26.2	(5,1)	28.0	(5.1)	**<0.001**
High urgency patients***	36	(10.0%)	16	(6.8%)	0.176
Last recertificated laboratory MELD**	20	(12–33)	16	(11–22)	**<0.001**
Pretransplant laboratory MELD**	20	(11–31)	16	(10–22)	**<0.001**
matchMELD**	28	(20–36)	24	(17–29)	**<0.001**
Dialysis before LT***	69	(19.1%)	26	(11.0%)	**0.009**
Mechanical ventilation before LT***	47	(13.0%)	9	(3.8%)	**<0.001**
Catecholamines prior LT***	46	(12.7%)	6	(2.5%)	**<0.001**
Donor age*	54.0	(16.5)	56.8	(17.0)	**0.048**
Donor BMI*	25.4	(3.9)	26.8	(4.8)	**<0.001**
Living donor***	9	(2.5%)	10	(4.2%)	0.235
Donor risk index*	2.4	(0.5)	2.5	(0.6)	0.133
BAR*	9.7	(6.2)	7.3	(5.0)	**<0.001**
D-MELD*	1157	(668)	997	(583)	**0.002**
Cold ischemia time (min)*	552.2	(176.6)	556.8	(193.5)	0.764
Split graft***	9	(2.5%)	10	(4.2%)	0.573
Surgery duration (min)*	366.0	(111.6)	339.6	(80.5)	**0.001**
Multi-organ LT***	14	(3.9%)	2	(0.8%)	**0.025**
PRBCs (units)**	8	(5–13)	6	(3–8)	**<0.001**
FFP (units)**	24	(16–33)	20	(15–27)	**<0.001**
ICU stay after LT (days)**	14	(7–39)	7	(5–13)	**<0.001**
Hospital stay after LT (days)**	38	(24–68)	29	(21–45)	**<0.001**

* Mean+standard deviation; ** median+interquartile range; *** count (percentage). BAR – balance of risk; BMI – body mass index; FFP – fresh frozen plasma; ICU – Intensiv Care Unit; LT – liver transplantation; MELD – Model for End-Stage Liver Disease; PRBCs – packed red blood cells.

for End-Stage Liver Disease – Sodium (MELD-Na) [26], 5-variable MELD [27], donor age and donor BMI. In the multivariable analysis recipient BMI (odds ratio (OR) 0.95, 95% CI 0.91–0.98, *P*=0.004), urea (OR 1.01, 95% CI 1.00–1.01, *P*=0.020), hospitalization status (OR 1.49, 95% CI 1.14–1.93, *P*=0.003), number of intraoperative red blood cell transfusions (OR 1.05, 95% CI 1.02–1.08, *P*=0.003) and donor BMI (OR 0.95, 95% CI 0.92–0.99, *P*=0.029) remained significant as risk factors (Table 2). The Hosmer Lemeshow test showed a significance of *P*=0.885 for this model, indicating an adequate goodness-of-fit.

Localization of pleural effusion requiring drainage was considerably unequal. Of all patients with pleural drainages, 350 patients (97%) received a CD on the right-hand side, only 11 patients (3.0%) had an isolated left-sided CD and 96 patients (26.6%) received bilateral drainage (Figure 2). Pleural drainage placement was performed at 3 different time points: pretransplantation, during LT, and post-transplantation. Typically, CD insertion was carried out after LT (n=394; 79.2%), mostly in the ICU as a bedside procedure (n=332; 66.8%), during reoperations (n=57; 11.5%) or postoperatively via computed

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Table 2. Risk factors associated with necessity of chest drain placement in logistic regression.

	Univariable analysis			Multivariable analysis		
	Odds ratio	95% confidence interval	p-value	Odds ratio	95% confidence interval	p-value
Recipient age			0.548			
Recipient sex			0.463			
Recipient BMI	**0.93**	**0.90–0.96**	**<0.001**	**0.95**	**0.91–0.98**	**0.004**
Waiting time			0.304			
Retransplantation	2.59	1.34–5.02	**0.005**			0.575
matchMELD	1.04	1.02–1.05	**<0.001**			0.797
Last laboratory values before LT						
Laboratory MELD	1.04	1.02–1.06	**<0.001**			0.691
INR			0.368			
Serum creatinine (mg/dl)	1.28	1.08–1.52	**0.004**			0.717
Total bilirubin (mg/dl)	1.04	1.02–1.06	**<0.001**			0.985
Serum urea (mg/dl)	**1.01**	**1.01–1.02**	**<0.001**	**1.01**	**1.00–1.01**	**0.020**
Aspartate transaminase (U/l)			0.073			
Alanine transaminase (U/l)			0.996			
Gamma-Glutamyl-tramsferase (U/l)			0.286			
Albumin (g/dl)			0.202			
Serum sodium (mmol/l)			0.750			
Urgency status			0.179			
Hospitalization status	**1.85**	**1.46–2.33**	**<0.001**	**1.49**	**1.14–1.93**	**0.003**
Dialysis	1.90	1.17–3.08	**0.009**			0.081
Catecholamine therapy	5.62	2.36–13.37	**<0.001**			0.081
Ventilation	3.79	1.82–7.89	**<0.001**			0.998
Split graft			0.574			
Cold ischemic time (min)			0.764			
Surgery duration (min)	1.003	1.00–1.01	**0.002**			0.253
Multi-organ LT	4.72	1.06–20.96	**0.041**			0.139
PRBCs (units)	**1.07**	**1.04–1.10**	**<0.001**	**1.05**	**1.02–1.08**	**0.003**
FFPs (units)	1.03	1.01–1.04	**<0.001**			0.402
BAR Score	1.08	1.04–1.11	**<0.001**			0.817
MELD-Na	1.04	1.02–1.06	**<0.001**			0.589
Five-variable MELD	1.04	1.03–1.06	**<0.001**			0.653
Donor age	0.99	0.98–1.0	**0.049**			0.807
Donor BMI	**0.93**	**0.89–0.97**	**<0.001**	**0.95**	**0.92–0.99**	**0.029**
Donor Sex	0.66	0.48–0.92	**0.014**			0.341
Regional allocation			0.402			
Donor risk index			0.138			

BAR – balance of risk; BMI – body mass index; FFP – fresh frozen plasma; INR – International Normalized Ratio; LT – liver transplantation; MELD – Model for End-Stage Liver Disease; PRBCs – packed red blood cells.

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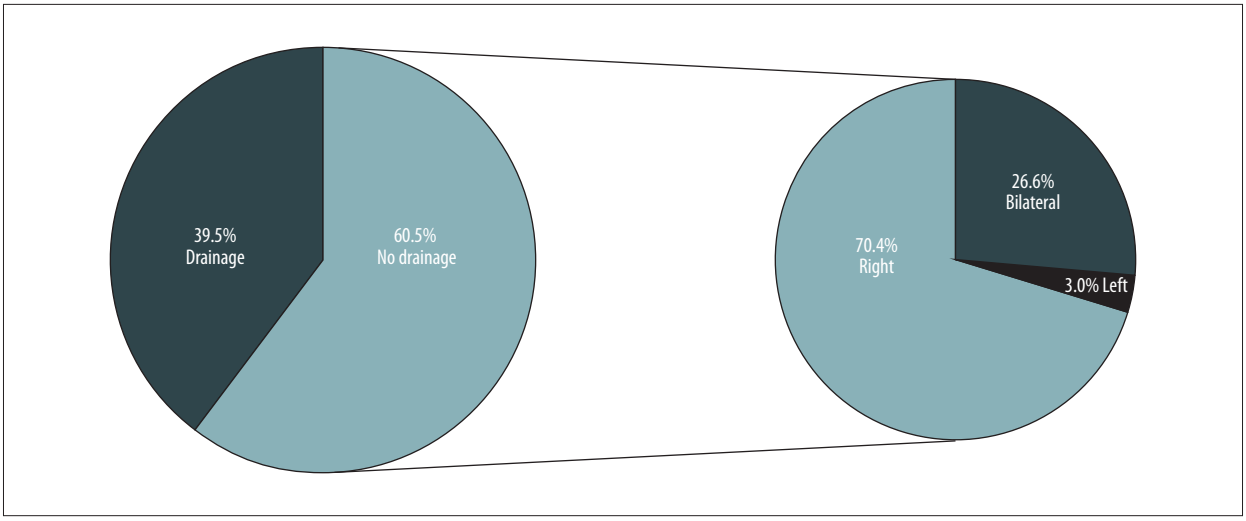

Figure 2. Patients receiving pleural drainage before, during or in the first ten days after liver transplantation and the localization thereof (study group n=597; patients with pleural drainage n=361).

Table 3. Complications after pleural drainage during or after liver transplantation by setting and used technique.

	Setting			
	Total placements (n=459)	**During LT (n=70)**	**In ICU (n=332)**	**During Re-OP (n=57)**
Total complications	21 (4.6%)	0	20 (6.0%)	1 (1.8%)
Pneumothorax	6 (1.3%)	0	6 (1.8%)	0
Hemorrhage	15 (3.3%)	0	14 (4.2%)	1 (1.8%)
No complications	438 (95.4%)	70 (100%)	312 (94.0%)	56 (98.0%)
	Technique			
	Bülau drain (n=297)	**Pleuracan© (n=109)**	**Cook Medical© (n=27)**	**Single puncture (n=26)**
Total complications	13 (4.4%)	5 (4.6%)	2 (7.4%)	1 (3.8%)
Pneumothorax	5 (1.7%)	0	0	1 (3.8%)
Hemorrhage	8 (2.7%)	5 (4.6%)	2 (7.4%)	0
No complications	284 (95.6%)	104 (95.4%)	25 (96.2%)	25 (96.2%)

ICU – Intensive Care Unit; LT – liver transplantation.

tomography guided punctures (n=5; 1.0%). The median time-period for CD insertion after LT was 3 days with an interquartile range of 2 to 5 days. CD placement before (n=33; 6.6%) or during LT (n=70; 14.1%) was performed less frequently. Except for the small group of patients receiving CD placement before LT, patients did not show relevant pleural effusions in pre-LT chest x-rays. In accordance with Imai et al., an isolated blunting of the costophrenic angle was not classified as a relevant pleural effusion for the purpose of this study [28]. Mean drainage volume for CD placed during LT was 774.2 mL in the first 24 hours and 1923.3 mL in the first 5 days. Overall CDs placed after LT drained an average of 848.5 mL of pleural fluid in the first 24 hours and those placed after LT in ICU drained mean pleural fluid volumes of 892.4 mL in the first 24 hours.

If the intervention was performed in the ICU, 112 patients (35.4%) received pre-interventional optimization of coagulation. Most patients (63 patients; 56.3%) received fresh frozen plasma, 30 patients (26.8%) thrombocytes and 19 patients (17.0%) received both. In average, patients received 2 units of the applied blood products (fresh frozen plasma: 2 (IQR 2–3); platelets: 2 (IQR 1–2)). Two different types of CD were used predominantly, the puncture set "Pleuracan©" (n=124; 24.9%) or surgical suction drainage (Bülau drain, n=315; 63.4%). The CD from Cook Medical was used in 32 interventions (6.4%)

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and thoracentesis without tube insertion was only performed in 26 procedures (5.2%). Regarding complications, no differences (*P*=0.927) were observed comparing the 2 predominant techniques (Table 3).

CD placement-related complications included pneumothorax and hemorrhage (Table 3). Six patients developed pneumothorax requiring further medical treatment, all 6 cases occurring after CD insertion in the ICU. There were 13 of 14 post-interventional bleedings that occurred in the ICU, whereas only 1 LT recipient suffered from hemorrhage during a reoperation. In 2 patients, surgical removal of the hematoma was necessary. No CD-related complications were developed after placement during LT. Correspondingly, complication rates after placement of CD were significantly higher in the ICU compared to LT or compared to all intraoperative procedures (*P*=0.035 and *P*=0.016 respectively).

Assuming a concept of pre-emptive right-sided CD inserted during LT in all patients, a number needed to treat (NNT) analysis revealed an NNT of 28 to prevent 1 complication of postoperative CD placement. In high-risk patients with a laboratory MELD of >25 prior to LT the NNT was 12.

When analyzing the pneumonia rate in our cohort we found that out of 597 patients, 75 patients (12.6%) developed pneumonia during the first 10 days after LT. No significant differences between patients with and without CD were noted (13.9% versus 10.6%; *P*=0.240). Despite representing sicker patients and a higher complication risk, patients with CD placement did not show inferior survival after LT (*P*=0.463 for 3-month patient survival).

Discussion

We determined that a considerable proportion of LT recipients suffer a pleural effusion requiring drainage in the early postoperative phase. Among the 597 patients in our cohort, nearly two-thirds underwent chest tube placement within the first 10 days after surgery, presumably due to local irritations considering that 97% of patients received a CD to the right hemithorax. Critically ill patients with a higher laboratory MELD and those dependent on hemodialysis, mechanical ventilation, or catecholamine therapy prior to LT were especially affected. Furthermore, a significant correlation between procedure-related parameters such as duration of surgery and the necessity of blood product administration was found. More than two-thirds of CD placements were performed bedside in the ICU, but intervention in the operation room was shown to be safer with regards to procedural complications. Moreover, ICU patients frequently received coagulation products prior to intervention, while patients undergoing surgery had no need for additional coagulation products.

In the existing literature, reported incidences for post-LT pleural effusion vary notably from 18.4% to 96.5% [5,29], but are mostly described as between 35% and 70% [6–8,30,31]. Among all analyzed patients between 9.1% and 32.4% required a pleural drainage, which corresponds to 18% to 52% of patients with pleural effusion [5–8,31]. In our cohort, we found a significantly higher incidence of drainage-relevant effusions. This is most likely because the patients in our cohort were sicker, as reflected by higher MELD scores [30,32,33]. In the German liver transplant allocation system, the MELD score is differentiated between a calculated laboratory MELD score and a match MELD score with exceptions for patients whose disease severity is not adequately reflected by the laboratory MELD score. Other allocation systems, used in the cited studies, only state the final allocation MELD. The considerable difference between laboratory MELD score and match MELD score in our study group can be best explained by the fact that 34.2% of all patients received allocation via MELD score exception. MELD score itself has been shown to be a risk factor for the development of pulmonary complications after LT [4,6,30,32]. Possible other risk factors contributing to the high incidence of pleural effusions found in our study cohort include the relatively high incidences of pre-transplant mechanical ventilation or renal insufficiency and high numbers of intraoperative blood transfusions [6,7,33,34]. In conclusion, the high incidence of various risk factors for pulmonary complications after LT could explain the high incidence of chest drainages seen in this study.

The increased MELD score in our cohort compared to other studies represents the increasing gap between required and available organs in Germany [35]. This inevitably results in higher MELD scores prior to LT [36], which is known to lead to inferior patient as well as graft survival, a prolonged ICU and hospital stay, higher intensive care unit costs [37], more administered blood products [38], delayed extubation [39] and – as demonstrated here – increased pleural effusion rate. However, in times of organ scarcity, these MELD-related effects gain more importance in other countries as well. Currently, MELD-based liver allocation has become widely accepted as the basis for organ allocation and increasing MELD scores at the point of LT have been reported in other countries [40]. The incidence of pleural effusion after LT can only be expected to increase with rising MELD scores and the management of pulmonary complications after liver transplantations shall gain increasing focus.

In general, the high incidence of drainage-relevant pleural effusions may be explained by various factors in liver transplant recipients: 1) low serum albumin levels and postoperative hypoproteinemia [4]; 2) high rates of intraoperative blood and fluid transfusions are associated with postoperative pulmonary complications and early postoperative pneumonia [6,7,32,41]; 3) local mechanisms at the right side of the diaphragm probably play an additional role. Diaphragmatic defects are a known

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cause of hydrothorax [42] and right hemidiaphragmatic paralysis caused by right phrenic nerve injury during LT is a recognized cause of right lower lobe atelectasis [43]. Despite the high incidence, little is known regarding possible complications in this unique patient group. Given the critical state of these patients, it seems fundamental to optimize the treatment of this common complication to reduce morbidity. We were able to identify several risk factors for CD placement, including intraoperative red blood cell transfusion, pre-transplant hospitalization status, recipient and donor BMI and serum urea. These statistical risk factors certainly require critical evaluation. Recipient and donor BMI are highly selected before LT and therefore difficult to interpret: While severe obesity may represent a relative contraindication for receiving LT [44,45], sarcopenia and frailty – as known risk factors for post-transplant outcomes – are likely to be more pronounced in recipients with a low BMI [46,47]. Likewise, organs of obese donors are probably less used for LT due to concomitant steatosis [48]. Nevertheless, the number of intraoperative blood transfusions and the recipient's overall health status, reflected by their hospitalization status before LT, appear to be suitable and easily applicable risk factors for the necessity of CD. Together with other described risk factors for pleural effusion after LT such as a higher preoperative MELD score [6], these could be used to select patients who would benefit from preemptive intervention, e.g., intraoperative CD during LT.

Further subgroup analysis was performed for drainage type (placement via needle puncture or surgical approach) and the circumstances of the application (operation room or the ICU). Decisions for indication, drainage type, and time point of the intervention were made by the responsible clinician. Whereas the type of drainage inserted did not alter significant relevance, the setting of CD procedure played a major role. The majority of CDs were performed post-LT bedside in the ICU under ultrasound guidance; others were placed directly during LT or in the context of reoperations. The rates of pneumothorax as well as of hemothorax after intraoperative CD placements were significantly lower compared to the interventions in the ICU. Furthermore, no additional optimization of coagulation was necessary as coagulation had been routinely optimized during major surgery. Although the necessity for coagulation products prior to minor interventions such as pleural drainage [18] is controversial, reducing the risk of bleeding by transfusion of fresh frozen plasma and platelets was performed in more than one-third of all drainage insertions in the ICU. However, blood product transfusion itself can cause side-effects, e.g., transfusion-related acute lung injury, acute and delayed transfusion reactions or at least unnecessary immunological sensitization [49–51]. In addition, blood products also represent an economic burden for hospitals and health systems [52]. Hence, intraoperative CD insertion represents an opportunity to reduce the total amount of administered blood and coagulation products. Different aspects likely contribute to our finding of safer placement in the OR compared to ICU. The overall setting is more controlled in the OR (e.g., patient position and equipment), and experience of the executing clinician may also vary between OR and ICU: placement during LT has the advantage of the attendance of a highly experienced surgeon. The prevention of potential complications and the reduction of blood transfusions could be benefits of preemptive placement of CD drains during surgery, especially in liver recipients with high risk for development of pulmonary complications.

In addition to better oxygenation, pneumonia prophylaxis represents an important indication for the drainage of pleural effusions as most cases of bacterial pneumonia after LT occur on the base of pleural effusion or atelectasis [31]. Interestingly, in our study no differences in pneumonia rates between the drainage group and the no-drainage group were identified. This might be interpreted as a positive result, because the group with need for a CD presented more pulmonary risk factors. Therefore, one would have expected this group to develop pneumonia more frequently, which did not occur.

Although CD placement can be referred to as a standard procedure, our findings show that there remains room for improvement in morbidity regarding pleura effusion-related complications, especially in a cohort of critically ill liver transplant recipients.

The concept of pre-emptive placement of right-sided CD in every patient immediately post-LT is not entirely new and was recommended by Lin et al. in 2010 [6]. Since then, the concept has seen little attention and at the time of publication there was only 1 existing study on a preemptive approach for CD insertion before LT: in a living donor LT cohort in Japan; Imai et al. analyzed risk factors for postoperative atelectasis and accordingly performed preoperative thoracic drainage if risk factors were present. They demonstrated that the group with preemptive thoracic drainage for at-risk patients showed significantly less atelectasis after LT, contracted pneumonia at a lower incidence and had a shorter ICU stay [28]. Despite major differences in LT between Japan and Germany (e.g., percentage of living donor transplantations [53]) these findings support the concept of preemptive CD to reduce morbidity.

Our study had some limitations. Firstly, data generation was conducted retrospectively in a single LT center. Due to its observational design, there was no rigid study protocol for the indication for CD insertion. Indications and procedure of CD placement may vary between different medical systems, transplantation centers and between clinicians, which decreases the generalizability of our findings.

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Conclusions

In conclusion, pleura effusion is one of the most common complications after LT and a majority of patients require interventional treatment. CD placement in LT recipients was associated with fewer complications if performed in the OR during LT or reoperations compared to placement on ICU. Further prospective studies should evaluate preemptive CD placement during LT, especially in high-risk patients.

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Conflicts of interest

None.

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