Hepatectomy with Takasaki’s Technique Using SonaStar Ultrasonic Aspiration System: An Experience from 58 Cases

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Objective: This study aims to explore the short-term results of hepatectomy with Takasaki’s technique using Sonastar ultrasonic aspiration system.

Materials and Methods: We retrospectively examined data of 58 patients who underwent hepatectomy with Takasaki’s technique using Sonastar ultrasonic aspiration system at Hue Central Hospital from 01/2018 to 02/2021.

Results: The mean age was 60.7 ± 10.5 years (25–80) and the male/female ratio was 6:1. Patients with solitary tumor accounted for 79%; 68.4% had tumor size greater than 5 cm. Pringle maneuver was used in 57.9%, while selective right or left Glissonean pedicle occlusion was used in 69.0% and 32.8%, respectively. Final transection surface reinforce- ment was achieved by Surgicel and BioGlue in 78.9% and 21.5% of cases, respectively. Major liver resection accounted for 73.7%. The mean parenchymal transection time was 50 (45–110) minutes, while mean total operative time was 125 (90–280) minutes. Mean operative blood loss was 250 (150–650) mL. Mean post-operative hospital stay was 8 days (7–23). Post-operative complication rate was 15.9% and mortality rate was 1.7%.

Conclusion: Hepatectomy using Takasaki technique with Sonastar ultrasonic aspiration system is safe, effective, allowing an anatomical resection with sufficient safety margin and resulting in low complication rates (liver failure, biliary leakage) and good survival outcomes.

Keywords: liver tumor, SonaStar, Takasaki’s technique

Background
Hepatectomy is the most popular radical treatment for hepatic malignancies which offers resectable patients better survival rates. However, hepatectomy is also associated with numerous complications including bleeding, acute liver failure and bile leakage … which can adversely affect survival result and mortality rate.

Among many Glissonean pedicle approaches, Takasaki’s extrafascial approach provides a safe, quick dissection of Glissonean pedicle compared to intrafascial approach by Lortat–Jacob and Robert and transfissural approach by Ton That Tung in Vietnam and Tien-Yu Lin in Taiwan as it follows the natural plane between Glisson’s and Laennec’s capsules. The Takasaki technique has been widely adopted in anatomical resection for hepatocellular carcinoma as well as other liver tumors.

Besides a traditional clamp-crush technique, novel parenchymal transection technology of Sonastar (Misonix Inc., Farmingdale, NY, USA) provide precise ultrasonic aspiration with high tissue selectivity and preservation of Glissonian pedicle
elements. Furthermore, anatomic liver resection has been
demonstrated to provide better recurrence-free survival in
hepatocellular carcinoma, as well as better preservation of
healthy liver parenchyma and limiting bile leakage by
accurate dissection in the intersegmental planes.8

A combination of these above-mentioned factors
could theoretically allow safer and more efficient liver
resection. Therefore, we conducted this study to evaluate
the short-term postoperative results of hepatectomy with
Takasaki’s technique using Sonastar ultrasonic aspiration
system (Sonastar).

Materials and Methods
A retrospective study was conducted on 58 patients who
underwent hepatectomy with Takasaki’s technique using
Sonastar in Hue Central Hospital from 01/2018 to 02/
2021. The recorded information included (1) general infor-
mation: age, gender, history of liver diseases and past
liver-directed therapy; (2) laboratory tests: hepatic func-
tion was classified using Child-Pugh classification; (3)
tumor characteristics: site, size, number, and Barcelona
Clinic Liver Cancer (BCLC) staging; (4) technical char-
acteristics and complications.

Using the International Study Group of Liver Disease
(ISGLS) criteria, bile leakage was defined as a bilirubin
concentration in the drain fluid at least three times the
serum bilirubin concentration measured at the same time)
from postoperative day 3 onwards or the need for re-
intervention (radiologic or surgical) for biliary collections
or peritonitis. Similarly, posthepatectomy liver failure was
defined as an increased international normalized ratio and
concomitant hyperbilirubinemia on or after
postoperative day 5.

Surgical Procedure
Step 1: Patients were all placed in supine position with
both arms tucked alongside the body. A J-shaped incision
was used. After placement of Kent retractor, the abdomen
was carefully explored for any contraindications for
a curative resection (eg unresectable local invasion, distant
metastasis). Liver mobilization was performed based on
which type of hepatectomy was planned. Cholecystectomy
was routinely performed to facilitate hilar dissection.

Step 2: A combination of blunt and sharp dissection
allowed us to enter the avascular plane between Glisson’s
and Laennec capsules. The bifurcation was first lower
from the inferior surface of segment 4. Left and right
pedicle could then be easily encircled and taped using
right angle dissector. Further dissection of the right ante-
ier and posterior sections could also be proceeded based
on the types of hepatectomy. Pringle maneuver can be
selectively used during this step. Dissection of higher
level Glissonean pedicles usually required an intrahepatic
approach after localisation by intraoperative ultrasound.

Step 3: The Glissonean pedicle supplying the to-be-
resected segment was clamped and the demarcation line
was marked with electrocautery. Sonastar system was then
used for parenchymal transsection. The rapid forward and
backward movement of the tip of the handpiece would
create a cavitation effect resulting in fragmentation of
tissue with higher water content (eg hepatocytes) and pre-
servation of fibrous tissue (biliary tracts and blood ves-
sels). All biliary and vascular elements were then clipped
or suture – ligated before division. Sonastar was also
equipped with aspiration and electrocautery components,
which further facilitated a bloodless and safe transsection.

Step 4: Final inspection was performed to identify sites
of bile leak or hemorrhage from the transection surface,
which were then reinforced by suture. Surgicel or BioGlue
was then placed on the transection surface. An abdominal
drain was placed under the liver and exteriorized on the
right flank.

Step 5: Abdominal closure.

Data Analysis
Data were analyzed using SPSS 16.0 (IBM, Chicago, IL,
USA). All descriptive Descriptive data were presented as
means and standard deviations (SDs) and percentages.

Results
Patient Characteristics
Fifty-eight patients (50 men and 8 women) underwent
hepatectomy with Takasaki’s technique using Sonastar.
The mean age was 60.7 ± 10.5 (25–80) years. There
were 57 (98.3%) patients with a medical history of hepa-
titis B or C (51 hepatitis B). Most patients were classified
as Child-Pugh Stage A and Performance Status (PS) 0. All
patients had platelet counts over 100.000/mm3 and normal
coagulation panel. The mean of serum AFP level was 379
± 110.7 (11.5–1660) ng/mL.

Tumor Characteristics
The majority of patients had solitary tumor (79.3%), tumor
that is more than 5cm in size (68.4%), and distinct tumor
capsule (89.5%) (Table 1).
Technical Characteristics
Pringle maneuver was used in 11 patients (19%), while selective right and left Glissonean pedicles occlusion was used in 40 (69%) and 19 (32.8%), respectively. Surgicel was used to reinforce the transection surface in 49 (84.5%), and Bioglue was used in 21.5% of cases. Anatomical liver resection was performed in 51 patients (87.9%). Major liver resection (≥3 segments) was done in 74.1% of cases (Table 2). The mean of liver parenchyma transection time was 50 (45–110) minutes. The mean operative time was 125 (90–280) minutes. The amount of blood lost during operation was 250 (150–650) mL.

Surgical results and Early Outcomes
Postoperative characteristics were listed in Table 3. Most patients experienced an uneventful postoperative course. In the majority of patients, liver function tests showed slight disturbances during the first 5 postoperative days and gradually normalized from day 5 onwards.

Postoperative complications occurred in 5 patients (8.5%) (Table 4). One patient (1.7%) experienced bile leakage which lead to bile peritonitis requiring second operation in the fifth day postoperatively. The patient was dead in the two days after the second operation cause of nonrecoverable septic shock. The posthepatectomy liver failure was reported in 1/58 patient (1.7%), which was treated conservatively with fresh frozen plasma and human albumin transfusion.

The overall 24-month survival rates were 31% (18/58 patients). 15.3% (9/58 patients) patients had recurrences and were treated by ultrasound guided percutaneous Radiofrequency Ablation (RFA), all of whom were still alive still the end of the study period (Table 5).

Discussions
Surgical Technique
The Takasaki’s technique helps reduce bleeding in hepatic parenchyma transection as well as easily detect the

Table 1 Tumor Characteristics
| Tumor Characteristics | n = 58 | Percentage (%) |
|-----------------------|--------|----------------|
| Number                |        |                |
| Solitary              | 46     | 79.3           |
| Two and above         | 12     | 20.7           |
| Diameter              |        |                |
| > 5 cm                | 40     | 68.4           |
| ≤ 5 cm                | 18     | 31.6           |
| Tumor capsule         |        |                |
| Present               | 52     | 89.5           |
| Absent                | 6      | 10.5           |
| BCLC Staging          |        |                |
| BCLC A                | 46     | 79.3           |
| BCLC B                | 12     | 20.7           |

Table 2 Characteristics of Liver Resection Technique
| Technical Characteristics | n = 58 | Percentage (%) |
|---------------------------|--------|----------------|
| Resection margin          |        |                |
| <0.5 cm                   | 3      | 5.2            |
| ≤ 1 cm                    | 34     | 58.6           |
| > 1 cm                    | 21     | 36.2           |
| Reinforcement materials   |        |                |
| Surgicel                  | 49     | 84.5           |
| Bioglue                   | 9      | 15.5           |
| Control of the Glissonean pedicle | | |
| Pringle maneuver          | 11     | 19.0           |
| Selective right pedicle occlusion | 40     | 69.0           |
| Selective left pedicle occlusion | 19     | 32.8           |
| Type of liver resection   |        |                |
| Right hepatectomy         | 24     | 41.4           |
| Left hepatectomy          | 12     | 20.7           |
| Central hepatectomy       | 7      | 12.1           |
| Single segmentectomy      | 15     | 25.8           |
| Parenchymal transection time (minutes) | 50 ± 6 (45–110) |
| Operative time (minutes)  | 125 ± 65.3 (90–280) |
| Bleeding volume (mL)      | 250 ± 190.5 (150–650) |

Table 3 Postoperative Characteristics
|                          | Mean (SD) | Range |
|--------------------------|-----------|-------|
| Clinical characteristics  |           |       |
| Time to first bowel movement (days) | 3 (1.0)  | 2–5   |
| Time to drain removal (days)       | 6 (2.0)  | 5–11  |
| Postoperative hospital stay (days) | 8 (5.2)  | 7–23  |
| Laboratory tests on day 5         |           |       |
| Albumin (g/l)              | 33 (0.5)  | 29–45 |
| Bilirubin (mmol/L)         | 1.5 (2.0) | 3.5–23|
| AST (U/L)                  | 165 (50.0)| 115–537|
| ALT (U/L)                  | 119 (47)  | 98–455|
| Prothrombin rate (%)       | 79.5 (14.3)| 65–129|
| Platelets (K/mm³)          | 155.1 (35)| 126–457|
The application of Sonastar ultrasonic aspiration system in the liver parenchymal transection provides many significant advantages including preservation of small blood vessels and bile ducts at the transection surface which then be subsequently controlled by clipping or ligation to prevent hemorrhage and bile leak. It also facilitate dissection close to important vascular and biliary structures when the tumor is nearby. On the other hand, the maximal preservation of healthy liver parenchymal help ensure sufficient remnant liver volume to prevent postoperative liver failure.

**Morbidity and Mortality**

The overall morbidity rate was 8.5%. Our study reported one case (1.7%) with postoperative bile leak which lead to bile peritonitis requiring second operation on day 5. The patient was dead on the second day after the second operation due to nonrecoverable septic shock. The postoperative hepatic failure was reported in only 1/58 patient (1.7%), which was treated conservatively with fresh frozen plasma and human albumin transfusion. Two patients (3.4%) had ascites and were treated human albumin transfusion and diuretic (furosemide 40 mg per day). All other patients recovered after 7–10 days postoperatively. Patients with residual abscess complication were treated with ultrasound guided drainage and broad-spectrum antibiotics.

Recent improvements in anesthesia and intensive care along with updated techniques and tools help reduce the morbidity and mortality rates significantly. According to recent studies, hepatectomy complications accounted for 25% to 50%, with common complications related to surgery including bleeding, bile leakage, prolonged abdominal distention, hepatic dysfunction, prolonged pleural effusion and abscess below the diaphragm. Mild and severe bleeding and the need of blood transfusion were the factors that increased the rate of morbidity and mortality.

Retrospective study and multivariate analysis in major liver resections revealed that Pringle maneuver technique and blood transfusion were risk factors for patients, especially those with chronic comorbidities. Moreover, blood transfusion was the independent risk factor of postoperative mortality. Liver failure was associated closely with preoperative hepatic functions, extent of liver resection and future liver remnant volume (FLRV). Hepatic failure was the main cause of postoperative mortality. Right portal vein embolization (PVE) was a procedure that induces regrowth on left liver to accomplish the required FLRV.

**Postoperative Survivals**

The survival rates of liver resection in patients with tumor more than 5 cm in diameter was approximately 68.4%. In fact, the tumor size, in most case, did not result in significant difficulty intraoperatively. Studies showed that the overall survival was dependent on the tumor size and the anatomical boundaries of hepatic segments. Therefore, it help minimize the ischemia of remnant hepatic parenchyma and avoid the spread of malignant cells to the adjacent liver segments.

### Table 4 Post-Operative Complications

| Complications       | n = 58 | (%) | Management               |
|---------------------|--------|-----|--------------------------|
|                     |        |     | Conservative | Minimally Invasive | Reoperation |
| Biliary leakage     | 1      | 1.7 | 0           | 0                 | 1           |
| Hepatic failure     | 1      | 1.7 | 1           | 0                 | 0           |
| Ascites             | 2      | 3.4 | 1           | 0                 | 0           |
| Abscess             | 1      | 1.7 | 1           | 0                 | 0           |
| Mortality           | 1      | 1.7 |             |                    |             |

### Table 5 Survival Prognosis

| Overall Survival Time (Months) | n = 58 | Percentage (%) |
|-------------------------------|--------|----------------|
| 0–3                           | 58     | 100.0          |
| 3–6                           | 55     | 78.9           |
| 6–12                          | 47     | 57.9           |
| 12–24                         | 33     | 36.8           |
| 18–24                         | 26     | 15.8           |
| > 24                          | 18     | 31.0           |
| Recurrences                   |        |                |
| ≤ 6                           | 1      | 1.7            |
| 6–12                          | 1      | 1.7            |
| 12–18                         | 2      | 3.4            |
| > 24                          | 5      | 8.5            |
| Total                         | 9      | 15.3           |
stage of disease as well as the preoperative hepatic function. Patients with less-than-5cm tumors had the 5-years survival rate was about 70%, meanwhile, patients with hepatocellular carcinoma and hepatitis, the 5-years survival rate after hepatectomy was just 60%, and the rate of mortality related to surgery was about 2 to 3%. 13

The recurrence rate in the current study was 15.3%. However, because only 18 patients in our study were followed longer than 24 months, longer follow-up time is required to accurately reflect the survival prognosis. In the current literature, recurrence rate in 5-year follow-up was about 50 to 80%. Despite of the application of updated techniques and supported tools, there was not much improvement in limiting recurrence. Therefore, a multidisciplinary approach to recurrence is important to prolong posthepatectomy survival. 14

This is only a retrospective observation of short-term outcomes of the current technique of hepatectomy on a limited number of patients. A longer follow-up time and a control group is required in future study to clarify the potential benefits of Sonastar system and Takasaki technique.

Conclusions
Hepatectomy using Takasaki technique with Sonastar ultrasonic aspiration system is safe, effective, allowing an anatomical resection with sufficient safety margin and resulting in low complication rates (liver failure, biliary leakage) and good survival outcomes.

Ethics Approval and Consent to Participate
This study has been reviewed by the Ethics Committee of Hue Central Hospital; all procedures performed in studies involving human participants were conducted according to the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent for Publication
Written informed consent for publication of the clinical details were obtained from each patient.

Author Contributions
All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure
The authors declare that they have no competing interests.

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