



Hepatic parenchymal resection with waterjet in the malignant setting – Results of an Initial Foray

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Abstract – Background: Liver resections for malignant disease are often complicated by significant intraoperative bleeding due to the liver's rich vascularity. The waterjet device offers a tissue-selective dissection technique aimed at reducing blood loss and preserve vital intrahepatic structures. This study evaluates the efficacy and safety of hydrodissection in liver resections performed for malignant indications. **Methods:** This retrospective analysis included 27 patients who underwent hepatic resections using the ERBE® waterjet device between April 2023 and June 2024 at a tertiary oncology center in North East India. Procedures included radical cholecystectomy ($n = 16$), metastasectomy ($n = 7$), left lateral sectionectomy ($n = 2$), right anterior sectionectomy ($n = 1$), and wedge resection ($n = 1$). Intraoperative parameters (blood loss, duration, need for inflow occlusion) and postoperative outcomes (bile leak, transaminase elevation, transfusion requirement) were assessed. **Results:** Median transection time was 36 min (range: 20–150), with a median blood loss of 150 mL (range: 80–350). Only one patient (3.7%) required the Pringle maneuver. Bile leak occurred in two patients (7.4%), resolving without intervention. Postoperative transaminase elevation ($>3 \times \text{ULN}$) was observed in 9 patients (33.3%), and 15 patients (59.3%) required blood transfusions. Median hospital stay was 4 days (range: 2–8). No reoperations or 30-day readmissions occurred. **Conclusions:** Waterjet-assisted liver resection appears to be a safe and hemostatically effective technique in malignant hepatic surgery, especially in limited resections. It minimizes blood loss, reduces reliance on vascular inflow occlusion, and preserves key vascular and biliary structures. These findings support the utility of hydrodissection in oncological liver surgery, warranting further prospective studies for broader validation.

Key words: Liver resection, Waterjet, Hydrojet, CUSA, Crush and clamp, Finger fracture, Radical cholecystectomy, Liver metastasectomy, Bile leak.

Introduction

The liver is a common site for malignant lesions, with an incidence of 10.4/100,000 population in South-East Asia [1]. This may be a primary liver malignancy (5.7%) [2], metastasis from malignant lesions elsewhere in the body (17% of patients with colorectal cancer have synchronous liver metastasis [3]), or contiguous extension in the setting of malignancies of the biliary tract. In the present day, a patient with limited liver disease is – more often than not – considered for a curative procedure and no longer condemned to palliative treatment due to the presence of metastatic disease. Similarly, major liver resections are regularly performed for primary liver malignancies that may contiguously involve multiple hepatic segments.

The liver is a highly vascular structure with the portal vein (70%) and the hepatic artery (30%) providing the main vascular inflow. In addition to this, the hepatic veins – the outflow channels – drain directly into the inferior vena cava. This increased

vascularity leads to the direct inference that any resection of the hepatic parenchyma will be fraught with torrential bleeding, not just from the parenchymal cut surface, but also from the extensive network of vessels traversing this organ. This led to the exploration of ways to reduce the blood loss while performing liver resections.

One of the methods to do this is by a Pringle maneuver, proposed by James. H. Pringle in 1908, whereby he aimed to minimize blood loss by clamping the vascular pedicle, which includes the hepatic artery and portal vein. Going a step further is the concept of “Total vascular exclusion” (TVE), where in addition to the portal pedicle, the supra- and infrahepatic vena cava is also clamped [4]. However, these procedures can be continuously performed for a limited time only (which is often not enough for a major hepatic resection) and require hypothermic perfusion. In addition, there is a possibility of ischaemia-reperfusion injury due to prolonged warm ischaemia time [5].

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The techniques of transecting the liver parenchyma are also numerous. The basic techniques of finger fracture or crush and clamp with a Kelly's forceps have further evolved. Surgeons and biomedical engineers have collaborated to develop surgical equipment that can minimize blood loss, prevent injury to intrahepatic structures, and ensure a rapid rate of division of the hepatic parenchyma. This led to the evolution of the bipolar sealing device (LigaSure™), ultrasonic dissector (HARMONIC™), cavitron ultrasonic surgical aspirator (CUSA™), hydrojet (ERBE®), and the radiofrequency dissecting sealer (tissueLINK™).

In our study conducted at a tertiary care center in Northeast India, we retrospectively compared conventional methods of hepatic resection (crush and clamp and finger fracture) with a waterjet device. The primary aim of this study is to evaluate the advantage offered by hydrodissection for hepatic parenchymal resection as compared to traditional methods. Our objectives were to evaluate the following parameters: intraoperative blood loss, operative duration, inflow control requirement, altered post-operative transaminase levels, and post-operative bile leak.

Materials and methods

Between April 2023 and June 2024, 27 patients underwent liver resections for malignant conditions at Dr. B. Borooah Cancer Institute, Guwahati. The procedures included radical cholecystectomy ($n = 16$), non-anatomical liver metastasectomy ($n = 7$), left lateral sectionectomy for hepatocellular carcinoma ($n = 2$), a right anterior sectionectomy ($n = 1$), and a wedge resection for colonic tumour infiltration ($n = 1$). Hydrodissection was used for parenchymal transection in all cases. Preoperative elastography was done to evaluate cirrhosis in hepatocellular carcinoma patients.

All patients were positioned supine with a mild reverse Trendelenburg tilt. Mops were packed beneath the right hemidiaphragm to facilitate liver mobilisation. The type of incision (midline, rooftop, or Makuuchi) was decided based on the operative requirement. In every case, the hepatoduodenal ligament was skeletonised and the portal triad isolated prior to transection. Only one case – a right anterior sectionectomy – required inflow occlusion via the Pringle manoeuvre. Total vascular exclusion and CVP modulation were not employed.

Nine of the sixteen patients undergoing radical cholecystectomy had a preoperative suspicion of malignancy confirmed intraoperatively by frozen section analysis of the gall bladder specimen. The rest had incidental cancers staged T1b or higher, necessitating completion surgery. Lymphadenectomy preceded liver resection in all cholecystectomy cases. In the colonic infiltration case, hepatic resection preceded colectomy to preserve the mesocolic plane [6] (Figure 1).

Transection was performed using the waterjet set at 550–600 psi with normal saline irrigation. The applicator was held 1–2 mm above the resection line and moved in a to-and-fro motion. Initial traction was achieved with thumb-forceps, transitioning to gauze counter-traction as the depth increased. The waterjet separated parenchyma along natural planes, exposing biliary and vascular structures. Minor vessels

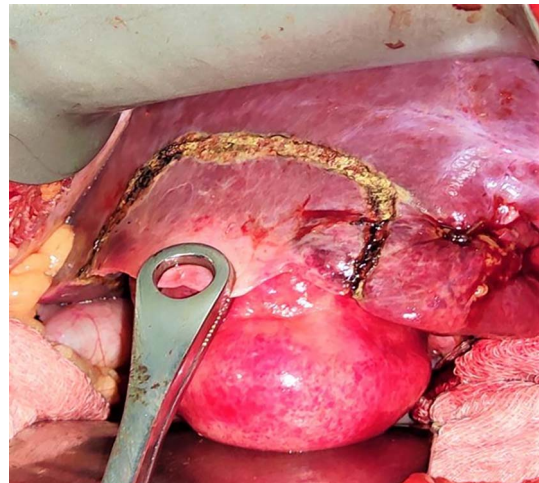


Figure 1. Incision of the Glisson's capsule prior to resection.

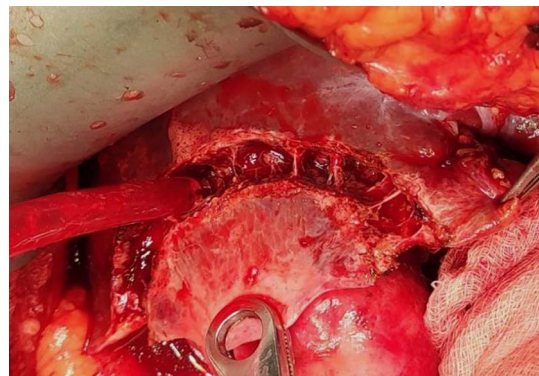


Figure 2. Exposed biliary ductules and vessels after hydrodissection.

were coagulated with bipolar energy devices; larger ones were clipped or ligated. Haemostasis was confirmed visually and reinforced with Gelfoam as needed (Figure 2).

Blood loss was estimated by subtracting saline input from total suction volume. A soaked 15×15 cm mop was considered equivalent to 200 mL of blood; fully soaked gauze was taken as 10 mL. Drains were placed in all patients. Oral intake resumed on postoperative day 1. Liver function tests were checked on day 2. Discharge occurred at a median of 4 days (range 2–8). Follow-up was weekly for one month, and subsequently at 3-month intervals. No patient required readmission within 30 days.

Statistical analysis

All data were compiled and analysed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Continuous variables, including operative time and intraoperative blood loss, were summarised using descriptive statistics and expressed as mean, median, and range. Categorical variables such as bile leak, requirement for inflow control, postoperative transfusion, and elevated serum transaminase levels were reported as frequencies and percentages. Subgroup analysis was performed

Table 1. Surgical subgroup summary.

Surgery type	<i>n</i>	Median duration (min)	Median blood loss (mL)	Range	Pringle used	Bile leaks	Elevated transaminases	Transfusions
Left Lateral Sectionectomy	2	50	175	150–200	0	0	2	2
Metastasectomy	7	40	100	80–250	0	0	2	1
Radical Cholecystectomy	16	25	150	100–200	0	1	4	11
Right anterior sectionectomy	1	150	350	350	1	1	1	1
Wedge resection	1	20	100	100	0	0	0	1

based on the type of liver resection undertaken. Graphical representations, including box plots and bar charts, were used to visually depict the distribution of operative parameters and postoperative outcomes across surgical subgroups. No inferential statistical tests or comparative analysis were performed, in view of the limited sample size and the predominantly non-anatomical nature of the resections included in the study (Table 1).

Results

A total of 27 patients underwent hepatic parenchymal resection using hydrodissection. Radical cholecystectomy was the most frequently performed procedure (*n* = 16), followed by metastasectomy (*n* = 7), left lateral sectionectomy (*n* = 2), right anterior sectionectomy (*n* = 1), and wedge resection (*n* = 1).

Intraoperative parameters

The median duration of liver parenchymal transection was 36 minutes (range: 20–150 min), with the longest durations observed in the right anterior sectionectomy and left lateral sectionectomy groups. The median estimated blood loss was 150 mL (range: 80–350 mL), with the highest loss observed in the right anterior sectionectomy (350 mL). Only one patient (3.7%) required the Pringle maneuver for vascular inflow occlusion. Neither total vascular exclusion nor central venous pressure modulation was employed in any case.

Postoperative outcomes

- Bile leak occurred in two patients (7.4%), one each in the radical cholecystectomy and metastasectomy groups, which was likely to have occurred from the cut surface of the liver. Both cases were resolved by post-operative day 5 without the need for any drainage procedures.
- Blood transfusions were required in 15 patients (59.3%), predominantly in the radical cholecystectomy (*n* = 7), left lateral sectionectomy (*n* = 2), and the single right anterior sectionectomy.
- Elevated liver transaminases (>3× ULN) were recorded in nine patients (33.3%), mostly after major resections.
- All patients resumed oral intake by postoperative day 1 and were discharged at a median of 4 days (range: 2–8).
- There were no reoperations or 30-day readmissions.

Comparative literature analysis

1. Operative time

The maximum operative time in our study reached 150 min with a mean of 36 min, consistent with reported values in other waterjet series. Vollmer and Callery [7] reported a median operative time of 289 min, which included complex donor hepatectomies. Our shorter duration likely reflects the predominantly limited resections and single-operator consistency.

2. Blood loss

Our median intraoperative blood loss of 150 mL is significantly lower than most published series:

- Vollmer and Callery [7] reported a median blood loss of 900 mL in a series of 101 waterjet-assisted liver resections.
- In a randomized trial by Lesurtel et al. [8], the hydrojet group had a mean blood loss of 3.5 mL/cm², which often translated into blood losses over 400–500 mL depending on resection size.
- Izumi et al. [9] found that waterjet resulted in significantly less blood loss than CUSA in cirrhotic livers.

Thus, our blood loss outcomes compare very favorably, particularly considering that no CVP control or routine Pringle maneuver was used.

3. Use of inflow occlusion

Only one patient (3.7%) required Pringle occlusion. This is similar to the late-stage experience described by Rau et al. [10], where Pringle rates dropped from 48% to 6% with increasing waterjet familiarity. In contrast, Lesurtel et al. applied Pringle routinely in clamp-crush cases, underscoring the hemostatic efficacy of waterjet dissection even without vascular inflow control.

4. Postoperative complications

- Bile leaks were rare (7.4%), comparable to the 5–10% range reported by Une et al. [11], Vollmer and Callery, and substantially lower than rates reported with traditional methods in high-risk cases.
- Enzyme spikes occurred predominantly in major resections, consistent with global findings, and are not considered predictive of poor outcomes per Lesurtel et al.

Given that most liver resections in our study were limited (non-anatomical) and performed predominantly for gallbladder

Table 2. Comparative analysis with similar studies.

Parameter	Current study (<i>n</i> = 27)	Lesurtel et al. (2005) [8]	Vollmer and Callery [7]	Rau et al. (2001) [10]
Operative time (min)	36	60	289	80
Blood loss (mL)	150	350	900	250
Bile leak (%)	7.4%	10%	6%	5%
Inflow control required (%)	3.6%	100% (routine)	~14%	6%

carcinoma, with only one major resection (right anterior sectionectomy), direct comparisons with studies focusing on major hepatectomies should be interpreted cautiously. That said, our operative parameters demonstrate encouraging trends. The median operative time of 36 min and mean blood loss of 150 mL are notably lower than those reported by Lesurtel et al. [8] (mean transection time 60 min, mean blood loss 350 mL), Vollmer and Callery [7] (median operative time 289 min, median blood loss 900 mL), and Rau et al. [10] (mean time 80 min, blood loss 250 mL), all of which involved major hepatic resections and often included donor hepatectomies or large segmentectomies. Similarly, the requirement for inflow occlusion in our series was only 3.7%, compared to routine Pringle maneuvers in the clamp-crush arm of Lesurtel’s study [8] and up to 14% in the hydrojet arm of Vollmer and Callery [7]. Bile leak rates in our study were low (7.4%), aligning with those seen by Une et al. [11], who reported between 5% and 10% in early hydrodissection studies. Similarly, postoperative transaminase spikes, while observed in 33.3% of our patients, were mild and transient, echoing trends reported in Lesurtel et al. [8], where enzyme elevations were not associated with adverse outcomes.

Overall, our results, while not directly comparable to those from large-volume major resection series, underscore the feasibility, safety, and hemostatic efficacy of waterjet-assisted transection even in oncological scenarios involving regional lymphadenectomy and complex dissection planes.

Discussion

The idea of using a waterjet for liver surgery has evolved steadily over the past few decades. Back in the 1980s, Papachristou and Barters [12] were among the first to explore its potential, showing that a focused water stream could dissect liver tissue while preserving nearby vessels and bile ducts. This early insight opened the door for safer, more controlled parenchymal transection. Later, Une et al. [11] and his team carried this forward with clinical applications, reporting cleaner planes and less bleeding compared to more conventional approaches. Their work highlighted the waterjet’s ability to offer a clear operative field, especially in complex resections. Izumi et al. [9] then added further weight to this concept, comparing the waterjet to the cavitron ultrasonic surgical aspirator (CUSA) in patients with cirrhotic livers. Their findings suggested that waterjet dissection not only reduced bleeding but also preserved vascular structures more effectively. Over time, these incremental steps helped establish the waterjet as a reliable tool in hepatic surgery, especially when precision and haemostasis are paramount.

One of the defining features of the waterjet dissection technique lies in its ability to preserve intrahepatic vessels and bile ducts while dividing the liver parenchyma. This selective action is rooted in basic tissue composition: unlike the softer liver tissue, which is disrupted by the mechanical force of the water stream, blood vessels and bile ducts contain higher concentrations of collagen and elastin – structural proteins that offer considerable resistance to pressure. As Rau et al. [10] described, these proteins act almost like natural reinforcements, allowing vessels to withstand the shearing force of the waterjet, while the surrounding hepatocytes are gently washed away. Other studies have reinforced this observation, reinforcing that the physical properties of connective tissue-rich structures make them less susceptible to disruption during hydrodissection [9, 11]. This not only reduces bleeding but also helps preserve vital structures, a major advantage in complex or cirrhotic livers.

This study reflects our institution’s early experience with the use of hydrodissection via waterjet technology in liver resections performed for malignancy. The patient cohort largely consisted of individuals undergoing radical cholecystectomy, with a few cases of liver metastasectomy and only one major anatomical resection. Given this distribution, most of the resections were limited in nature. Nevertheless, the waterjet proved to be a reliable and safe tool for parenchymal transection in all included procedures.

One of the most consistent observations was the notably low blood loss. With a mean of 150 mL across all resections and only one case requiring vascular inflow occlusion, the technique showed excellent hemostatic control. This finding is consistent with the gradual reduction in Pringle usage described by Rau et al. [10] as familiarity with the device increased. Additionally, the transfusion rate, although not insignificant at 59.3%, can be attributed in part to the extensive nodal dissection performed in radical cholecystectomy cases.

Operative time remained within a manageable range, with most procedures completed efficiently despite the absence of central venous pressure modulation. Compared to published series involving extended hepatectomies such as those by Lesurtel et al. [8] and Vollmer and Callery [7], our operative durations were considerably shorter (mean = 36 min) – though this likely reflects the nature of the procedures rather than technical superiority alone (Table 2).

Postoperative complications were few and manageable. Bile leaks occurred in two patients (7.4%), both of whom were managed conservatively. This rate aligns with figures seen in other hydrodissection studies [11]. Similarly, the transient elevation in liver enzymes observed postoperatively in a third of patients was not unexpected and did not translate into clinical liver dysfunction. These trends are consistent with the findings in prior literature [8, 10].

Although this study does not report on margin status or long-term outcomes, the operative and postoperative safety data support continued use of the waterjet, particularly in limited resections where precision and soft-tissue handling are priorities. Overall, hydrodissection using the waterjet offers a balance of control, safety, and adaptability. It proved effective across a variety of procedures without the routine need for vascular occlusion or pressure modulation. While this experience cannot be directly compared to series focused on major hepatectomies, it adds to the growing body of evidence supporting hydrodissection as a practical technique for liver surgery in diverse oncological settings.

There is a study that compares in detail the various types of techniques for liver resection, a review article by Gurusamy et al. [13]. The article focused mainly on the perioperative outcomes and compared the previous studies on liver resection.

Conclusions

Waterjet-assisted liver parenchymal transection appears to be a safe and effective technique in malignant hepatic surgery. It provides excellent haemostasis with minimal need for inflow occlusion, preserves key vascular and biliary structures, and is associated with low rates of major complications. Blood loss and operative duration were significantly lower than many reported benchmarks.

Limitations

This study was retrospective in design and limited to a single institution, which introduces potential biases in patient selection, operative technique, and outcome reporting. The surgeries performed were predominantly limited liver resections. The relatively small sample size, particularly in the anatomical resection subgroups, restricts the statistical power of intergroup comparisons. Additionally, there was no control arm using conventional transection techniques, and our comparison relied on published literature, which may vary in methodology and patient demographics.

Future directions

There is a need for larger, prospective, randomized studies comparing hydrodissection directly with traditional techniques such as clamp-crush and CUSA. These studies should standardize endpoints such as transection speed, blood loss per square centimetre, bile leak grading, and biochemical liver injury. Cost-effectiveness and long-term oncological outcomes are also important areas for further exploration. Integration of real-time imaging and navigational tools may further enhance the precision and utility of the waterjet system.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Data availability statement

Data will be available to the author and the corresponding author upon reasonable request.

Author contribution statement

Scientific and ethical clearance, patient selection, and data collection: Dr Shahir Merchant.

Manuscript writing, statistical calculations: by Dr Shivaji Sharma.

Patients were operated on by Dr Shivaji Sharma and Dr Gaurav Das.

Staging workup, perioperative management, intraoperative assistance was done by Dr. Shahir, Dr. Yogesh, Dr. Mohit, Dr. Manthan, Dr. Dibyajyoti, Dr. Jayavarmaa, and Dr. Karan.

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Ethics approval

Ethical approval was not required.

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