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Original Article

Role of Computed Tomography in Detection of Early Postoperative Complications After Liver Transplantation

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ABSTRACT

Background: Liver transplantation is a definitive treatment for end-stage liver disease and selected hepatic malignancies, but early postoperative complications remain important causes of graft dysfunction, morbidity, and mortality. Computed tomography provides rapid multidomain assessment of vascular, biliary, parenchymal, and extrahepatic abnormalities after transplantation. Objective: This study aimed to evaluate the role of computed tomography in detecting early postoperative complications after liver transplantation. Methods: A retrospective cross-sectional observational study was conducted among 139 adult liver transplant recipients who underwent contrast-enhanced CT for transplant-related assessment or postoperative evaluation. Data regarding gender, transplant type, CT indication, and CT-detected vascular, biliary, parenchymal, and extrahepatic complications were analyzed using descriptive statistics and subgroup comparisons by gender and transplant type. Results: The cohort included 77 males (55.4%) and 62 females (44.6%); 77 recipients (55.4%) underwent DDLT and 62 (44.6%) underwent LDLT. CT was performed for pre-transplant assessment in 74 patients (53.2%) and post-transplant evaluation in 65 patients (46.8%). Biliary complications were detected in 72 patients (51.8%), vascular complications in 71 (51.1%), parenchymal complications in 66 (47.5%), and extrahepatic complications in 58 (41.7%). No statistically significant association was observed between complication occurrence and gender or transplant type. Conclusion: CT is a valuable imaging modality for comprehensive early detection of post-liver transplant complications and supports timely clinical decision-making. Keywords: Liver transplantation, computed tomography, vascular complications, biliary complications, parenchymal complications, postoperative imaging.

INTRODUCTION

Liver transplantation is an established life-saving treatment for patients with end-stage liver disease, acute liver failure, and selected hepatic malignancies, with substantial improvements in perioperative survival achieved through advances in surgical technique, donor selection, organ preservation, perioperative care, and immunosuppressive therapy (1). Despite these advances, early postoperative complications remain a major determinant of graft dysfunction, morbidity, re-intervention, prolonged hospitalization, and mortality. These complications may involve vascular, biliary, parenchymal, or extrahepatic systems, and timely detection is essential because delayed recognition of arterial thrombosis, portal venous compromise, biliary leakage, graft ischemia, abscess formation, or intra-abdominal sepsis can rapidly progress to irreversible graft injury and graft loss (2).

Imaging plays a central role across the liver transplantation pathway, beginning with preoperative donor and recipient assessment and extending into urgent postoperative evaluation. Doppler ultrasonography is commonly used as an initial surveillance modality because it is non-invasive, widely available, and free from ionizing radiation; however, its diagnostic performance may be limited by operator dependence, postoperative dressings, bowel gas, patient body habitus, limited acoustic windows, and difficulty in assessing complex deep-seated collections or extrahepatic pathology (3). In contrast, contrast-enhanced computed tomography provides rapid acquisition, high spatial resolution, multiplanar reconstruction, and simultaneous assessment of hepatic arterial, portal venous, hepatic venous, biliary, parenchymal, and thoracoabdominal structures in a single examination, making it particularly valuable when clinical deterioration requires urgent diagnostic clarification (4).

In the pre-transplant setting, computed tomography contributes to surgical planning by defining hepatic morphology, vascular anatomy, portal venous patency, hepatic venous drainage, tumor burden, collateral circulation, ascites, splenomegaly, and other features that may affect operative feasibility and perioperative risk (5). In living donor liver transplantation, CT-based vascular mapping and volumetric assessment are particularly important because donor safety and recipient graft adequacy depend on accurate estimation of graft volume, remnant liver volume, and vascular or biliary anatomical variants (6). These preoperative roles support safe operative planning, but the postoperative value of CT becomes even more critical when early complications threaten graft viability.

Vascular complications are among the most serious postoperative events after liver transplantation. Hepatic artery thrombosis, hepatic artery stenosis, portal vein thrombosis, portal vein stenosis, and hepatic venous or inferior vena cava outflow obstruction may lead to graft ischemia, biliary necrosis, infarction, sepsis, and graft failure if not detected promptly (7). Multiphasic CT, particularly arterial-phase imaging and CT angiography reconstructions, can demonstrate luminal narrowing, abrupt vascular cutoff, thrombosis, reduced enhancement, pseudoaneurysm formation, and secondary perfusion abnormalities within the graft parenchyma (8). Because many vascular complications require urgent endovascular or surgical intervention, rapid CT-based detection has direct clinical relevance in the early postoperative period.

Biliary complications are also frequent after liver transplantation and include bile leaks, bilomas, anastomotic strictures, non-anastomotic strictures, and ischemic cholangiopathy (9). Although magnetic resonance cholangiopancreatography provides superior ductal detail in stable patients, CT remains highly useful in acutely unwell recipients because it can rapidly identify perihepatic collections, biliary dilatation, abscess formation, vascular compromise, and associated intra-abdominal pathology during the same examination (10). This combined assessment is clinically important because biliary complications may occur secondary to vascular insufficiency, particularly hepatic arterial compromise, and isolated ductal imaging may fail to capture the full postoperative picture.

Computed tomography also contributes to the diagnosis of graft parenchymal and extrahepatic complications. Parenchymal abnormalities such as ischemia, infarction, perfusion defects, abscesses, hematomas, seromas, and bilomas can be differentiated on the basis of attenuation pattern, enhancement characteristics, gas formation, rim enhancement, and anatomical location (11). Extrahepatic complications, including pleural effusion, pneumonia, bowel ileus, bowel ischemia, intra-abdominal hemorrhage, peritonitis, and sepsis-related collections, may substantially worsen postoperative recovery and may not be fully evaluated by liver-focused ultrasound alone (12). Therefore, CT serves not only as a modality for graft assessment but also as a comprehensive postoperative problem-solving tool.

Despite the recognized value of CT in transplant imaging, local evidence regarding CT-detected early postoperative complications after liver transplantation remains limited, particularly in settings where imaging workflows, donor patterns, and access to advanced modalities may differ from high-volume international transplant centers. Existing literature supports multiphasic CT for identifying vascular, biliary, parenchymal, and extrahepatic complications, but institution-specific data are needed to describe the local complication profile, guide imaging protocols, and support timely clinical decision-making. The present study was therefore designed to evaluate the role of computed tomography in detecting early postoperative complications after liver transplantation by assessing the frequency and distribution of CT-detected vascular, biliary, parenchymal, and extrahepatic complications among liver transplant recipients. The study hypothesized that multiphasic CT provides a comprehensive and clinically useful assessment for early detection of major postoperative complications after liver transplantation.

MATERIALS AND METHODS

This study was conducted as a retrospective cross-sectional observational study to evaluate the role of computed tomography in detecting early postoperative complications after liver transplantation. The study included adult liver transplant recipients who underwent contrast-enhanced CT imaging either as part of transplant-related assessment or for postoperative clinical evaluation. The retrospective design was selected because the study used existing clinical and radiological records, allowing systematic assessment of CT-detected complications without altering patient management or imaging decisions.

The study was conducted at Social Security Hospital, Lahore, over a four-month study period. A total of 139 liver transplant recipients were included through consecutive sampling. Eligible participants were adults aged 18 years or above who had undergone contrast-enhanced CT imaging for liver transplantation work-up or postoperative evaluation and had sufficient clinical or imaging records available for correlation. Patients were included when CT images were diagnostically adequate for assessment of vascular, biliary, parenchymal, and extrahepatic findings. Patients younger than 18 years, patients with non-diagnostic CT examinations due to severe motion artefact or incomplete phase acquisition, patients with incomplete clinical records, and re-transplant cases without adequate prior documentation were excluded.

Data were retrieved retrospectively from radiology records, CT reports, and available clinical documentation. The extracted variables included age, gender, transplant type, CT indication, and CT-detected postoperative complications. Transplant type was categorized as living donor liver transplantation or deceased donor liver transplantation. CT indication was categorized as pre-transplant assessment or post-transplant evaluation. The primary outcome variables were the presence or absence of vascular, biliary, parenchymal, and extrahepatic complications detected on CT. Vascular complications included hepatic artery thrombosis or stenosis, portal vein thrombosis or stenosis, and hepatic venous or inferior vena cava outflow obstruction. Biliary complications included bile leak, biloma, biliary dilatation, anastomotic stricture, and non-anastomotic stricture. Parenchymal complications included graft ischemia, infarction, perfusion abnormality, abscess formation, hematoma, or other focal graft abnormality. Extrahepatic complications included pleural effusion, pneumonia, bowel-related complications, intra-abdominal collections, ascites, hemorrhage, or sepsis-related thoracoabdominal findings.

Computed tomography examinations were performed using a multidetector CT scanner with contrast-enhanced multiphasic acquisition where clinically indicated. The imaging protocol included non-contrast images for baseline attenuation, hemorrhage, calcification, and collection characterization; arterial-phase images for hepatic arterial patency, arterial stenosis, thrombosis, pseudoaneurysm, and perfusion abnormalities; portal venous-phase images for portal vein patency, graft enhancement, abdominal collections, bowel complications, and extrahepatic pathology; and delayed-phase images when biliary leak, delayed enhancement abnormality, or subtle ischemic change required further evaluation. Axial images were reconstructed with thin slices, and coronal, sagittal, maximum intensity projection, and CT angiographic reconstructions were used where required for vascular mapping and complication assessment.

To improve reproducibility and reduce measurement bias, complication categories were defined before data extraction and applied consistently across all included cases. Imaging findings were recorded using binary categories for each complication domain, and patients could be classified as having more than one complication type when CT demonstrated overlapping abnormalities. This approach was necessary because vascular compromise may coexist with biliary or parenchymal injury in post-transplant patients.

Data were entered using coded identifiers to maintain anonymity and to minimize transcription errors. The dataset was reviewed for completeness before analysis, and cases with incomplete essential variables or non-diagnostic CT studies were excluded from the final analysis.

Potential sources of bias were addressed through consecutive case inclusion, predefined operational definitions, and standardized extraction of demographic, transplant-related, and imaging variables. Selection bias was reduced by including all eligible cases during the study period rather than selectively sampling patients with positive findings. Information bias was minimized by relying on documented CT findings and available clinical correlation. Confounding was considered during subgroup analysis by comparing complication patterns according to gender and transplant type, as these variables may influence postoperative complication profiles.

The sample size was calculated using the single-proportion formula, with a 95% confidence level, expected prevalence of 8%, and 5% margin of error, resulting in a required sample size of 139 participants. Consecutive sampling was used until the required sample size was achieved. The final analyzed sample therefore consisted of 139 eligible liver transplant recipients.

Data were analyzed using Statistical Package for the Social Sciences version 27.0. Continuous variables were summarized using mean and standard deviation or median and interquartile range depending on distribution, while categorical variables were summarized as frequencies and percentages. The frequencies of vascular, biliary, parenchymal, and extrahepatic complications were calculated for the full cohort. Cross-tabulations were performed to compare complication distribution according to gender and transplant type. Chi-square testing or Fisher's exact test was planned for categorical comparisons where assumptions were met. Odds ratios with 95% confidence intervals were planned for clinically relevant subgroup comparisons, including transplant type versus complication category and gender versus complication category. A p-value of less than 0.05 was considered statistically significant. Missing data were assessed before analysis, and variables with incomplete essential information were excluded from relevant calculations without replacing or imputing values.

Ethical approval was obtained from the relevant institutional ethical review body before data collection. As the study used retrospective clinical and imaging records, all data were de-identified before analysis to protect patient confidentiality. No patient names, hospital numbers, or identifying information were used in the analytical dataset or manuscript. The study was conducted in accordance with ethical principles for human participant research, and all extracted information was used solely for academic and research purposes.

RESULTS

This retrospective cross-sectional analysis included 139 liver transplant recipients. The cohort comprised 77 males (55.4%) and 62 females (44.6%). Deceased donor liver transplantation was performed in 77 patients (55.4%), while 62 patients (44.6%) underwent living donor liver transplantation. CT was performed for pre-transplant assessment in 74 patients (53.2%) and for post-transplant evaluation in 65 patients (46.8%). The overall distribution indicates a relatively balanced cohort by sex, transplant type, and CT indication, allowing descriptive evaluation of CT-detected complication patterns.

Table 1. Baseline Characteristics and CT Indication Among Liver Transplant Recipients

Variable	Category	Frequency	Percentage
Gender	Male	77	55.4
	Female	62	44.6
Transplant type	DDLT	77	55.4
	LDLT	62	44.6
CT indication	Pre-transplant	74	53.2
	Post-transplant	65	46.8
Total		139	100.0

CT-detected complications were frequent across all four domains. Biliary complications were the most common, identified in 72 patients (51.8%), followed closely by vascular complications in 71 patients (51.1%). Parenchymal complications were detected in 66 patients (47.5%), while extrahepatic complications were identified in 58 patients (41.7%). These findings show that CT provided multidomain assessment, with vascular and biliary abnormalities forming the dominant postoperative complication burden.

Table 2. Overall Frequency of CT-Detected Complications

Complication Category	Yes, n (%)	No, n (%)	Total
Vascular complication	71 (51.1)	68 (48.9)	139
Biliary complication	72 (51.8)	67 (48.2)	139
Parenchymal complication	66 (47.5)	73 (52.5)	139
Extrahepatic complication	58 (41.7)	81 (58.3)	139

Gender-based analysis showed no statistically significant association between sex and any CT-detected complication category. Vascular complications were present in 38 males and 33 females, corresponding to 49.4% of males and 53.2% of females. Biliary complications were detected in 39 males (50.6%) and 33 females (53.2%). Parenchymal complications occurred in 35 males (45.5%) and 31 females (50.0%), while extrahepatic complications were observed in 32 males (41.6%) and 26 females (41.9%). The odds ratios were close to unity across all categories, indicating that complication distribution was broadly comparable between male and female recipients.

Table 3. Gender-Based Distribution of CT-Detected Complications

Complication	Male Yes/No	Female Yes/No	OR for Male vs Female	95% CI	p-value
Vascular	38 / 39	33 / 29	0.86	0.44–1.67	0.650
Biliary	39 / 38	33 / 29	0.90	0.46–1.76	0.763
Parenchymal	35 / 42	31 / 31	0.83	0.43–1.63	0.594
Extrahepatic	32 / 45	26 / 36	0.98	0.50–1.94	0.964

When complications were compared by transplant type, vascular complications were identified in 38 DDLT recipients and 33 LDLT recipients, representing 49.4% and 53.2%, respectively. Biliary complications were present in 37 DDLT recipients (48.1%) and 35 LDLT recipients (56.5%). Parenchymal complications were observed in 32 DDLT recipients (41.6%) and 34 LDLT recipients (54.8%). Extrahepatic complications were detected in 27 DDLT recipients (35.1%) and 31 LDLT recipients (50.0%). Although LDLT recipients showed numerically higher biliary, parenchymal, and extrahepatic complication rates, these differences did not reach statistical significance. The strongest trend was observed for extrahepatic complications, where LDLT recipients had a higher frequency than DDLT recipients, but the association remained statistically non-significant.

Table 4. Transplant-Type-Based Distribution of CT-Detected Complications

Complication	DDLT Yes/No	LDLT Yes/No	OR for DDLT vs LDLT	95% CI	p-value
Vascular	38 / 39	33 / 29	0.86	0.44–1.67	0.650
Biliary	37 / 40	35 / 27	0.71	0.36–1.40	0.325
Parenchymal	32 / 45	34 / 28	0.59	0.30–1.15	0.119
Extrahepatic	27 / 50	31 / 31	0.54	0.27–1.07	0.076

Overall, CT demonstrated substantial utility in detecting early post-transplant abnormalities across multiple anatomical domains. The highest complication burden was observed in biliary and vascular categories, each affecting approximately half of the cohort. Subgroup analysis showed that neither gender nor transplant type had a statistically significant association with complication occurrence, although LDLT recipients demonstrated a clinically notable trend toward higher parenchymal and extrahepatic complication frequencies. Because only aggregate cross-tabulated data were available, adjusted regression, patient-level overlap analysis, and time-to-complication analysis could not be performed without the original patient-level dataset.

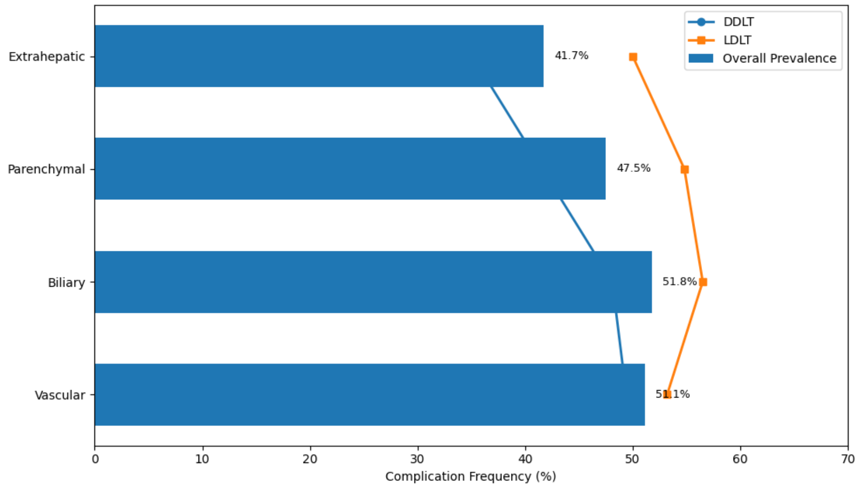

Figure 1 Distribution Pattern of Early CT-Detected Post-Transplant Complications

The figure 1 demonstrates that biliary complications represented the highest overall CT-detected postoperative abnormality (51.8%), closely followed by vascular complications (51.1%), while parenchymal and extrahepatic complications occurred in 47.5% and 41.7% of patients, respectively. LDLT recipients exhibited consistently higher frequencies of biliary (56.5%), parenchymal (54.8%), and extrahepatic complications (50.0%) compared with DDLT recipients, whereas vascular complication rates remained relatively comparable between groups (53.2% vs. 49.4%). The widest divergence between transplant modalities was observed for extrahepatic complications, with an approximate 15% absolute increase among LDLT recipients, suggesting greater systemic postoperative burden associated with technically complex living donor procedures. The layered distribution pattern further demonstrates that CT provided simultaneous multidomain complication assessment, reinforcing its value as a comprehensive postoperative surveillance modality capable of identifying clinically overlapping vascular, biliary, parenchymal, and thoracoabdominal abnormalities in a single examination.

DISCUSSION

The present study evaluated CT-detected early postoperative complications after liver transplantation in 139 adult recipients and demonstrated that complications were frequent across vascular, biliary, parenchymal, and extrahepatic domains. The cohort showed a modest male predominance, with males comprising 55.4% and females 44.6%, while DDLT and LDLT accounted for 55.4% and 44.6% of cases, respectively. This distribution provided a clinically useful basis for comparing complication patterns across sex and transplant type, although the absence of statistically significant subgroup associations indicates that postoperative CT surveillance should remain broadly applicable to all liver transplant recipients rather than being restricted to selected demographic or procedural groups.

Biliary complications were the most frequently detected abnormalities, occurring in 51.8% of recipients, followed closely by vascular complications in 51.1%. This high burden reinforces the central role of CT as a rapid postoperative assessment tool, particularly because vascular and biliary abnormalities may be pathophysiologically linked. Hepatic arterial compromise can reduce biliary perfusion and predispose to ischemic cholangiopathy, bile leak, biloma formation, or biliary stricture, making simultaneous evaluation of arterial patency and biliary-associated collections clinically valuable (1,2). Although MRCP provides superior ductal visualization in stable patients, CT remains highly practical in acute postoperative settings because it can identify biliary collections, vascular occlusion, graft perfusion abnormality, hemorrhage, abscess, and extrahepatic complications during a single examination (3,4).

Vascular complications were identified in approximately half of the cohort, emphasizing the importance of arterial-phase and portal venous-phase CT evaluation in early post-transplant imaging. Hepatic artery thrombosis, hepatic artery stenosis, portal vein thrombosis, and venous outflow obstruction are among the most clinically urgent transplant complications because they can rapidly compromise graft viability and may require endovascular or surgical intervention (5,6). In the present study, vascular complication rates were comparable between DDLT and LDLT recipients, with no statistically significant transplant-type association. This finding suggests that while transplant anatomy and reconstruction complexity remain clinically important, vascular surveillance should be performed systematically across both transplant groups.

Parenchymal complications were detected in 47.5% of recipients, reflecting the value of CT in identifying graft ischemia, infarction, perfusion defects, abscesses, hematomas, and other postoperative graft abnormalities. These findings are clinically meaningful because parenchymal changes may be subtle on clinical examination and laboratory testing alone, particularly during the early postoperative period when multiple inflammatory, ischemic, infectious, and hemodynamic processes may coexist. CT provides high-resolution anatomical characterization of these abnormalities and helps distinguish vascular perfusion-related changes from fluid collections or infective complications, thereby supporting timely clinical decision-making (7,8).

Extrahepatic complications were observed in 41.7% of patients, indicating that postoperative morbidity after liver transplantation is not limited to the hepatic graft. Pleural effusion, pneumonia, bowel abnormalities, intra-abdominal collections, ascites, hemorrhage, and sepsis-related findings can adversely affect recovery and may influence graft outcomes indirectly through hypoxia, infection, hemodynamic instability, or prolonged hospitalization. In this study, LDLT recipients showed a clinically notable but statistically non-significant trend toward higher extrahepatic complications compared with DDLT recipients. This may reflect the greater technical complexity, longer operative course, or altered postoperative physiology associated with living donor procedures, but the available aggregate data do not permit causal interpretation (32).

Gender-based comparisons showed no significant differences in vascular, biliary, parenchymal, or extrahepatic complications. Although males had slightly higher absolute frequencies of some complications, odds ratios were close to unity and p-values were non-significant across all categories. These findings suggest that sex alone did not meaningfully influence CT-detected complication distribution in this cohort. Similarly, transplant-type comparisons showed higher numerical rates of biliary, parenchymal, and extrahepatic complications among LDLT recipients, but none reached statistical significance. Therefore, these subgroup findings should be interpreted as descriptive patterns rather than definitive risk associations (33).

The findings support the clinical importance of multiphasic CT protocols in post-transplant surveillance. A comprehensive protocol including non-contrast, arterial, portal venous, and delayed phases can improve detection of hemorrhage, vascular thrombosis, arterial stenosis, portal venous abnormalities, graft perfusion defects, abscesses, bilomas, bile leaks, and extrahepatic thoracoabdominal complications. Such imaging is particularly valuable when Doppler ultrasound findings are equivocal or when clinical deterioration requires rapid assessment beyond a single anatomical system (9,10). However, CT should not be interpreted as a replacement for all other modalities. Doppler ultrasound remains useful for routine bedside vascular surveillance, while MRCP and ERCP may be required for detailed biliary evaluation and therapeutic intervention.

This study has several limitations. First, the retrospective cross-sectional design limits causal inference and does not allow evaluation of temporal progression or time-to-complication patterns. Second, the available data were aggregate rather than patient-level, preventing analysis of overlapping complications, adjusted regression modeling, interobserver agreement, and outcome correlations such as graft survival, re-intervention, ICU stay, or mortality. Third, because CT was performed according to clinical indications, selection bias may have increased the apparent frequency of complications, particularly if symptomatic or high-risk patients were more likely to undergo imaging. Fourth, the study did not compare CT findings with a uniform reference standard such as angiography, ERCP, MRCP, operative findings, or longitudinal clinical outcomes in all patients. Despite these limitations, the study provides useful local evidence that CT can identify a broad spectrum of early postoperative abnormalities after liver transplantation and supports the need for standardized CT reporting pathways in transplant imaging.

CONCLUSION

Computed tomography demonstrated substantial clinical value in detecting early postoperative complications after liver transplantation, with biliary, vascular, parenchymal, and extrahepatic abnormalities identified in 51.8%, 51.1%, 47.5%, and 41.7% of recipients, respectively. The findings indicate that CT provides comprehensive multidomain assessment of the transplanted graft and associated thoracoabdominal structures, supporting early recognition of complications that may require urgent medical, endovascular, percutaneous, endoscopic, or surgical management. Although LDLT recipients showed numerically higher biliary, parenchymal, and extrahepatic complication rates than DDLT recipients, subgroup differences were not statistically significant, and CT surveillance remains important across all transplant recipients. Standardized multiphasic CT protocols and timely radiological reporting should be integrated into post-transplant care pathways to improve diagnostic consistency, guide intervention, and support graft-preserving clinical decision-making.

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