A hybrid method of laparoscopic-assisted open liver resection through a short upper midline laparotomy can be applied for all types of hepatectomies

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Key words: hepatectomy, minimally-invasive liver resection, hybrid method, living donor hepatectomy, midline incision

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Abstract

Background Although hepatectomy procedures should be designed to provide both curability and safety, minimal invasiveness should be also pursued. **Methods** We analyzed the data related to our method for laparoscopy-assisted open resections (hybrid method) through a short upper midline incision for various types of hepatectomies. Of 215 hepatectomies performed at Nagasaki University Hospital between November 2009 and June 2012, 102 were performed using hybrid methods. **Results** A hybrid method was applicable for right trisectionectomy in 1, right hemihepatectomy in 32, left hemihepatectomy in 29, right posterior sectionectomy in 7, right anterior sectionectomy in 1, left lateral sectionectomy in 2, and segmentectomy in 7 patients, and for a minor liver resection in 35 patients (12 combined resections). The median duration of surgery was 366.5 minutes (range: 149 – 709 minutes) and the median duration of the laparoscopic procedure was 32 minutes (range: 18 – 77 minutes). The median blood loss was 645 g (range: 50 – 5370 g). Twelve patients (12%) developed postoperative complications, including bile leakage in 3 patients, wound infections in 2 patients, ileus in 2 patients, and portal venous thrombus, persistent hyperbilirubinemia, incisional hernia, local liver infarction each in 1 patient. There were no perioperative deaths.

Conclusions Our method of hybrid hepatectomy through a short upper midline incision is considered to be applicable for all types of hepatectomy and is a reasonable approach with no abdominal muscle disruption, that provides safe management of the hepatic vein and parenchymal resection even for patients with bilobular disease.

Introduction

Liver resection is one of the most challenging fields in minimally invasive surgery. In 2007, Koffron et al. reported 300 minimally invasive liver resections (MILR) for hepatic lesions (1). In their report, they employed three different methods of liver resection; pure laparoscopic liver resection, hand-assisted laparoscopic resection and laparoscopy-assisted open resection (hybrid) as the MILR. Compared to open hepatic resection, all of their MILR procedures were less invasive, and were associated with a shorter operation time, lower blood loss, and a shorter hospital stay, with the same rates of local recurrence and complications.

In a worldwide review of laparoscopic liver resection performed in 2009, pure laparoscopic resections were performed in 75% of cases, hand-assisted laparoscopic resections in 17% and a hybrid procedure was done in only 2% of cases (2). However according to the review, the resected area of the liver was a wedge resection in 45%, and left lateral section in 20%, revealing that only 23% of procedures were performed for anatomical resections larger than a sectionectomy.

We have employed hybrid liver resection with hand-assisted laparoscopic liver mobilization and subsequent liver resection with the hanging maneuver and a two-surgeon technique through a short upper midline incision. Our initial data on hybrid

liver resection were herein analyzed to clarify the parameters related to their use for various types of hepatectomies.

Patients and Methods

Of 215 hepatectomies performed between November 2009 and May 2013 at Nagasaki University Hospital, we employed laparoscopy-assisted open resections (hybrid method) for 102 patients (47%).

The contraindications for the hybrid procedure were as follows: 1. the cases with a previous history of upper abdominal laparotomy, 2. tumor involvement of the diaphragm or a tumor large enough to require an anterior liver resection, and 3. the cases with portal or hepatic venous tumor thrombus. The resections for small tumors located in the anterocaudal side of the liver and left lateral sectionectomy were performed under pure laparoscopic liver resection. As a standardized anatomical resection of the normal liver, we chose living donor left hemihepatectomy for comparison of the surgical outcomes of the hybrid technique and the open procedure.

Among the analyzed patients who underwent hybrid resection, the median age (62 males, 40 females) was 59 years (range: 21-85 years) (Table 1). The patients' median height was 161cm (range: 145-181), and the median weight was 60kg (range:

37-88). Body mass index (BMI) was 22.8 (range: 16.5-31.6).

All but one patient had Child-Pugh grade A status; one patient was considered to have Child-Pugh grade B disease. The liver functional reserves were as follows: the indocyanine retention rate at 15 minutes (ICGR15) had a median of 11 % (range: 1 – 28%), and the median 99mTc-GSA scintigraphy receptor index [ratio of the liver to heart-plus-liver radioactivity at 15 minutes (LHL15)] was 0.920 (range 0.834 – 0.956). The liver functional reserve evaluations, including the ICG retention test and 99mTc-GSA scintigraphy were not performed for living liver donors.

The primary reasons for the operations were hepatocellular carcinoma in 32, metastatic liver cancer in 14, hilar cholangiocarcinoma in 3, intrahepatic cholangiocellular carcinoma in 5, hepatic epithelial hemangioendothelioma in 1, hepatic carcinoid in 1, cystadenoma in 1, Caroli's disease in 1, and living liver donor in 44 (Table 1). The surgical methods employed were a right trisectionectomy in 1, right hemihepatectomy in 32, left hemihepatectomy in 29, right posterior sectionectomy in 7, left lateral sectionectomy in 2, and segmentectomy (S5, 6, 7) in 7 patients, and a minor liver resection was performed in 35 patients (combined in 12) (Table 2). We evaluated surgical outcomes in the patients who underwent the hybrid procedure. We also compared the surgical outcomes of the hybrid procedure and open procedure for living

donor hemihepatectomy.

The Mann-Whitney U-test was applied to compare the groups. A *P* value <0.05 was considered to be statistically significant.

Surgical techniques

Patients were placed in the supine position with their arms adducted, and a urinary catheter, and arterial and central venous lines were inserted. An 8 cm upper midline laparotomy was made, followed by a 5 mm umbilical incision for the laparoscope. The round, falciform, and coronary ligaments were divided, and a wound retractor was installed. Before starting the laparoscopic procedure, a surgical towel was inserted through the upper midline incision to displace the small intestine and colon away from the surgical site. A GelPort (Applied Medical, CA, USA) was attached to the wound retractor at the 8 cm incision, and a 5 mm trocar was placed in the right lateral upper abdomen under pneumoperitoneum (CO_2 at 8 mmHg) (Fig. 1A). This configuration enabled the first assistant surgeon, who stood on the left side of the patient, to use the hand port for liver manipulation. The primary surgeon stood on the right side and used the right lateral 5 mm port for dissection. Using laparoscopic electrocautery and a hand assist, the right lobe of the liver was mobilized until the inferior vena cava (IVC) was recognized for all types of hepatectomies. The IVC does

not need to be fully exposed at this stage to avoid incidental massive bleeding.

For patients indicated for left side hepatectomy, the left triangle ligament was also dissected through the 5 mm port placed through the GelPort (Fig. 1B). After these mobilizations, the midline incision was extended to 10 cm for left side anatomical resection and 12 cm for the right side anatomical resection, and a wound retractor was applied. For minor partial resections, even for multiple lesions, the 8 cm incision was still used. The wound was retracted and opened with the Omnitract retractor. For a right side hepatectomy, the short hepatic veins were divided under direct view, and the right hepatic vein was encircled and a 6 mm Penrose drain was placed for a subsequent liver hanging maneuver through a midline incision (Fig. 2A). For an extended left hemihepatectomy, the common trunk of the middle and left hepatic veins was carefully encircled. The left hepatic vein was isolated and encircled in advance of parenchymal resection, when it could be safely performed. A Penrose drain was also placed between the hepatic veins for the liver hanging maneuver for left hemihepatectomies.

When cholecystectomy was necessary, we performed it by an open procedure. Hilar dissection was conducted through the midline incision under direct vision (Fig. 2B). By placing surgical towels in the right subphrenic space, the liver can be stabilized in an ideal position by setting the intended transection line in the middle of

the incision (Fig. 3).

The 4-0 polypropylene stay sutures were placed at the anterocaudal edge of the liver along the plane of the intended transection. The chief surgeon dissected the hepatic parenchyma from the patient's right side using a Cavitron ultrasonic surgical aspirator (CUSA) system (Integra Life Sciences, Plainsboro, NJ), while the assistant surgeon used a saline-linked cautery device (Dissecting Sealer DS 3.5; Salient Surgical Technologies, Portsmouth, NH) from the patient's left side. The occlusion of the hepatic arterial and portal inflow was not performed in any of the cases. The liver parenchyma was dissected with the CUSA, and the intraparenchymal vascular anatomy was defined so that a decision on the hemostatic technique could be made based on the vessel size. The saline-linked cautery device was used to coagulate and divide the dissected vessels that were 3 mm or smaller in diameter. Vessels larger than 3 mm in diameter were ligated with 3-0 or 4-0 synthetic polyester ties, and were sharply divided. The few larger vessels were ultrasonically dissected and controlled with 4-0 absorbable monofilament transfixing sutures, and were then sharply divided. The traction on the stay sutures was used to separate and to expose the deepening transection plane. During the parenchymal dissection, the upward traction on the tape (hanging maneuver) allowed the surgeon to follow a direct plane and facilitated the exposure and hemostasis of the deeper

parenchymal plane in front of the IVC (5, 13). A closed suction drain was inserted at the conclusion of each procedure.

Preparations for an open hepatectomy were always executed as a back-up plan before surgery.

Results

The median length of the operation was 366.5 minutes (range: 149-709 min). The median duration of the laparoscopic procedure was 32 minutes (range: 18-77 min). The median blood loss was 645 g (range: 50-5370 g). There were no macroscopic or microscopic-positive margins seen in any of the patients. No cases were converted to conventional open heptectomy with subcostal incision. The postoperative complications included surgical site infections in 2 patients, bile leakage in 3 patients, ileus in 2 patients, local liver infarction, portal venous thrombus, incisional hernia, and postoperative hyperbilirubinemia each in 1 patient. According to the Clavien-Dindo classification (4), the patient with portal venous thrombus and the patient with ileus was a Grade III complication, while the others were of Grade I. The median hospital stay 13 days (range: 8 – 123 days).

Comparing the findings for the hybrid technique and the open procedure for living donor left hemihepatectomy (n=24 per group) and right hemihepatectomy (n=19),

no significant differences were seen in the duration of the operation (hybrid group: median 440 minutes (range: 282-581 minutes), open hepatectomy: median 400 minutes (range: 305-636 minutes). In donor left hemihepatectomy, the intraoperative blood loss was significantly lower in the hybrid method group [median 510 g (50-1,950) vs. 637.5 g, (250-3,150)]. No significant difference was seen in the intraoperative blood loss between open and hybrid donor right hemihepatectomy [meidan 625 g (320-1,800) vs. 710 g (234-2,550)] (Fig 4).

As a result, a hybrid method was successfully employed even in the cases that needed combined hepatectomy with hemihepatectomy and minor liver resection, or multiple minor liver resections for bilobular lesions, or a right posterior sectionectomy.

Case studies

Case 1

A 56-year-old male with hepatic carcinoid had multiple lesions in the right lobe, and a lesion close to the middle hepatic vein. In addition, another tumor was present in the left lateral section. The patient underwent right hemihepatectomy with local resection of the left lateral section by a hybrid method. Radiofrequency ablation was performed for the lesion close to the middle hepatic vein with intraoperative ultrasound guidance (Fig. 5).

Case 2

A 75-year-old male with multiple colorectal liver metastases. The tumors were located in segments 4, 6, and 7 (Fig. 6A). Since his hepatic functional reserve was disturbed as a result of the adverse effects of chemotherapy, a right hemihepatectomy was not possible. The patient underwent multiple local resections by a hybrid method through a 10 cm upper midline incision (Fig. 6B).

Case 3

A 74-year-old female with solitary hepatocellular carcinoma in segment 7 underwent an extended posterior sectionectomy by a hybrid method (Fig. 7).

Discussion

We herein reported the largest case series of hepatectomies performed by hybrid methods. To date, two other large case series employing hybrid methods have been reported (1, 5). Our data further support the safety, feasibility and efficacy of the hybrid approach for anatomical liver resection.

Although the term 'hybrid method' is becoming common, there are some differences among institutions in terms of the following procedures: the location of the incision, the trocar locations, the extent of hand-assist procedures, etc. At our institution, we have adopted an upper midline incision for both the hand access and the open procedure. The hybrid method with an upper midline incision can be performed irrespective of the type of resection. Even posterior sectionectomies (S6+7) were consistently performed through the upper midline incision after hand-assisted right lobe mobilization. The benefits of anatomical resection for HCC have been reported (8, 9). Hepatic parenchymal resection under direct vision in hybrid method can achieve meticulous and accurate resection with exposing vessels as well as conventional open procedure.

In addition to the effective application of the hybrid method for anatomical liver resections, we consider that a multiple partial hepatectomy is a good indication for the hybrid technique. Bilobular multiple liver tumors can be consistently managed through

the short upper midline incision after the sufficient mobilization of the liver.

The upper midline incision contributes to the effective hand-assist compared to access through a subcostal incision as a result of the wider working space. In terms of ergonomics, a hand-assist through the upper-midline incision may be more natural, because the rotation of the liver and the hand-movement of the first assistant go in the same direction. Furthermore, the midline incision offers easy access to bilobular lesions. By using a GelPort hand-device in place of trocar insertion, less-port surgery can be achieved.

Hand-assisted procedures performed during the management of the area around the IVC and hepatic veins guarantees that there can be rapid emergency management of incidental massive bleeding. We consider that dividing the short hepatic veins and the subsequent encircling of the right hepatic vein or the common trunk of the middle hepatic vein and left hepatic vein can be more securely performed under direct vision compared to by a laparoscopic procedure. Once the right lobe is mobilized, the liver can be rotated to the left of the midline and retracted; therefore, the surgeon can easily approach the inferior vena cava and the right hepatic vein even through a mini-laparotomy with a short upper midline incision. Since the IVC and hepatic hilum are basically located in the middle of the abdomen, the surgeon can approach these

areas without stress through the midline under the exposure provided by the wound retractor and surgical retractor. The safety guaranteed by the hand-assist procedure seems to be superior to the magnification effect obtained during laparoscopy.

Reducing blood loss is one of the goals of liver surgery, and several technical inventions have been introduced to achieve this, including the Pringle maneuver (8, 9) and selective vascular occlusion (10), among other techniques. Regarding surgical devices, the CUSA has contributed to the safety of hepatectomies by making it easy to identify the vessels during parenchymal transections. However, because the CUSA cannot seal tissues, meticulous ligation is required to avoid bleeding or bile leakage from the cut surface of the liver. Saline-linked electric cautery (SLC) is another novel device that contributes to reducing the need for ligation during liver parenchymal transections, because it can be used for tissue sealing (11). Aloia et al. introduced a two-surgeon technique for hepatectomies to resect neoplasms in adults, and demonstrated promising results (12). Palavecino et al. demonstrated that the mean intraoperative blood loss was significantly decreased after the introduction of the two-surgeon technique compared with other techniques (stapling alone, ultrasonic dissection alone, saline-linked cautery alone, and the clamp-crush technique) (13). We previously demonstrated that SLC could be safely adapted for living liver donor surgery

without injuring either the graft or the remnant liver (14). With the introduction of the liver hanging maneuver, which brings the transection line to just beneath the upper midline incision with pulling up of the liver (5, 15), to the hybrid method, parenchymal transection with the two-surgeon technique can be conducted as well as during open procedures. As a result, parenchymal transection can be successfully completed through the 10-12 cm upper midline incision without additional stress for the surgeon.

The upper midline incision that we adopted for the hybrid procedure is considered to have several advantages compared to the right subcostal incision, which was previously reported for the hybrid method. The upper midline can avoid muscle disruption and disturbing the sensory nerve dominating the abdominal wall. Jain et al. reported the presence of persistent numbness of the abdominal skin between the subcostal incision and the umbilicus in patients who had undergone liver transplantation (16). Surprisingly, 100% of the patients (n=101) had persistent numbness up to 9 years following liver transplantation. Five percent of these patients developed thermal injuries or blunt trauma complications. According to the results of a randomized double-blind trial concerning midline versus transverse incisions in major abdominal surgery, although no relevant differences between midline and transverse incisions were observed for pulmonary complications, the median length of hospital stay and incidence

of incisional hernias after one year was higher, and patients showed more wound infections, in the transverse group (P=0.02) (17). Given the development of the above-mentioned postoperative complications, the upper midline incision seems to be a more reasonable approach.

Some authors reported the feasibility of major hepatectomy under midline incision including living donor hepatectomy (18,19). Lee et al. concluded that the procedure after an upper midline incision is more difficult in male donors with large fatty livers and deep truncal cavities. Without randomized controlled trial, we presently cannot show objective data comparing our procedure and midline hepatectomy without laparoscopy. However, laparoscopic mobilization of the liver under pneumoperitoum has been reported as safe and effective procedure with good multidirectional operative view and wide working space (1, 20). Hence, this virtue of laparoscopic procedure would allow mobilization of the liver even in patients with deep truncal cavities irrespective of length of midline incision. The influence of each patient's constitution on our technique seems smaller than that on midline major hepatectomy without laparoscopic procedure. In this study, 17 patients (17%) showed BMI higher than 25 that figure is cut-off value between normal and overweight. Among the patients, 4 patients showed BMI higher than 30 that is considered obesity. We hereby considered

that concept of our procedure can be applied in almost all of patients except the case of morbid obesity accompanied with extremely thick abdominal wall.

Furthermore, quick celiotomy and closure of the abdomen were also benefits of the upper midline incision (21). The additional duration of the preparation for laparoscopic procedure was offset by the rapid opening and closing of the abdominal incision.

Although the long-term outcomes should be carefully evaluated, given the aforementioned advantages, in addition to the safety and feasibility, we consider that our technique should become more widely accepted as a standard hybrid method. Moreover, this method does not require expert laproscopic surgical skills.

Disclosures

Drs. Akihiko Soyama, Mitsuhisa Takatsuki, Tomohiko Adachi, Amane Kitasato, Yasuhiro Torashima, Koji Natsuda, Takayuki Tanaka, Izumi Yamaguchi, Shiro Tanaka, Ayaka Kinoshita, Tamotsu Kuroki, and Susumu Eguchi have no conflicts of interest or financial ties to disclose.

Figure legends

Fig. 1. The trocar placement. A) The dotted line shows the upper midline incision. A 5 mm camera port is inserted from the umbilicus. Another 5 mm trocar is used for dividing the ligaments for mobilization of the right lobe. B) When mobilizing the left lobe of the liver is necessary, a 5 mm trocar is inserted through a GelPort handport device.

Fig. 2. A) When mobilizing the right lobe of the liver, the surgeon can manage short hepatic veins, the right hepatic vein, and the inferior vena cava through the upper midline incision with adequate exposure. The blue vessel loop is encircling the right hepatic vein, and a Penrose drain was also passed around the right hepatic vein for the later hanging maneuver during parenchymal resection.

B) Hilar dissection under direct vision from the 12 cm upper midline incision. An Omni-tract surgical retractor is useful to maintain a good surgical field.

Fig. 3. With sufficient mobilization, the planned resection line can be exposed under an upper midline incision. The dotted line shows the planned resection line for a posterior sectionectomy. The photograph shows the demarcation line with control of the inflow to

the posterior sector.

Fig. 4. CT images of multiple hepatic carcinoid tumors treated by hybrid resection, and a lesion treated by radiofrequency ablation (arrow). The right panel is a 3D reconstructed image made from CT scans obtained by a Synapse Vincent instrument (Fujifilm Medical, Tokyo, Japan).

Fig. 5. A. CT images of multiple colorectal metastases treated by a hybrid method. The right panel is a 3D reconstructed image made from CT scans obtained by a Synapse Vincent instrument (Fujifilm Medical, Tokyo, Japan). B. Local resection was performed for 4 lesions because of insufficient liver functional reserve for major hepatectomy. A 10 cm upper midline incision was made for the hybrid method.

Fig. 6. A contrast-enhanced CT scan showed a mass lesion in segment 7 of the liver. The middle panel is a 3D reconstructed image made from CT scans obtained by a Synapse Vincent instrument (Fujifilm Medical, Tokyo, Japan). The intraoperative photograph shows the line of resection for the posterior sectionectomy.

Fig. 7. Comparing the surgical outcomes of the hybrid procedure and open procedure

for (A) living donor left hemihepatectomy and (B) right donor left hemihepatectomy.

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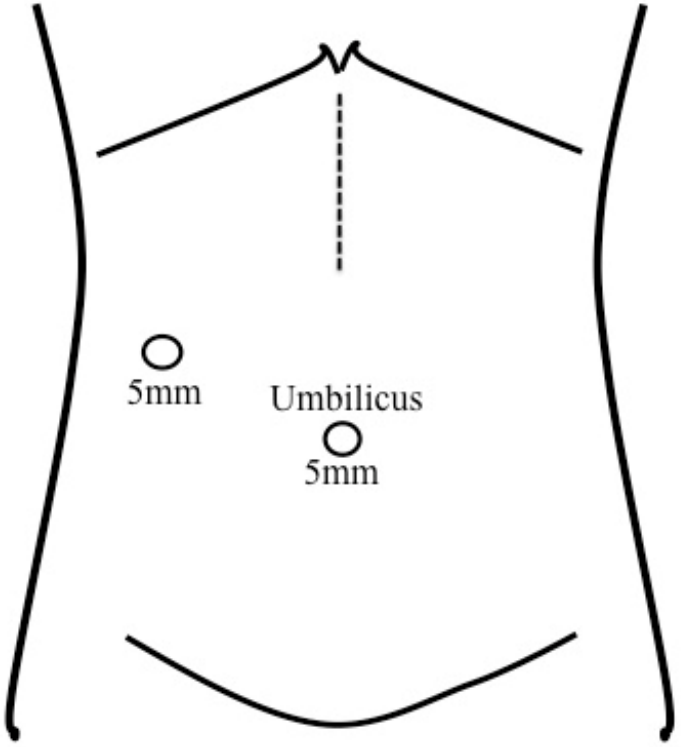
Fig. 1

A)



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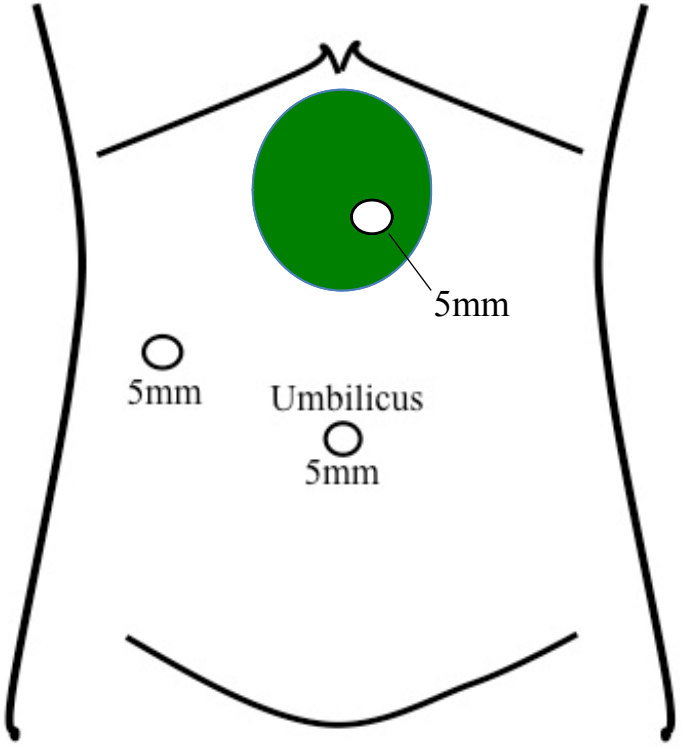
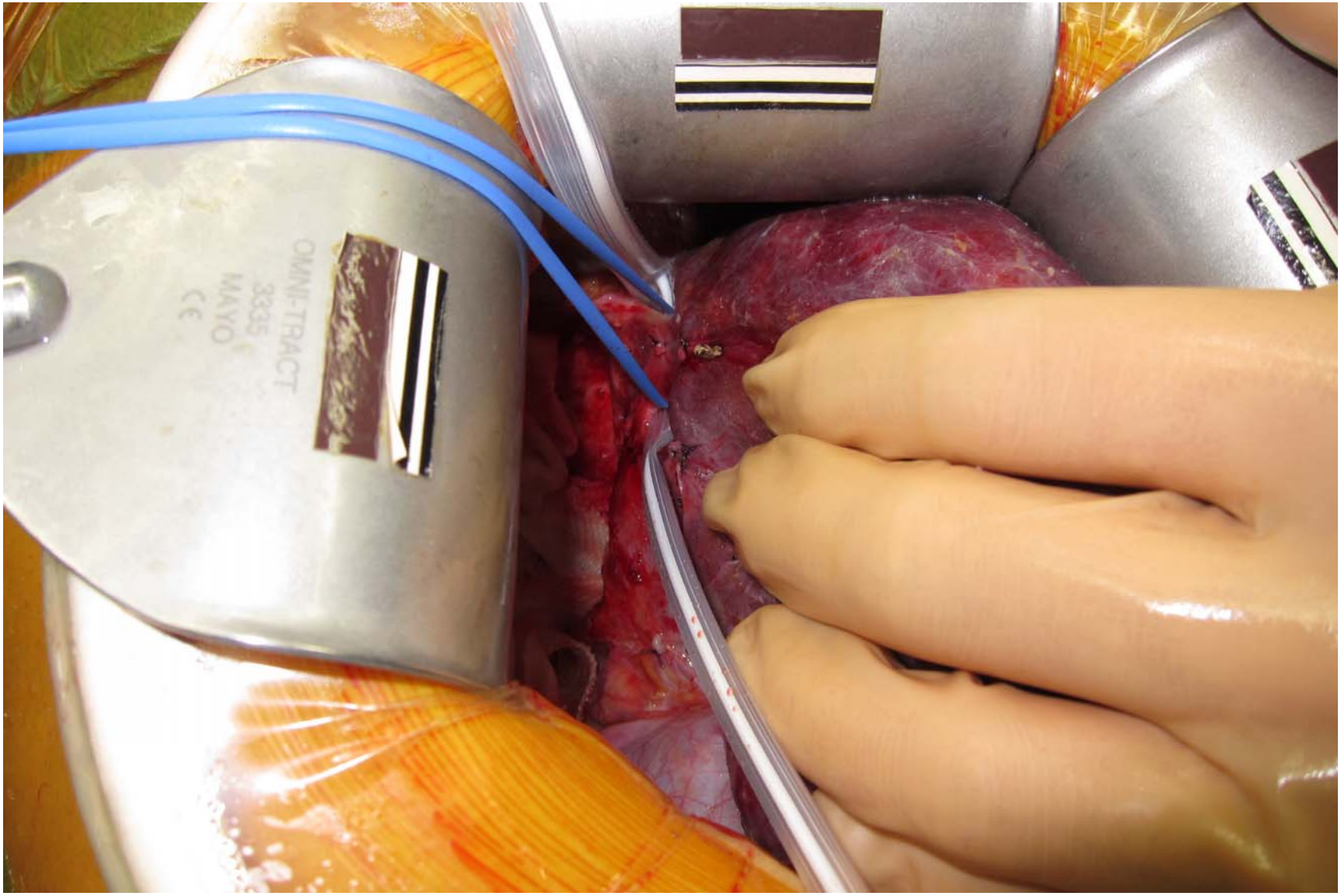


Fig. 2 A)



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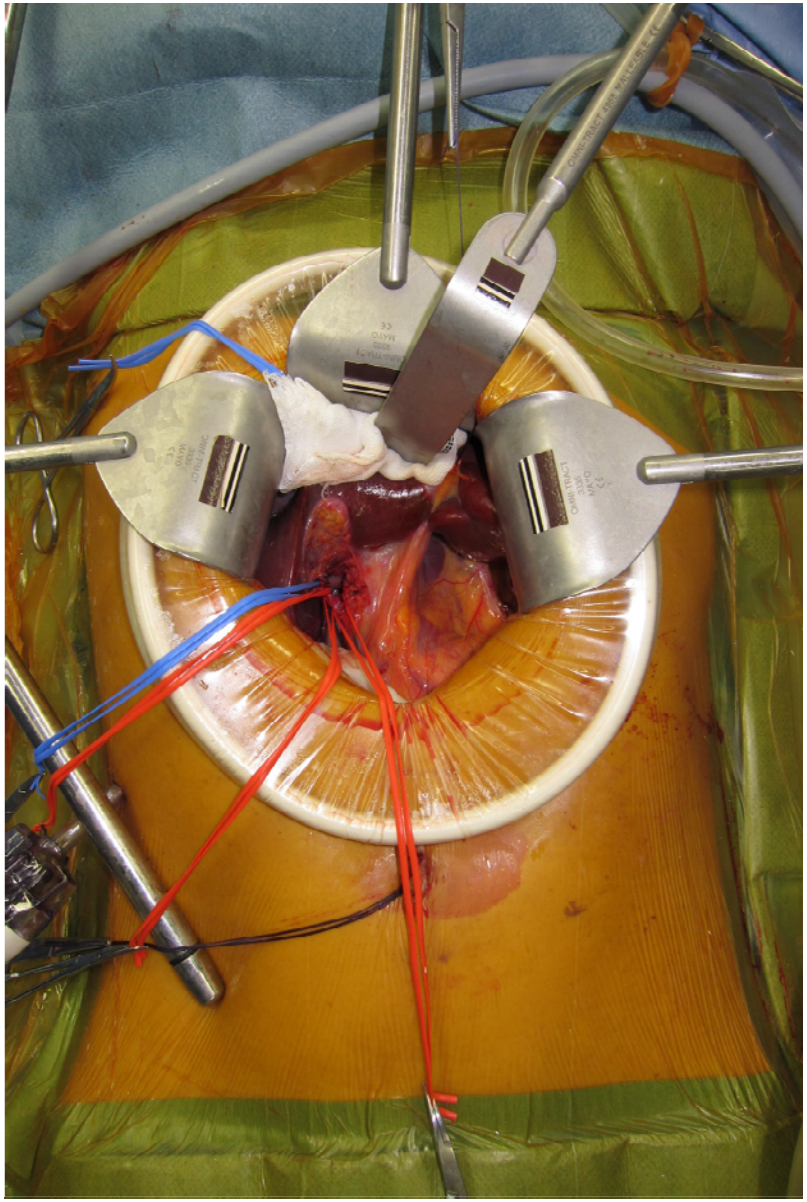
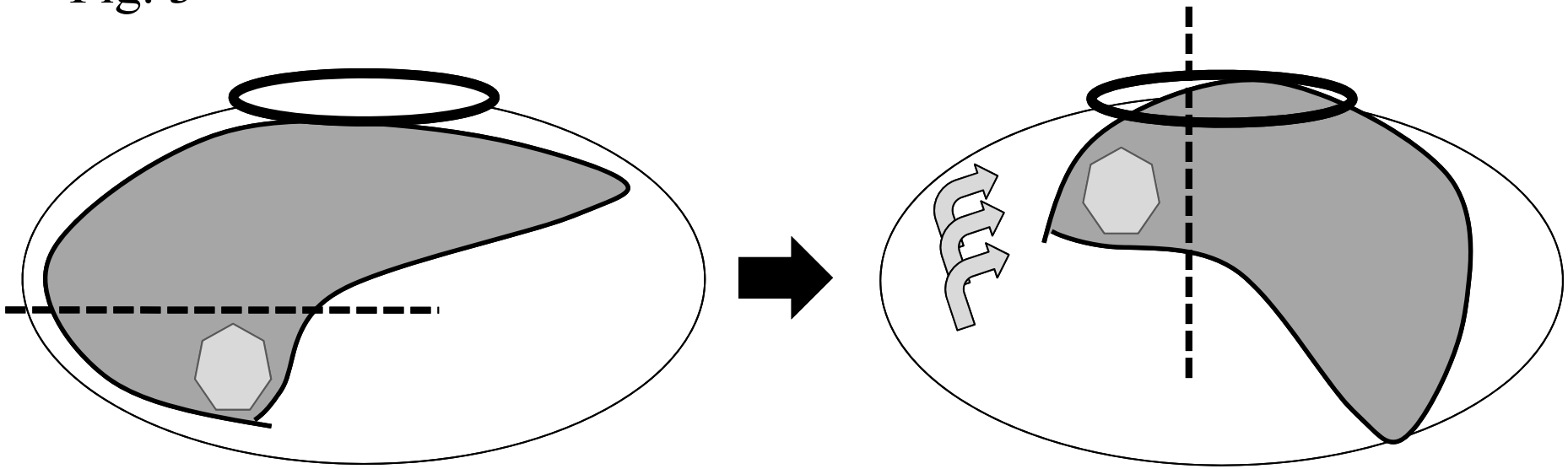


Fig. 3



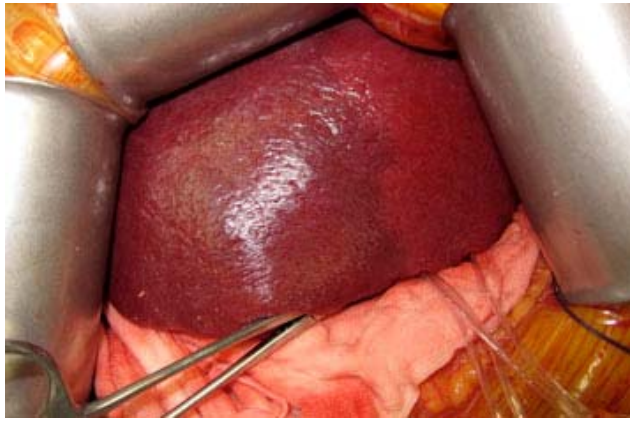


Fig. 4

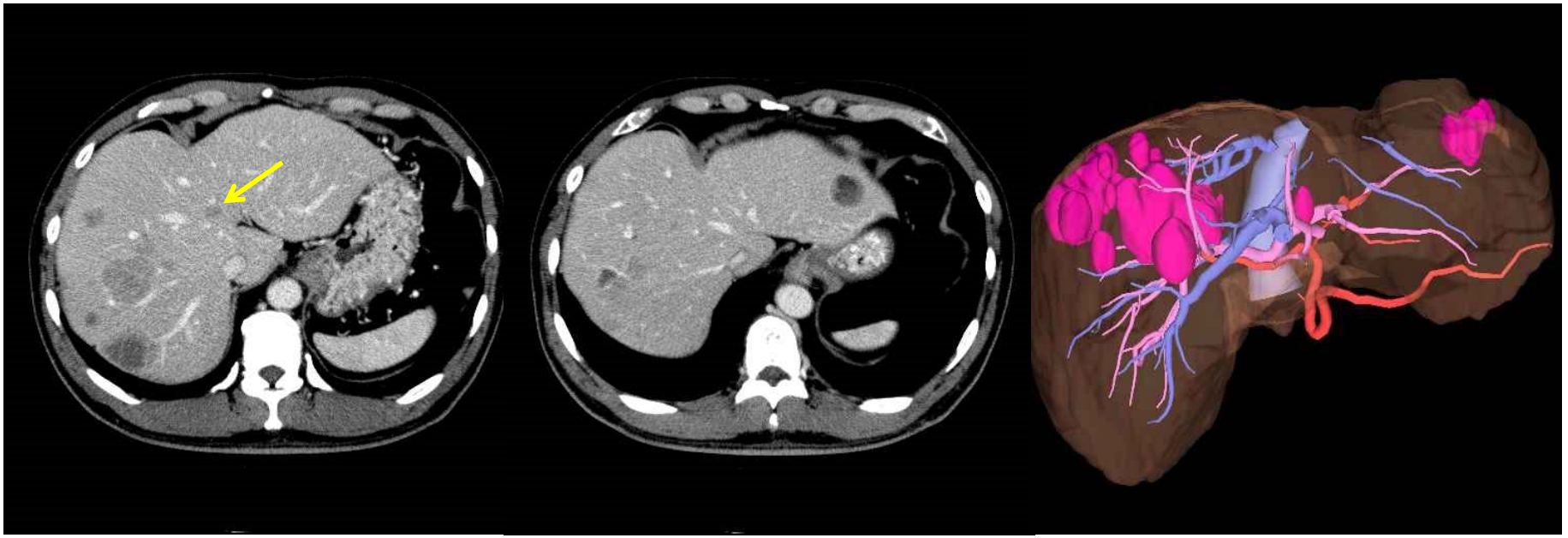


Fig. 5 A

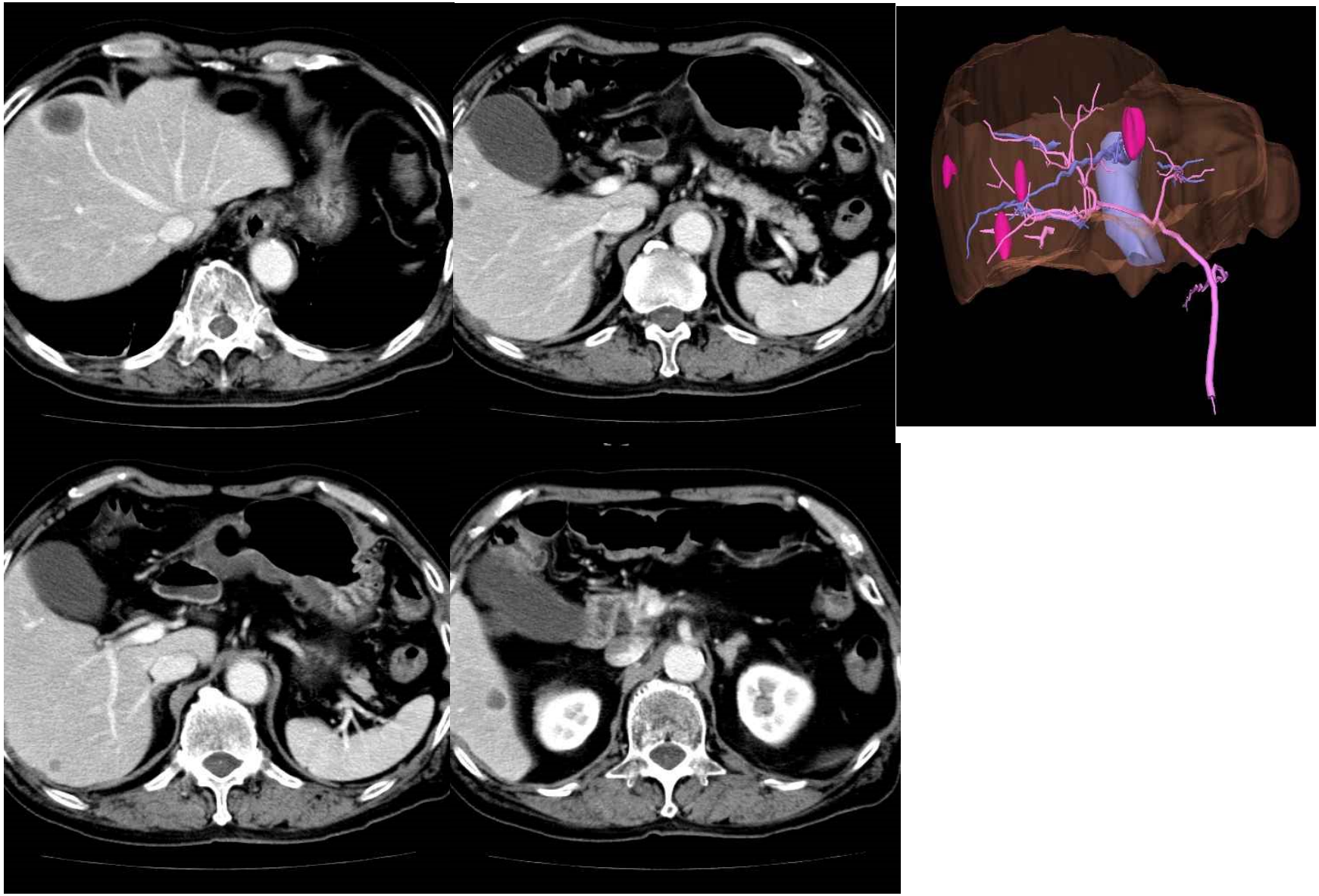
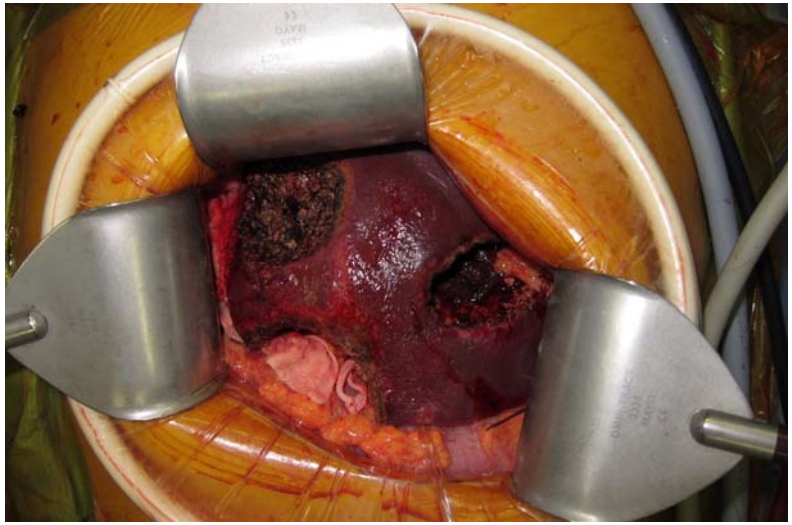


Fig. 5 B



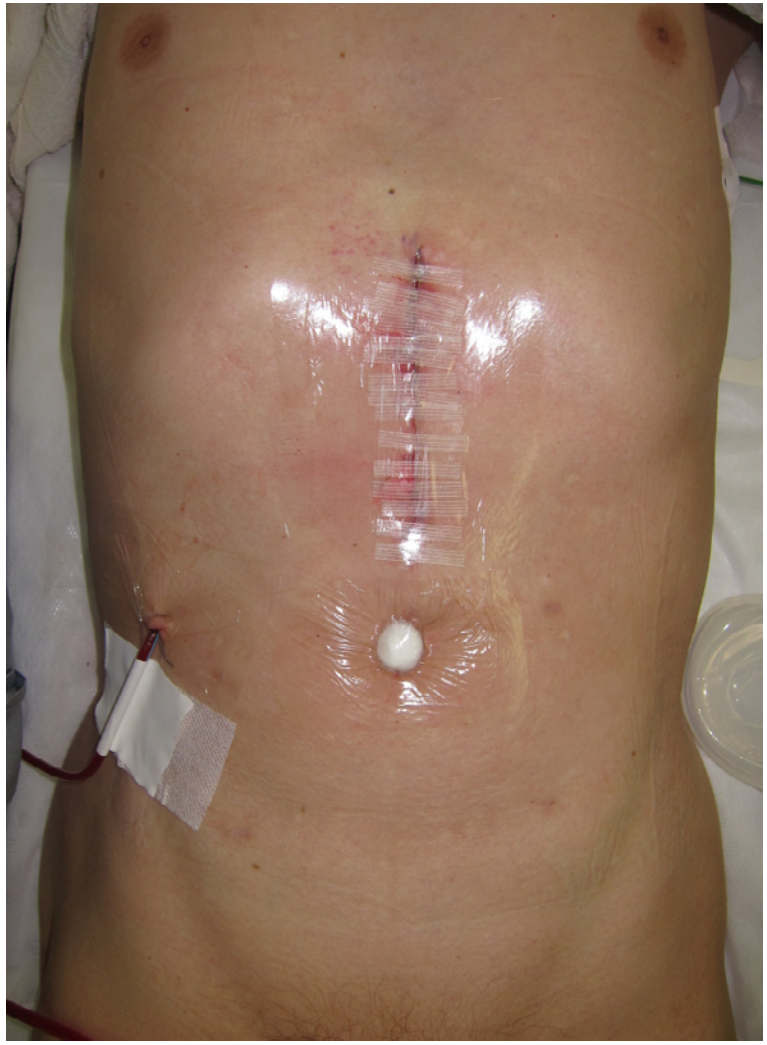


Fig. 6

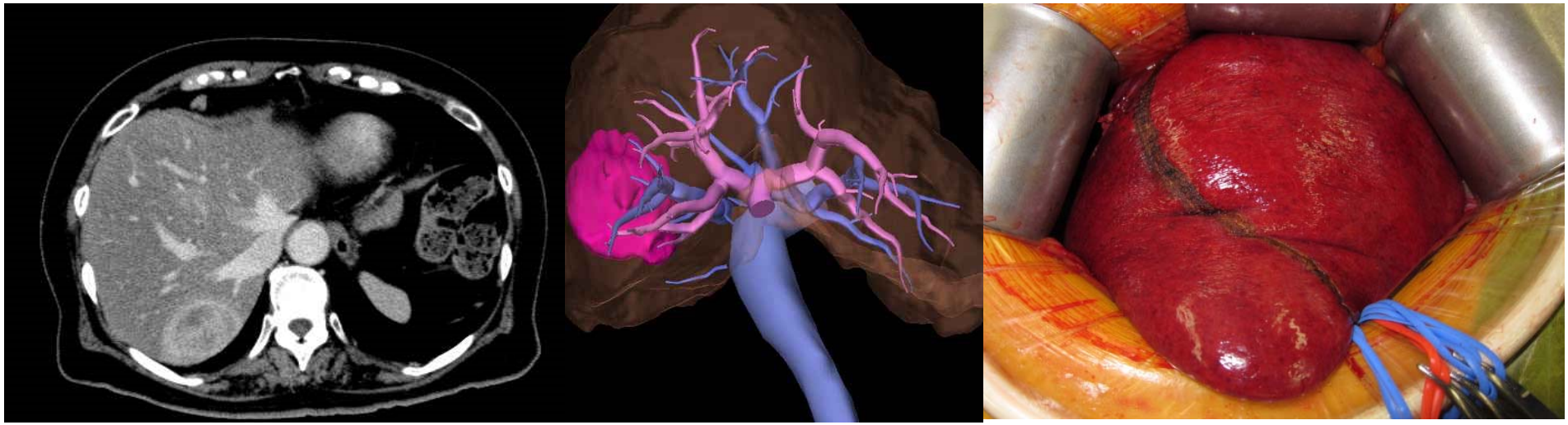


Fig. 7

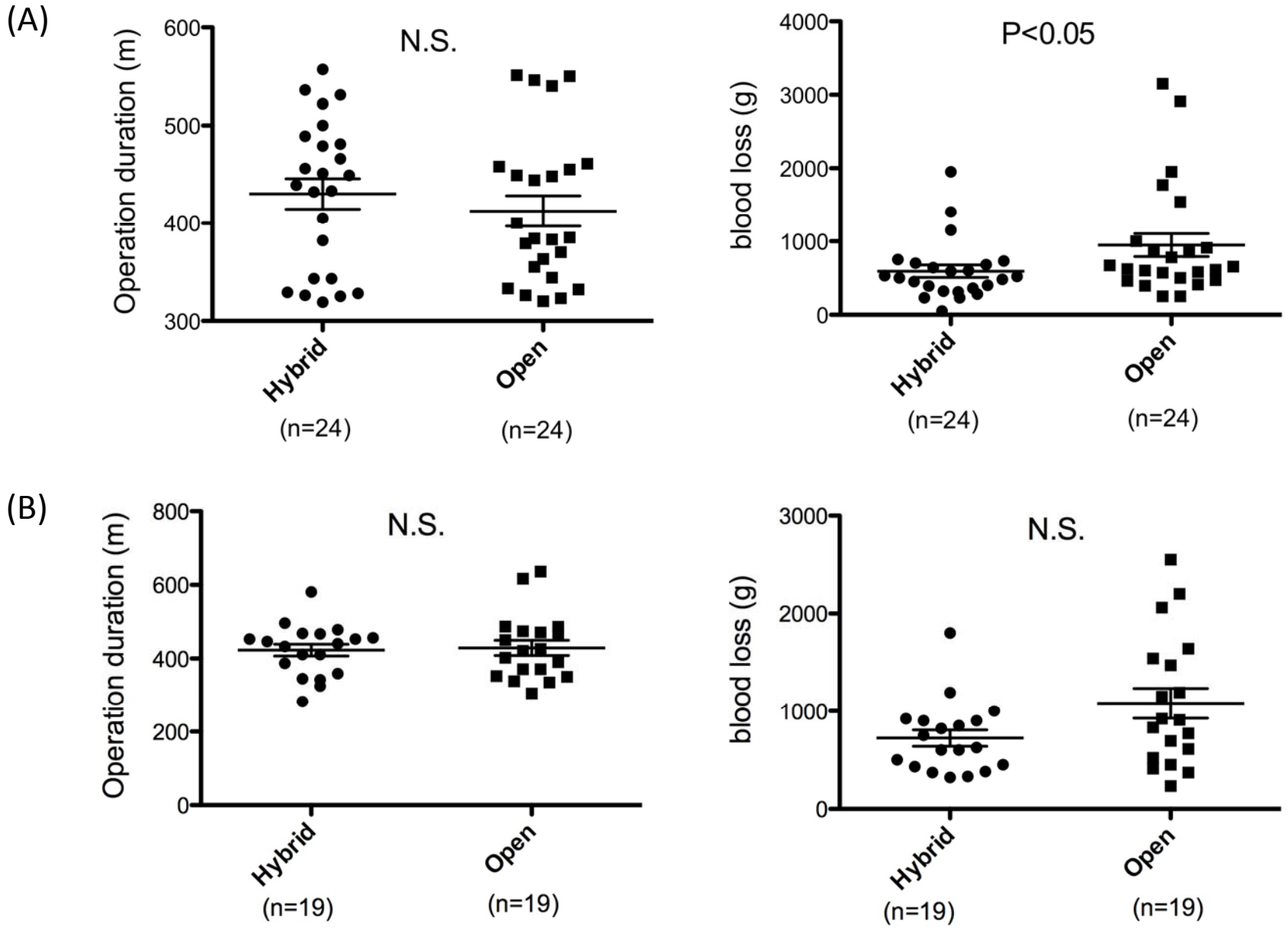

(A)
Operation duration (m)
600
500
400
300
N.S.
Hybrid
Open
(n=24)
(n=24)
blood loss (g)
4000
3000
2000
1000
0
P<0.05
Hybrid
Open
(n=24)
(n=24)
(B)
Operation duration (m)
800
600
400
200
0
N.S.
Hybrid
Open
(n=19)
(n=19)
blood loss (g)
3000
2000
1000
0
N.S.
Hybrid
Open
(n=19)
(n=19)

Table 1. Patient characteristics

age (years)	59 (range, 21-85)
sex (M:F)	62:40
height (cm)	161 (145-181)
weight (kg)	60 (37-88)
BMI	22.8 (16.5-31.6)

Indications	*Number*
Hepatocellular carcinoma	32
Metastatic liver tumor	14
Hilar cholangioma	3
Intrahepatic cholangioma	5
Epithelial hemangioendotheliom	1
Hepatic carcinoid	1
Cystoadenoma	1
Caroli's disease	1
Living donor	44

Table 2. Types of hepatectomies

Types of hepatectomies	Number
Right trisetionectomy	1
Right hemihepatectomy	32
Left hemihepatectomy	29
Anterior sectionectomy	1
Posterior sectionectomy	7
Left lateral sectionectomy	2
Segmentectomy	7
Minor liver resection	35 (combined in 12)