

Early Detection of Morbidity following Liver Resection by Serum Arterial Lactate Concentration: A Cross-sectional Study Care Hospital of Bangladesh



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Abstract

Background: Liver resection is a technically demanding procedure with a relatively high risk of morbidity. Identifying reliable early predictors of postoperative complications is essential for timely intervention and improved outcomes. **Objective:** The aim of the study was to evaluate the role of initial serum arterial lactate concentration (ALC) in predicting early postoperative liver and renal dysfunction following liver resection (LR). **Methodology:** This cross-sectional study was conducted in the Department of Hepatobiliary, Pancreatic and Liver Transplant Surgery at Bangladesh Medical University, Dhaka, Bangladesh from September 2022 to August 2023. Thirty-seven patients undergoing LR for various indications were included. Pre- and postoperative assessments of liver function, coagulation profile, and renal function were performed. Renal dysfunction was defined as a creatinine rise $>1.5\times$ baseline, while liver dysfunction was defined as bilirubin >2 mg/dL, prothrombin time >17 s, or INR ≥ 1.5 . Arterial lactate samples were obtained at the end of surgery, prior to abdominal closure or upon arrival in the high dependency ward. **Results:** The mean ALC was 3.97 ± 1.28 mmol/L (range 1.67–6.30), with elevated levels (≥ 4 mmol/L) observed in 15 patients (40.5%). Overall, 19 patients (51.3%) had an uncomplicated recovery, while 13 (35.1%) developed liver dysfunction and 8 (21.6%) developed renal dysfunction. The probability of dysfunction increased progressively with rising lactate concentration, reaching 100% for liver dysfunction and 66% for renal dysfunction at lactate ≥ 6 mmol/L. Chi-square and Fisher's exact tests confirmed significant associations between lactate ≥ 4 mmol/L and both liver dysfunction ($P = 0.001$) and renal dysfunction ($P = 0.000$). Regression analysis demonstrated a strong correlation between initial lactate and peak prothrombin time ($P = 0.016$) and a highly significant correlation with renal dysfunction ($P = 0.003$), while associations with bilirubin and hospital stay were weak. Operative factors such as anatomical and major resections, nodular parenchyma, and male gender were independently associated with elevated lactate levels. **Conclusion:** Elevated postoperative arterial lactate (≥ 4 mmol/L) was a strong independent predictor of liver and renal dysfunction, correlating significantly with adverse outcomes and operative factors. [Bangladesh Journal of Infectious Diseases, June 2026;13(1):375-385]

Keywords: Arterial lactate concentration; Liver dysfunction; Renal dysfunction; Liver resection

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Introduction

Liver resection (LR) is considered the gold standard curative approach to numerous liver lesions. In recent years, liver surgeries have been steadily increasing for treatment of primary and secondary liver tumors¹. Appropriate patient selection, advances in surgical and anesthetic techniques, use of minimally invasive surgery, and improvement in perioperative care have expanded the indication of liver resection^{2,3}. However, despite the/technical improvements, major complication rates remain low after liver resection still range from 19 to 23.0% cases⁴⁻⁶, with mortality rates of approximately 6.0% cases⁶⁻¹⁰. However, postoperative morbidity remains high at around 12.5 to 66% cases¹¹⁻¹², including liver dysfunction¹³, renal dysfunction¹⁴ and bile leak¹⁵.

Early identification of patients at risk of complications gives an opportunity to further improve post-hepatectomy outcomes¹⁶. Multiple prognostic models have been developed to stratify risk of complication after hepatectomy^{13,17-19}. Despite progress, precise prediction remains hard to achieve²⁰. Lactic acid, produced during anaerobic metabolism in states of tissue hypoxia, is cleared mainly by the liver, kidneys²¹ and skeletal muscle. Hyperlactatemia is associated with increased mortality and morbidity in a critical care setting²²⁻²³ in patients with liver failure²⁴. Similar relationships have been shown in the post-operative setting following other major abdominal surgery¹² and after hepatic transplantation²⁵. Lactate measurement is strongly associated with clinical prognosis in critically ill patients and has become a central criterion for identifying shock^{26,27}. Elevated lactate levels are recognized as a significant prognostic indicator of adverse postoperative outcomes, including mortality, in cardiac surgery patients²⁸⁻²⁹. More recently, arterial lactate levels at the end of liver transplantation have been found to predict primary liver graft function³⁰. In Liver surgery, lactate measurement demands particular attention because of the liver's pivotal role in lactate metabolism³¹.

Although biochemical monitoring is routinely employed after elective hepatectomy to detect abnormal postoperative evolution, the reliability of current markers remains uncertain. Serum transaminase peaks (cytolysis) show no association with morbidity or mortality³², while other parameters such as prothrombin time, INR, and bilirubin become informative only after postoperative day 3 to 5. Outcomes after liver surgery depend on many different factors, yet no single scoring system captures them all. Tools like

the ASA grade and the P-POSSUM score are widely used to estimate surgical risk³³ and have also been applied to liver surgery. Still, these models may not fully reflect the unique challenges of liver resection. The '50–50 criteria,' defined as a serum bilirubin level greater than 50 $\mu\text{mol/L}$ and a prothrombin index below 50% on the fifth postoperative day, have been shown to correlate with mortality from post-hepatectomy liver failure (PHLF)¹³. However, a system that enables earlier prediction may be more clinically valuable in guiding timely interventions. In addition, mortality after liver resection is often driven by failure of multiple organ systems, underscoring the need for a comprehensive perioperative measure capable of predicting the risk of significant postoperative morbidity and mortality.

Clinicians thus require an earlier marker to anticipate adverse outcomes and intervene promptly to prevent post-hepatectomy liver failure (PHLF). In this regard, lactate measurement appears to be a promising parameter, as it can be assessed rapidly and routinely in clinical practice. There is no studies in our country to investigate the role of perioperative lactate levels as predictors of post-operative liver outcomes. The study aimed to evaluate whether serum arterial lactate measurement can predict post-hepatectomy early morbidity.

Methodology

Study Design: This was a cross-sectional study of patients who underwent liver resection at the Department of Hepatobiliary, Pancreatic and Liver Transplant Surgery at Bangladesh Medical University, Dhaka, Bangladesh, from September 2022 to August 2023. Immunocompromised patients, including patients on Steroid therapy and patients with emergency surgery, were excluded from the study. Sample size calculation by Buderer's formula. The final calculated sample size is 39. Before commencing the ethical clearance was taken IRB at Bangladesh Medical University, Dhaka, Bangladesh. After considering inclusion and exclusion criteria, a total of 37 participants undergoing liver resection were enrolled in the study. All participants received detailed information about the study objectives, procedures, potential risks, and benefits, and written informed consent was obtained prior to enrollment.

Patient evaluation and preparation for surgery:

All patients underwent proper evaluation and prepared for surgery according to Departmental

Protocol. All patient evaluated through history taking, Physical examinations, laboratory investigations, and imaging studies properly. Preoperative diagnoses were recorded. Full optimization of the general condition of the patient to improve performance status was carried out. Biochemical parameters regarding anaesthetic fitness were within normal limits.

Surgical details: All patients were operated on under general anesthesia in the same standard procedure for the LR b by a team of surgeons with experience in hepatobiliary and pancreatic surgery. The same team of surgeons carried out the follow-up. Liver resections were performed according to the Brisbane 2000 Terminology of Liver Anatomy and Resections. A major liver resection was defined as the removal of three or more liver segments, whether contiguous or non-contiguous. The abdomen was opened using one of several standard approaches-bilateral subcostal, modified Makuuchi (reverse L), or inverted T incision-selected at the discretion of the operating surgeon. A comprehensive exploration of the abdominal cavity, including careful inspection of the liver, was performed in all cases. Hepatic inflow and outflow control were applied when required, particularly during major resections. Parenchymal transection was performed using the Cavitron Ultrasonic Surgical Aspirator (CUSA), LigaSure, or the crush-and-clamp technique. Smaller vascular and biliary structures were divided with titanium clips, whereas larger structures were securely ligated, with meticulous attention to hemostasis and the prevention of bile leakage. All resected specimens were submitted for histopathological examination.

Blood sample collection: The serum lactate was recorded from an arterial blood sample taken immediately prior to abdominal closure or early in the postoperative room. To collect arterial blood, we first selected a hand with adequate radial artery pulsation. Disinfected the area by using 70% alcohol. We took a pre-heparinized syringe with a needle (20/23 or 25 gauge). Holding the syringe and needle like a dart, use the index finger to locate the pulse again, insert the needle at a 45-degree angle, approximately 1 cm distal to (i.e. away from) the index finger, to avoid contaminating the area where the needle enters the skin. After collecting blood, roll the specimen between the hands to gently mix it. Care was taken with the puncture site, and the sample was sent to the laboratory, maintaining standard laboratory protocol.

Measurement of Arterial Lactate Concentration:

Arterial lactate concentration (ALC) was measured from an arterial blood sample taken either immediately before abdominal closure or upon arrival in the high-dependency unit (HDU). In the normal population, arterial lactate levels are typically below 1.6 mmol/L, whereas elevated values are frequently observed in critical care settings. An ALC ≥ 3.8 mmol/L has been associated with adverse outcomes¹⁶, and postoperative ALC ≥ 4.0 mmol/L has been linked to significantly higher rates of renal failure and mortality³⁴.

Follow-up: The patients were kept overnight in the post-operative ward. All variables of interest were noted. Serum biochemistry and coagulation assays were performed on all patients within the first 24 hours of surgery, and the tests were repeated based on the clinical course.

Post-operative Complications: The primary outcomes were 30-day major morbidity, defined as Clavien–Dindo grade III to V complications, and 90-day mortality. The secondary outcome was the length of hospital stay (LOS), calculated from the day of surgery until discharge or in-hospital death. Surgical complications were considered as any deviation from the expected postoperative course within 30 days of liver resection, excluding events inherent to the procedure or failure to cure. Liver dysfunction was defined as an elevation of serum bilirubin greater than 2 mg/dl, prothrombin time exceeding 17 seconds, and an INR of ≥ 1.535 . Post-hepatectomy liver failure (PHLF) was defined as impaired liver function characterized by elevated INR and concomitant hyperbilirubinemia (based on local laboratory reference ranges) occurring on or after postoperative day 5. Renal dysfunction was assessed according to the Risk, Injury, Failure, Loss, and End-stage kidney disease (RIFLE) criteria. For categorical analyses, renal dysfunction was defined as any increase in serum creatinine of ≥ 1.5 -fold from the preoperative baseline³⁶. The length of hospital stay was measured from the day of surgery to the day of discharge. Stigmata of chronic liver disease, including clinical features such as spider angiomas, jaundice, scleral icterus, palmar erythema, gynecomastia, ascites, encephalopathy, and asterixis, were considered indicative of chronic liver disease. ASA score (2020) defines I – healthy; II – mild systemic disease; III – severe systemic disease; IV – severe disease, life-threatening; V – moribund, not expected to survive without surgery; VI – brain-dead, organ donor. Bile leakage is defined as a bilirubin concentration in the drain fluid at least three times higher than the serum bilirubin on or

after postoperative day 3, or the need for radiologic or operative intervention due to biliary collections or bile peritonitis¹⁵. Post-hepatectomy hemorrhage was defined as a postoperative hemoglobin drop of more than 3 g/dl compared with baseline, and/or the need for transfusion of packed red blood cells, radiological intervention (e.g., embolization), or re-laparotomy to control bleeding. All of the information was gathered on a well-structured questionnaire sheet. The highest level of confidentiality and ethical standards were maintained during data storage and analysis.

Statistical analysis: After compilation and cleaning, the dataset for analysis was prepared in Microsoft Excel 2019. All statistical analyses were performed using IBM SPSS Statistics version 23. Categorical variables were reported as percentages, and continuous variables with a normal distribution were presented as mean $\pm$ standard deviation. Associations between operative variables and an arterial lactate concentration ≥ 4.0 mmol/L were assessed using the chi-square test or Fisher's exact test as appropriate. All tests were two-sided; results were reported with 95% confidence intervals, and a p-value < 0.05 was considered statistically significant.

Ethical Consideration: Ethical clearance was obtained from the Institutional Review Board of Bangladesh Medical University (IRB registration no. 4013; memo no. BSMMU/2022/9133; dated 07-09-2022).

Results

Among 37 patients who underwent elective liver resection, the average age was 47 years (range 20–74), with a normal mean BMI of 21.8 kg/m². Women made up nearly two-thirds of the group. Hypertension and diabetes were common, affecting about half and one-third of patients, respectively. Most presented with abdominal pain, while a smaller proportion had abdominal lumps, systemic symptoms, or were asymptomatic. Benign conditions were the leading indication (27 cases, 78%), most often hepatolithiasis (13 cases, predominantly left-sided). Other benign causes included giant hepatic haemangioma and gallbladder carcinoma. Malignant disease accounted for 8 cases (22%), all due to hepatocellular carcinoma. Preoperative blood work was generally within normal limits, except for mild elevations in ALT and ALP, consistent with underlying hepatobiliary disease. Surgically, 29 (78%) were minor resections, and 8 (22%) were

major resections. Using Brisbane 2000 terminology, the most frequent single procedure was left lateral sectionectomy (14 cases, 37.8%), followed by right hepatectomy (5 cases, 13.5%) and extended cholecystectomy (5 cases, 13.5%) (Table 1).

Blood tests were done on postoperative day (POD) 1, 3, and 5 to monitor liver and kidney function; all patients had samples on POD1, and only those with abnormal results were rechecked on later days. Bilirubin was highest early after surgery (mean 1.46 mg/dl on POD1) and showed a steady decline by POD5 (1.19 mg/dl), suggesting an early peak with gradual recovery. Prothrombin time fell slightly by POD3 (14.72 $\rightarrow$ 13.35 seconds) then rose again on POD5 (14.50 seconds), but changes were small and not suggestive of progressive coagulopathy. Creatinine remained essentially stable across measurements (around 1.3 mg/dl), indicating preserved renal function (Table 2).

Observing key postoperative measures and complications for the 37 patients shows, mean peak values were bilirubin 1.46 $\pm$ 0.73 mg/dl, prothrombin time 14.72 $\pm$ 3.23 s, and creatinine 1.30 $\pm$ 0.72 mg/dl; the average length of stay was 12.24 $\pm$ 3.48 days. Regarding renal function, 29 (78.4%) had no dysfunction, 7 (18.9%) met the “risk” criterion (creatinine $\geq 1.5 \times$ baseline), and 1 (2.7%) met the “injury” criterion ($> 2 \times$ baseline); no patients reached the “failure” threshold. Liver dysfunction occurred in 13 (35.1%): 10 (27.0%) had bilirubin ≥ 2 mg/dl, and 5 (13.5%) had prolonged coagulation (PT > 17 s and/or INR ≥ 1.5). Overall, 19 (51.3%) patients had an uncomplicated postoperative course, while 18 (48.7%) experienced one or more complications; 5 (13.5%) had multiple morbidities. The most common complications were liver dysfunction (13; 35.1%) and renal dysfunction (8; 21.6%), with wound problems and minor pulmonary issues occurring less frequently. - do not integrate the table number (Table 3).

The mean lactate concentration was 3.97 $\pm$ 1.28 mmol/L, with values ranging from 1.67 to 6.30 mmol/L. A majority of patients (22; 60%) had lactate levels below 4 mmol/L, while the remaining (15; 40%) demonstrated levels ≥ 4 mmol/L (Table 4).

The study further examined how rising arterial lactate levels related to postoperative organ dysfunction. When lactate remained below 4 mmol/L, the probability of liver dysfunction was low (0.13; 3 of 22 patients) and renal dysfunction did not occur. At concentrations between 4.0–4.9 mmol/L, the likelihood of liver dysfunction

Table 1: Distribution Of the Study Population According to Clinic-Demographic Characteristics

Variables	Value	Normal Range
Age(years), Mean±SD	46.8±12.6	-
Male, n (%)	13(35.1%)	-
Female, n (%)	24(64.9%)	-
BMI (kg/m ²), Mean ± SD	21.8 ± 3.4	-
Comorbidities		
• Diabetes mellitus	13(35.1%)	-
• Hypertension	18(48.6%)	-
• Ischaemic Heart disease	1(2.7%)	-
Other Complaints(multiple response), n (%)		
• Abdominal pain	29(78.3%)	-
• Abdominal lump	7(18.9%)	-
• Fever	6(16.2%)	-
• Weight loss	3(8.1%)	-
• Anorexia	2(5.4%)	-
• Asymptomatic	3(8.1%)	-
• Early satiety	1(2.7%)	-
• Jaundice	1(2.7%)	-
Preoperative diagnosis, n (%)		
• Hepatolithiasis	13(35%)	-
• Giant Haemangioma	7(19%)	-
• Hepatocellular Carcinoma	8(21.6%)	-
• Gallbladder Carcinoma	5(13.5%)	-
• Post-operative Biliary Stricture	3(11%)	-
• Simple cyst	1(2.7%)	-
Laboratory findings		
• Haemoglobin, gm/dl	11.98 ± 1.21	12-16 g/dl
• Haematocrit	37.93 ± 1.78	37-50 %
• Red blood cell	4.35 ± 1.24	4.5-5.5 x 10 ¹² /L
• White blood cell	8.10 ± 2.56	4.5-11 x 10 ⁹ /L
• Platelet	248.70 ± 98.42	150-450 x 10 ⁹ /L
• Alanine Aminotransferase (ALT)	81.82 ± 62.77	< 45 U/L
• Alkaline Phosphatase (ALP)	151.0 ± 124.66	20-120 U/L
• S. Creatinine	0.86 ± 0.33	0.7-1.2 mg/dl
• Prothrombin time	12.43 ± 1.94	12.00 Seconds
• International Normalized Ratio (INR)	1.03 ± 0.19	<1.2
• Serum albumin	3.64 ± 0.50	3.5-5.2 g/L
• Serum total bilirubin	0.75 ± 0.51	0.12-1.2 mg/dl
Liver resection type, n (%)		
• Anatomical	11(29.7%)	-
• Non-anatomical	26(70.3%)	-
Extent of resection, n (%)		
Major (≥ 3 segments)	8(21.6%)	-
• Right hepatectomy	6(16.2%)	-
• Left hepatectomy	1(2.7%)	-
• Trisectionectomy	1(2.7%)	-
Minor (< 3 segments)	29(78.4%)	-
• Extended cholecystectomy	5(13.5%)	-
• Liver resection for Hepatocellular carcinoma	2(5.4%)	-
• Liver resection for Haemangioma	2(5.4%)	-
• Liver resection for simple cyst	1(2.7%)	-

Table 2: Post-operative hematological and biochemical parameters of patients undergoing Liver Resection (LR)

Blood parameter	POD 1	POD 3	POD 5
Bilirubin (mg/dl)	N=37 1.46± 0.73	N=28 1.23 ± 0.50	N=16 1.19±0.63
Prothrombin time, Second	N=37 14.72 ± 3.23	N=33 13.35 ± 2.30	N=10 14.50 ± 1.64
Creatinine(mg/dl)	N=37 1.30 ± 0.72	N=11 1.32 ± 0.48	N=9 1.27 ± 0.38

Table 3: Post-operative outcomes after liver resection (N=37)

Variables	Mean ± SD	Median(range)
Peak Bilirubin (mg/dl)	1.46 ± 0.73	1.4 (0.5-3.0)
Peak Prothrombin time (s)	14.72 ± 3.23	13.8 (11-25)
Peak creatinine	1.30 ± 0.72	1.1 (0.48-3.10)
Length of hospital stay	12.24 ± 3.48	12 (6-21)
*Renal Dysfunction		
• None	29(78.38%)	
• Risk (>1.5x Preoperative creatinine)	7(18.92%)	
• Injury (>2x Preoperative creatinine)	1(2.70%)	
• Failure (>3x Preoperative creatinine)	0	0
ηLiver Dysfunction		
• None	24(64.8%)	
• Bilirubin ≥ 2	10(27.0%)	
• Prothrombin time> 17	5(13.5%)	
• INR≥ 1.5	5(13.5%)	
Operative Outcomes		
No complication	19(51.3%)	
Complications (Multiple responses)	18(49.7%)	
• Liver dysfunction	13(35.1%)	
• Renal dysfunction	8(21.6%)	
• Wound infection	4(13.8%)	
• Wound dehiscence	4(13.8%)	
• Atelectasis	1(2.7%)	
• Bile Leak	1(2.7%)	
• Ascites	1(2.7%)	

* means Creatinine ≥1.5 times higher than preoperative value (Risk), Injury (>2x Preoperative creatinine), Failure (>3x Preoperative creatinine); η means Bilirubin ≥ 2, PT >17, INR ≥1.5 preoperative value.

Table 4: Distribution of Arterial Lactate Concentration Following Liver Resection (n=37)

Lactate concentration (mmol/L)	Value
Mean (±Standard deviation)	3.97 (±1.28)
Range(min-max)	1.67 to 6.30
< 4	22(60%)
≥ 4	15(40%)

increased to 0.25 (1 of 4), and renal dysfunction appeared at the same rate (0.25; 1 of 4). With higher lactate levels, the risk rose progressively. At ≥6 mmol/L, the probability of liver dysfunction reached 1.0 (3 of 3), while renal dysfunction was present in two-thirds of patients (0.66; 2 of 3). In summary, the data demonstrate a clear dose-response relationship: higher postoperative lactate concentrations were strongly associated with increased risk of both liver and renal dysfunction, with the greatest risk observed at levels ≥6 mmol/L (Figure I).

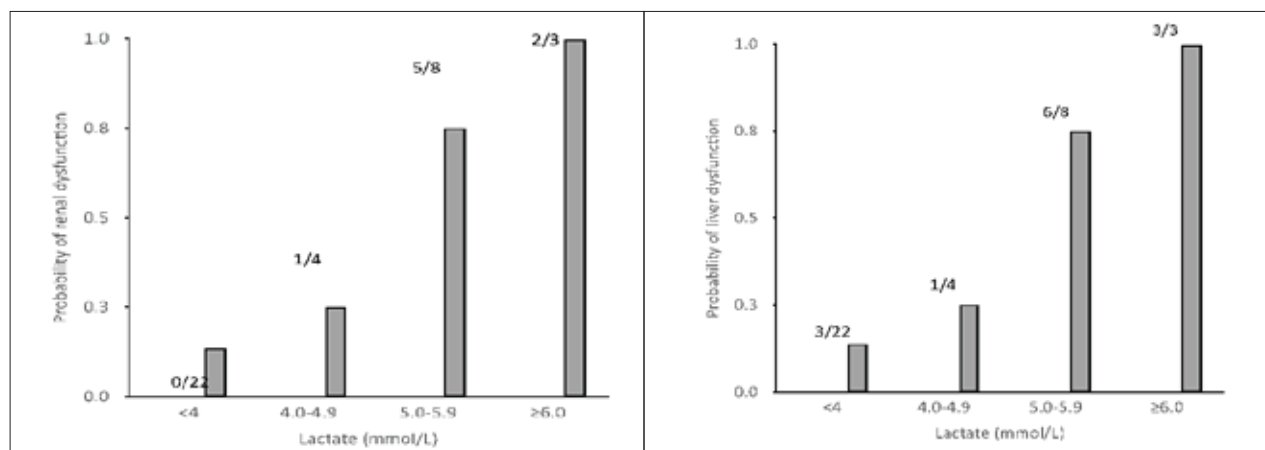


Figure I: Probability of renal and liver dysfunction after liver resection according to lactate concentration.

Regression analysis revealed that the initial lactate concentration was noted to be associated with all recorded outcome measures. In this study, we found that there was a weak correlation between initial lactate and both bilirubin ($P < 0.648$) and length of hospital stay ($P < 0.178$). But there is a strong association between initial lactate and peak prothrombin time ($P < 0.016$). However, renal dysfunction after liver resection has a highly positive correlation with lactate concentration ($P < 0.003$) (Table 5).

Table 5: Univariate Analysis of the Association Between Lactate and Postoperative Outcomes Of The Study Participants Undergoing Liver Resection

Postoperative outcome Variables	Coefficient $\pm$ SE	P value
Peak bilirubin	0.12 $\pm$ 0.27	0.648
Peak prothrombin time	0.14 $\pm$ 0.06	0.016
Length of hospital stay	0.07 $\pm$ 0.05	0.178
Renal dysfunction	0.75 $\pm$ 0.24	0.003

Chi-square and Fisher's exact tests were performed to assess the relationship between arterial lactate levels and postoperative organ dysfunction. Among the 13 patients with liver dysfunction, 10 (67%) had lactate concentrations ≥ 4 mmol/L, a statistically

significant association ($P = 0.001$). Similarly, renal dysfunction was observed only in patients with lactate ≥ 4 mmol/L, while none of those with lactate < 4 mmol/L developed renal impairment. This association was highly significant ($P = 0.000$). In summary, elevated lactate concentrations (≥ 4 mmol/L) were strongly linked to both liver and renal dysfunction, underscoring lactate as a reliable predictor of adverse postoperative outcomes (Table 6).

The study also examines the relationship between lactate concentration (≥ 4 vs < 4 mmol/L) and selected patient and operative characteristics. Among demographic variables, male sex was significantly associated with higher lactate levels ($P < 0.001$). Age, hypertension, diabetes, and ischemic heart disease showed no significant associations. In terms of operative factors, patients undergoing anatomical resections ($P = 0.009$), major resections ($P < 0.001$), and those with nodular liver parenchyma ($P = 0.007$) were significantly more likely to have lactate concentrations ≥ 4 mmol/L. In summary, elevated lactate levels were strongly linked to male gender and specific operative features—particularly anatomical and major resections, as well as nodular liver—while baseline comorbidities did not show significant associations (Table 7).

Table 2: Post-operative hematological and biochemical parameters of patients undergoing Liver Resection (LR)

Lactate Concentration (N=37)	Liver dysfunction			Renal dysfunction		
	Yes	No	P value	Yes	No	P value
Lactate con. < 4	3(14.0%)	19(86.0%)	0.001	0(0.0%)	22(100.0%)	0.00
Lactate con. ≥ 4	10(67.0%)	5(33.0%)		8(53.0%)	7(47.0%)	
Total	13	24		8	29	

Table 7: Association between Lactate Category and the Selected Independent Variables (n=37)

Variables	Lactate category		P value
	≥4	<4	
Age Group			
≤Years	7 (46.7%)	11 (50.0%)	0.842
≤48	8 (53.3%)	11 (50.0%)	
Gender			
Male	10 (66.7%)	3 (13.6%)	<0.001
Female	5 (33.3%)	19 (86.4%)	
HTN			
Yes	6 (40.0%)	12 (54.5%)	0.385
No	9 (60.0%)	10 (45.5%)	
DM			
Yes	6 (40.0%)	7 (31.8%)	0.609
No	9 (60.0%)	15 (68.2%)	
IHD			
Yes	1 (6.7%)	0	0.22
No	14 (93.3%)	22 (100.0%)	
Resection type			
Anatomical	8 (53.3%)	3 (13.6%)	0.009
Non anatomical	7 (46.7%)	19 (86.4%)	
Resection extent			
Major	8 (53.3%)	0	<0.001
Minor	7 (46.7%)	22 (100.0%)	
Liver assessment			
Nodular	6(40%)	1 (4.5%)	0.007
Normal	9(60%)	21(95.5%)	

Discussion

The principal findings of this study is that higher initial serum lactate concentration after liver resection is associated with an increased risk of liver and renal dysfunction. Our univariate analysis showed that higher perioperative lactate was linked to worse postoperative outcomes after liver resection, most notably with peak prothrombin time and postoperative renal dysfunction. This finding fits with earlier observations that hepatectomy causes a transient drop in the liver's synthetic capacity, reducing production of clotting factors and regulatory proteins and producing a characteristic rise in PT INR³⁷. A systematic review has further shown that early postoperative lactate reliably predicts morbidity and mortality after hepatectomy, supporting its use as a simple bedside biomarker to identify patients who may need closer monitoring for hepatic and renal complications³¹. On the other hand, postoperative renal dysfunction is a major complication following

liver resection, of which the incidence is reported to be approximately 8.7 to 15% cases³⁸.

About 22.0% of patients in our cohort developed both liver and renal dysfunction after hepatectomy. Arterial lactate concentration higher than 4.0 mmol/L after liver resection is associated with an increased risk of liver and renal dysfunction and may result in a longer hospital stay. Several authors have shown that high lactate concentration at the end of hepatectomy or in the early postoperative phase can be variably associated with renal and hepatic dysfunctions, postoperative peaks in serum bilirubin concentration, length of hospital stay, and mortality^{31,39}.

Previous studies reported similar findings in a series of patients with a very low postoperative mortality rate. However, Watanabe et al³⁸ in 2007 examined for the first time the relationships between lactate level and outcome in liver resection. Similarly, Lemke et al¹⁶ suggested that a lactate value ≥ 3.8 mmol/L was associated with an adverse outcome. Also, Wiggans et al³⁴ reported a significantly higher rate of renal failure and mortality in patients with a postoperative arterial lactate concentration ≥ 4.0 mmol/L in comparison with those with arterial lactate levels less than 4 mmol/L, and risk rose further at very high values (for example, ≥ 6.0 mmol/L).

In univariate analysis, an arterial lactate concentration ≥ 4.0 mmol/L at the end of surgery was significantly associated with anatomical resection, major hepatectomy, and a nodular liver. Anatomical resections often require earlier and longer vascular inflow occlusion to minimize blood loss, leaving the remnant segment relatively hypoxic; major resections take longer and entail greater blood and fluid replacement and a smaller residual liver volume; nodularity on inspection commonly reflects chronic liver disease with reduced metabolic reserve. Together, these issues increase lactate production through tissue hypoxia and reduce hepatic lactate clearance, thereby raising the risk of postoperative hepatic and renal dysfunction. These observations are consistent with prior reports linking perioperative hyperlactatemia to worse postoperative liver and kidney outcomes and longer hospital stay.

This study found that 61.5% of males and 16.7% of females developed liver dysfunction after liver resection, and this was statistically significant. Studies found that sex-specific hormonal conditions can also affect recovery and outcome after surgery⁴⁰. For instance, it has been reported that estrogen is hepatoprotective and improves survival following liver ischemia-reperfusion (IR), possibly by suppressing cellular oxidative stress⁴¹.

We have performed elective liver resections chiefly

for benign diseases, notably hepatolithiasis. This is because of the high prevalence of these diseases in this region. We had no 30-day mortality, though the morbidity rate was slightly on the higher side (49.7%) compared to the literature¹¹. This relatively high rate of morbidity may be due to the careful identification and documentation provided by both clinical and biochemical examinations performed in the post-operative period at our hospital, so that no minor complications were overlooked.

Conclusion

Initial arterial lactate concentration is a clinically meaningful predictor of postoperative liver and renal dysfunction undergoing hepatectomy. Incorporating initial arterial lactate into routine postoperative assessment can help guide early escalation of monitoring and supportive care. Because postoperative lactate correlates with organ dysfunction and mortality, it may serve as a single, practical metric to evaluate the effect of new surgical techniques or perioperative care pathways on patient outcomes. However, these findings should be interpreted with caution because our analysis was limited to univariate comparisons and the cohort included heterogeneous indications for resection, so future work using multivariable models and more homogeneous or larger validation cohorts is needed to confirm thresholds and guide clinical decision making.

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Conflict of interest:

There is no conflict of interest to disclose.

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Authors' contributions

Conception and design, or design of the research; or the acquisition, analysis, or interpretation of data: AI, AMAAA, MSU, MS, MSA, SM, BCD.

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Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: AMAAA, AI. Both first and second authors have equal contribution to the study. All authors read and approved the final manuscript. AI and AMAAA are equal contributors.

Data Availability

We confirm that the data supporting the findings are available from the corresponding author upon reasonable request.

AI disclosure

We accept full responsibility for the content of this manuscript. We acknowledge that AI (Co pilot) was used to assist with English language editing: prompts were employed to refine sentence structure, grammar, and word choice. Every suggestion from the AI was reviewed and edited by the authors to ensure accuracy and preserve the integrity of our original expressions.

Ethics Approval and Consent to Participate

Ethical approval for the study was obtained from the Institutional Review Board. As this was a prospective study the written informed consent was obtained from all study participants. All methods were performed in accordance with the relevant guidelines and regulations. The ethical approval was obtained from July 2024 to December 2024.

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References

1. Recknagel S, Rademacher S, Höhne C, Lederer AA, Lange UG, Herta T, Seehofer D, Sucher R, Scheuermann U. Prediction of the postoperative outcome in liver resection using perioperative serum lactate levels. *Journal of Clinical Medicine*. 2023 Mar 7;12(6):2100.
2. Braunwarth E, Staettner S, Fodor M, Cardini B, Resch T, Oberhuber R, Putzer D, Bale R, Maglione M, Margreiter C, Schneeberger S. Surgical techniques and strategies for the treatment of primary liver tumours: hepatocellular and cholangiocellular carcinoma. *European Surgery*. 2018 Jun;50(3):100-12.
3. Primavesi F, Stättner S, Jäger T, Göbel G, Presl J, Tomanová K, Buchner S, Maglione M, Resch T, Hutter J, Öfner D. Progressive oncological surgery is associated with increased curative resection rates and improved survival in metastatic

- colorectal cancer. *Cancers*. 2019 Feb 14;11(2):218.
4. Aloia TA, Fahy BN, Fischer CP, Jones SL, Duchini A, Galati J, Gaber AO, Ghobrial RM, Bass BL. Predicting poor outcome following hepatectomy: analysis of 2313 hepatectomies in the NSQIP database. *Hpb*. 2009 Sep 1;11(6):510-5.
 5. Virani S, Michaelson JS, Hutter MM, Lancaster RT, Warshaw AL, Henderson WG, Khuri SF, Tanabe KK. Morbidity and mortality after liver resection: results of the patient safety in surgery study. *Journal of the American College of Surgeons*. 2007 Jun 1;204(6):1284-92.
 6. Dokmak S, F  riche FS, Borscheid R, Cauchy F, Farges O, Belghiti J. 2012 Liver resections in the 21st century: we are far from zero mortality. *HPB*. 2013 Nov 1;15(11):908-15.
 7. Farges O, Goutte N, Bendersky N, Falissard B. Incidence and risks of liver resection: an all-inclusive French nationwide study. *Annals of surgery*. 2012 Nov 1;256(5):697-705.
 8. Filmann N, Walter D, Schadde E, Bruns C, Keck T, Lang H, Oldhafer K, Schlitt HJ, Sch  n MR, Herrmann E, Bechstein WO. Mortality after liver surgery in Germany. *Journal of British Surgery*. 2019 Oct;106(11):1523-9.
 9. Tzeng CW, Cooper AB, Vauthey JN, Curley SA, Aloia TA. Predictors of morbidity and mortality after hepatectomy in elderly patients: analysis of 7621 NSQIP patients. *HPB*. 2014 May 1;16(5):459-68.
 10. Hoffmann K, Hinz U, Stravodimos C, Knoblich T, Sch  n MR, B  chler MW, Mehrabi A. Risk assessment for liver resection. *Surgery*. 2018 Nov;164(5):998-1005. doi: 10.1016/j.surg.2018.06.024. Epub 2018 Aug 12. PMID: 30107885.
 11. Longchamp G, Labgaa I, Demartines N, Joliat GR. Predictors of complications after liver surgery: a systematic review of the literature. *HPB*. 2021 May 1;23(5):645-55.
 12. Li SH, Liu F, Zhang YT. Initial serum lactate level as predictor of morbidity after major abdominal surgery. *Zhonghua yi xue za zhi*. 2008 Sep 1;88(35):2470-3.
 13. Balzan S, Belghiti J, Farges O, Ogata S, Sauvanet A, Delefosse D, Durand F. The "50-50 criteria" on postoperative day 5: an accurate predictor of liver failure and death after hepatectomy. *Annals of surgery*. 2005 Dec 1;242(6):824-9.
 14. Saner F. Kidney failure following liver resection. In *Transplantation proceedings 2008 May 1* (Vol. 40, No. 4, pp. 1221-1224). Elsevier.
 15. Koch M, Garden OJ, Padbury R, Rahbari NN, Adam R, Capussotti L, Fan ST, Yokoyama Y, Crawford M, Makuuchi M, Christophi C. Bile leakage after hepatobiliary and pancreatic surgery: a definition and grading of severity by the International Study Group of Liver Surgery. *Surgery*. 2011 May 1;149(5):680-8.
 16. Lemke M, Karanicolas PJ, Habashi R, Behman R, Coburn NG, Hanna SS, Law CH, Hallet J. Elevated lactate is independently associated with adverse outcomes following hepatectomy. *World journal of surgery*. 2017 Dec;41(12):3180-8.
 17. Hyder O, Pulitano C, Firoozmand A, Dodson R, Wolfgang CL, Choti MA, Aldrighetti L, Pawlik TM. A risk model to predict 90-day mortality among patients undergoing hepatic resection. *Journal of the American College of Surgeons*. 2013 Jun 1;216(6):1049-56.
 18. Etra JW, Squires III MH, Fisher SB, Rutz DR, Martin BM, Kooby DA, Cardona K, Sarmiento JM, Staley III CA, Maithel SK, Russell MC. Early identification of patients at increased risk for hepatic insufficiency, complications and mortality after major hepatectomy. *Hpb*. 2014 Oct 1;16(10):875-83.
 19. Herbert GS, Prussing KB, Simpson AL, D'Angelica MI, Allen PJ, DeMatteo RP, Jarnagin WR, Kingham TP. Early trends in serum phosphate and creatinine levels are associated with mortality following major hepatectomy. *Hpb*. 2015 Dec 1;17(12):1058-65.
 20. Lim C, Dejong CH, Farges O. Improving the quality of liver resection: a systematic review and critical analysis of the available prognostic models. *HPB*. 2015 Mar 1;17(3):209-21.
 21. Record CO, Iles RA, Cohen RD, Williams R. Acid-base and metabolic disturbances in fulminant hepatic failure. *Gut*. 1975 Feb 1;16(2):144-9.
 22. Husain FA, Martin MJ, Mullenix PS, Steele SR, Elliott DC. Serum lactate and base deficit as predictors of mortality and morbidity. *The American journal of surgery*. 2003 May 1;185(5):485-91.
 23. Khosravani H, Shahpori R, Stelfox HT, Kirkpatrick AW, Laupland KB. Occurrence and adverse effect on outcome of hyperlactatemia in the critically ill. *Critical care*. 2009 Jun 12;13(3):R90.
 24. MacQuillan GC, Seyam MS, Nightingale P, Neuberger JM, Murphy N. Blood lactate but not serum phosphate levels can predict patient outcome in fulminant hepatic failure. *Liver Transplantation*. 2005 Sep;11(9):1073-9.
 25. Nishimura A, Hakamada K, Narumi S, Totsuka E, Toyoki Y, Ishizawa Y, Umehara M, Yoshida A, Umehara Y, Sasaki M. Intraoperative blood lactate level as an early predictor of initial graft function in human living donor liver transplantation. In *Transplantation proceedings 2004 Oct 1* (Vol. 36, No. 8, pp. 2246-2248). Elsevier.
 26. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, Bellomo R, Bernard GR, Chiche JD, Coopersmith CM, Hotchkiss RS. The third international consensus definitions for sepsis and septic shock (Sepsis-3). *Jama*. 2016 Feb 23;315(8):801-10.
 27. Lee SM, An WS. New clinical criteria for septic shock: serum lactate level as new emerging vital sign. *Journal of thoracic disease*. 2016 Jul;8(7):1388.
 28. Haanschoten MC, Kreeftenberg HG, Bouwman RA, van Straten AH, Buhre WF, Hamad MA. Use of postoperative peak arterial lactate level to predict outcome after cardiac surgery. *Journal of cardiothoracic and vascular anesthesia*. 2017 Feb 1;31(1):45-53.
 29. Joudi M, Fathi M, Soltani G, Izanloo A. Factors affecting on serum lactate after cardiac surgery. *Anesthesiology and Pain Medicine*. 2014 Oct 14;4(4):e18514.
 30. Golse N, Guglielmo N, El Metni A, Frosio F, Cosse C, Naili S, Ichai P, Ciacio O, Pittau G, Allard MA, Castaing D. Arterial lactate concentration at the end of liver transplantation is an early predictor of primary graft dysfunction. *Annals of surgery*. 2019 Jul 1;270(1):131-8.
 31. Connolly C, St  ttner S, Niederwieser T, Primavesi F. Systematic review on peri-operative lactate measurements to predict outcomes in patients undergoing liver resection. *Journal of Hepato-Biliary-Pancreatic Sciences*. 2020 Jul;27(7):359-70.
 32. Boleslawski E, Vibert E, Pruvot FR, Le Treut YP, Scatton O, Laurent C, Mabrut JY, R  gimbeau JM, Adham M, Cosse C, Farges O. Relevance of postoperative peak transaminase after elective hepatectomy. *Annals of Surgery*. 2014 Nov 1;260(5):815-21.
 33. Copeland GP, Jones D, Walters MP. POSSUM: a scoring system for surgical audit. *Journal of British Surgery*. 1991 Mar;78(3):355-60.
 34. Wiggins MG, Starkie T, Shahtahmassebi G, Woolley T, Birt D, Erasmus P, Anderson I, Bowles MJ, Aroori S, Stell DA. Serum arterial lactate concentration predicts mortality and organ dysfunction following liver resection. *Perioperative Medicine*. 2013 Oct 7;2(1):21.
 35. Menon KV, Al-Mukhtar A, Aldouri A, Prasad RK, Lodge PA, Toogood GJ. Outcomes after major hepatectomy in elderly patients. *Journal of the American College of Surgeons*. 2006 Nov 1;203(5):677-83.
 36. Bellomo R, Ronco C, Kellum JA, Mehta RL, Palevsky P, ADQI workgroup. Acute renal failure—definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. *Critical Care*. 2004 May 24;8(4):R204.
 37. Siniscalchi A, Begliomini B, De Pietri L, Braglia V, Gazzi M, Masetti M, Di Benedetto F, Pinna AD, Miller CM, Pasetto A.

Increased prothrombin time and platelet count in living donor right hepatectomy: implications for epidural anesthesia. *Liver Transplantation*. 2004 Sep 1;10(9):1144-9.

38. Watanabe I, Mayumi T, Arishima T, Takahashi H, Shikano T, Nakao A, Nagino M, Nimura Y, Takezawa J. Hyperlactemia can predict the prognosis of liver resection. *Shock*. 2007 Jul 1;28(1):35-8.

39. Recknagel S, Rademacher S, Höhne C, Lederer AA, Lange UG, Herta T, Seehofer D, Sucher R, Scheuermann U. Prediction of the postoperative outcome in liver resection using

perioperative serum lactate levels. *Journal of Clinical Medicine*. 2023 Mar 7;12(6):2100.

40. Yokoyama Y, Nagino M, Nimura Y. Which gender is better positioned in the process of liver surgery? Male or female? *Surgery Today*. 2007 Oct;37(10):823-30.

41. Vegeto E, Belcredito S, Etteri S, Ghisletti S, Brusadelli A, Meda C, Krust A, Dupont S, Ciana P, Chambon P, Maggi A. Estrogen receptor- α mediates the brain anti-inflammatory activity of estradiol. *Proceedings of the National Academy of Sciences*. 2003 Aug 5;100(16):9614-9.