

# Laparoscopic Liver Resection Using a Silicone Band Retraction Method (With Video)

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**Background:** The success of laparoscopic liver resection (LLR) depends on stable and full exposure of the parenchymal transection plane. We evaluated the efficacy of LLR using a silicone band retraction method for lesions in the anterolateral and posterosuperior segments.

**Methods:** We retrospectively analyzed 189 consecutive patients who had undergone LLR in our hospital between July 2010 and July 2020. They were divided into 2 groups according to whether LLR was performed before (conventional group; n = 64) or after (silicone band group; n = 125) the introduction of the silicone band retraction method.

**Results:** The silicone band group demonstrated significantly less blood loss than that by the conventional group. The mean operative time and the hospital stay in the silicone band group were obviously shorter than that in the conventional group. The open conversion rate and the major complication rate were significantly lower in the silicone band group than that in the conventional group.

**Conclusion:** The silicone band retraction method is a useful approach that results in a safe LLR.

**Key Words:** silicone band retraction method, laparoscopic liver resection, silicone band uplift technique, one-surgeon technique, posterosuperior segment

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Laparoscopic liver resection (LLR) is being increasingly performed worldwide owing to its curative nature and minimal invasiveness with respect to liver tumors, particularly liver cancers.<sup>1–4</sup> Minor LLR and left lateral sectionectomy have now been established as standard procedures following the 2 International Consensus Meetings.<sup>5,6</sup> Significant advances have been made in LLR following advancements in surgical techniques and the development of efficient and useful laparoscopic equipment.<sup>7–9</sup> The most favorable indication for

LLR is a lesion located in the anterolateral segments (segments 2 to 6) of the peripheral liver;<sup>5</sup> performing LLR in the posterosuperior segments such as segments 7 and 8 is technically difficult because of the limited visibility and difficulty in controlling the bleeding.<sup>6,10–12</sup> Although laparoscopic liver surgery has the benefits of magnified views and hemostatic effects from pneumoperitoneum pressure, and despite the significant advances made in the equipment for LLR, safe transection of the liver parenchyma remains a challenge. Parenchymal transection is the most important step in the procedure, which can result in intraoperative bleeding and prolonged operation time. LLR requires meticulous dissection and exposure of the intrahepatic vessels together with careful transection of the hepatic parenchyma. Therefore, the success of LLR depends on the stable and full exposure of the parenchymal transection plane. It is critical to maintain a sufficiently exposed operative field to perform appropriate procedures; however, few reports have focused on the approach to the transection plane used during the exposure of the operative field.<sup>13</sup> Furthermore, none of the reports have provided a thorough assessment of the technique of exposure of the operative field.

Here, we describe the LLR using a silicone band retraction method for lesions in the anterolateral and posterosuperior segments. The aim of this study was to analyze the safety and efficacy of this procedure in patients undergoing LLR.

## METHODS

### Patients

We retrospectively analyzed 189 consecutive patients who underwent laparoscopic partial liver resection and left lateral sectionectomy (segments 1 to 8) between July 2010 and July 2020 at Kurume University Hospital (Kurume, Japan). A total of 189 patients were divided into 2 groups according to whether LLR was performed before (conventional group; n = 64) or after (silicone band group; n = 125) the introduction of the silicone band retraction method. In 64 patients (conventional group), the operating surgeon performed the liver transection using the harmonic scalpel (Ethicon, Somerville, NJ) and the Cavitron Ultrasonic Surgical Aspirator (CUSA), while the assisting surgeon aided hemostasis using the HiQ+ Suction and Irrigation System (Olympus Corporation, Tokyo, Japan) with the monopolar soft-coagulation (SOFT COAG). In 125 patients (silicone band group), the 1-surgeon technique was used for liver transection, with the harmonic scalpel or the CUSA handled by the main surgeon's right hand and the HiQ+ Suction and Irrigation System with SOFT COAG handled by the left hand using the silicone band retraction method. The 1-surgeon technique for LLR using the silicone band retraction method was initiated only from July 2015. Patients in both groups underwent either partial resection of liver or left lateral sectionectomy. We compared the preoperative patient characteristics and surgical

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outcomes between the silicone band ( $n=125$ ) and the conventional ( $n=64$ ) groups. Indications for LLR in our department were tumor size  $<8$  cm with fewer than 3 lesions, without macroscopic vascular invasion or the need for biliary reconstruction. The study was approved by the Ethics Committee of Kurume University Hospital. The study design was approved by the concerned Ethics Review Board and informed consent of the patients was waived owing to the retrospective nature of the study.

## Operative Procedures

Patients were placed in the supine position for left-sided liver resection and in the left semidecubitus position for right-sided liver resection. A left semidecubitus position allows rotation from almost supine to the left lateral position. The main surgeon stood on the patient's right side or left side. A flexible laparoscope was usually inserted through an umbilical port of 12 mm. Three working ports were placed along the costal arch. A tourniquet device for the Pringle maneuver was introduced through a 5-mm port in the most lateral side. Five ports were used, as shown as in Figure 1. Pneumoperitoneum was established and maintained at 10 mm Hg. The patient was placed in the Trendelenburg position on a 15 to 30 degree incline. The transection line was determined by intraoperative ultrasonography. The Pringle maneuver is routinely used for controlling the hepatic inflow by a tourniquet. The central venous pressure was kept low during liver parenchymal transection. The hepatic parenchyma was transected using the harmonic scalpel with the clamp-crushing technique or the CUSA. The thin vessels were incised by the harmonic scalpel, whereas the thick vessels were incised by the harmonic scalpel after clipping by Hem-o-Lok (Teleflex) on the remnant side. The HiQ+ Suction and Irrigation System with SOFT COAG allows for clear visualization through the transection plane and hemostasis. The specimen was retrieved using a plastic bag through the extended port site, including the subumbilical port.

## Silicone Band Retraction Method

### Anterolateral Lesions

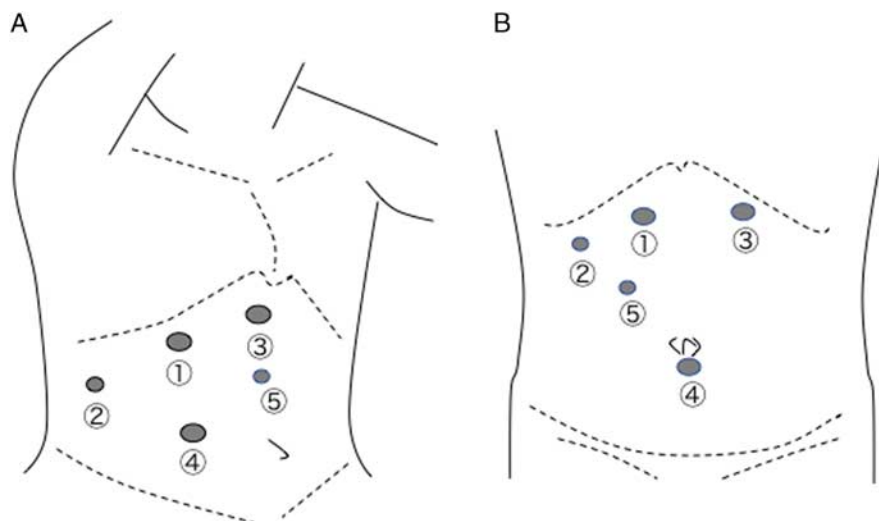
Two silicone bands (Surg-I-Loop, Scanlan International, Minnesota) were fixed using stay sutures at both edges of the

transection line. The other ends of the silicone bands were pulled out through the abdominal wall in the opposite direction using Endo Close (Medtronic plc, Dublin, Ireland). Following liver mobilization and retraction, the silicone band retraction method allowed rotation of the favorable resection line by pulling the transection plane into view of the laparoscopic camera. The extracted silicone bands were fixed outside with appropriate strength using mosquito clamps. The parenchymal transection was carried out by the harmonic scalpel with the clamp-crushing technique or the CUSA. In the 1-surgeon technique, the operator can easily achieve hemostasis and maintain a dry operative field, using the HiQ+ Suction and Irrigation System with SOFT COAG with the left hand, at the required instant. The silicone band provided stable retraction with a constant countertraction. During dissection of the liver parenchyma, the elastic power of the silicone band retracted the liver with adequate tension and automatically exposed the transection plane. When extending the transection plane, the silicone bands were pulled out further from the abdominal wall and fixed again. During partial resection for lesions in the anterolateral segments, the silicone bands were pulled out and fixed again 3 or 4 times (Figs. 2, 3; also see Video 1, Supplemental Digital Content 1, <http://links.lww.com/SLE/A266>).

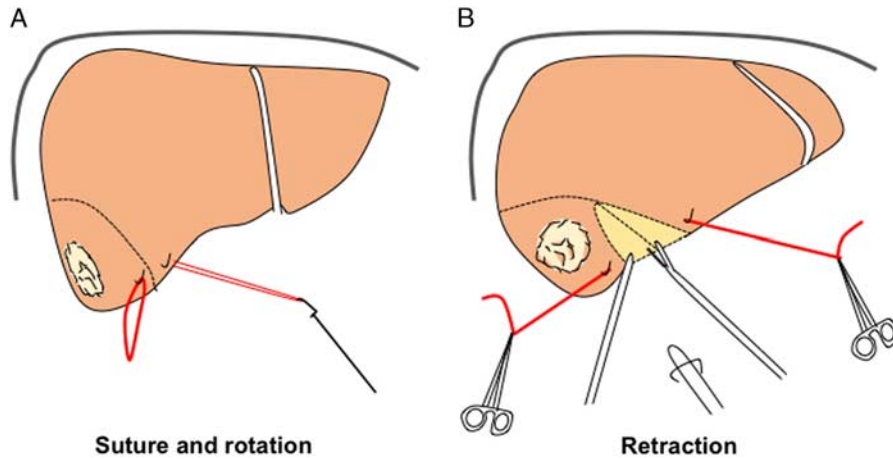
## Silicone Band Uplift Technique

### Posterosuperior Lesions

The patient was placed in the left-decubitus position. The coronary and right triangular ligaments were divided from the right lobe. Following exposure of the most posterosuperior area (Segment 7), the short hepatic veins and the right adrenal gland were dissected from the right lobe completely and the patient was tilted to a complete left lateral position. The silicone ring with needle (Aesculap AG, Tuttingen, Germany) was fixed using stay sutures at the edge of the liver to be resected. The needle was lifted up in the direction of the diaphragm and fixed to the diaphragm with appropriate strength. The liver for resection was lifted upward by the silicon band. When the right lobe was mobilized with the patient in the left lateral position, the right lobe naturally fell to the lower left, presenting a large space under the diaphragm. The assistant retracted the inferior edge of the resection



**FIGURE 1.** Port placement: A, for right-sided liver resection and B, for left-sided liver resection. Circles 1 and 2 were used by the operator. Circle 3 was used by the assistant. Circle 4, a 12-mm port for a camera port and Circle 5, 5-mm port for the Pringle maneuver.



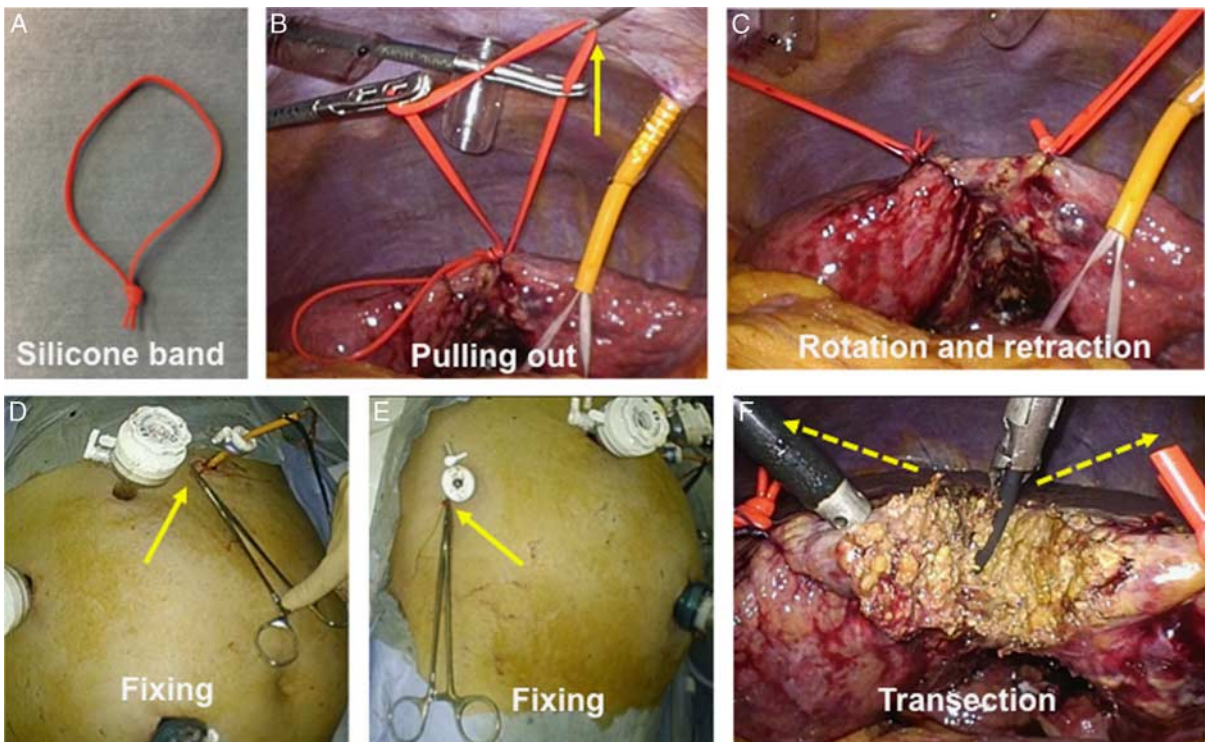
**FIGURE 2.** Schematic diagram of the silicone band retraction method—anterolateral lesions. A, Two silicone bands were fixed using stay sutures at both the edges of the transection line. The other end of a silicone band was pulled out through the abdominal wall in the opposite direction by Endo Close. B, The silicone band retraction method allows rotation of the favorable resection line by pulling the transection plane into view of the laparoscopic camera. The extracted silicone bands were fixed outside with appropriate strength using mosquito clamps.

line inferiorly using the instruments, following which upward countertraction was applied with the silicone band. Once the mobilization and retraction were established, the parenchymal transection was performed in the same manner as done for the anterolateral lesion. The elastic power of the silicone band retracted the liver appropriately and automatically exposed the transection plane. When extending the transection plane, the needle was temporarily released and lifted up in the direction of

the cranial side and the position in which the needle was fixed was changed (Figs. 4, 5; also see Video. 2, Supplemental Digital Content 2, <http://links.lww.com/SLE/A267>).

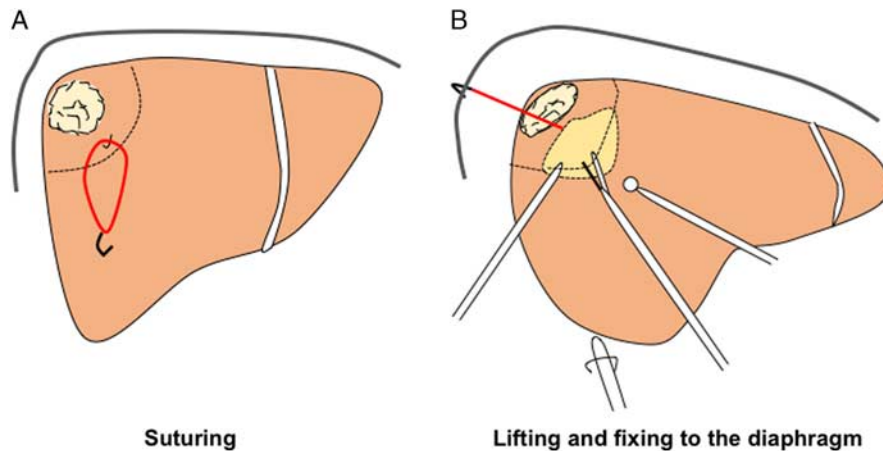
**Statistical Analysis**

We evaluated the clinical data retrospectively. All continuous data were expressed as mean ± SD. The Student *t* test was used to analyze continuous variables. Categorical



**FIGURE 3.** The approach of the silicone band retraction method—anterolateral lesions: A, the silicone band; B, two silicone bands were pulled out of the abdomen (yellow arrow); C, rotation of the favorable resection line and retraction with appropriate tension; D, E, the extracted silicone bands were fixed using mosquito clamps (yellow arrow); F, the elastic power of the silicone band retracted the liver with adequate tension and automatically exposed the transection plane (dotted yellow arrow).





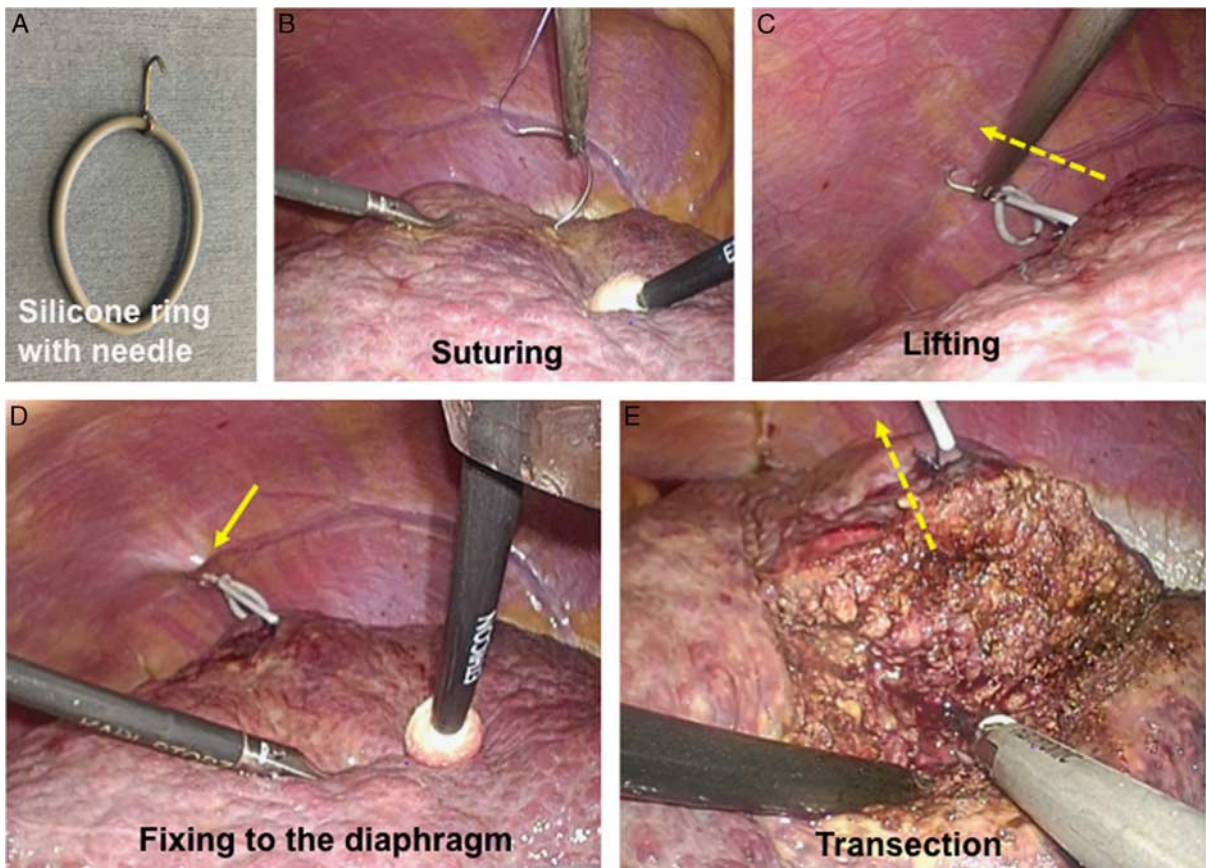
**FIGURE 4.** Schematic diagram of the silicone band uplift technique—posterosuperior lesions: A, the silicone ring with needle was fixed using stay sutures at the edge of the liver for resection; B, the needle was lifted up in the direction of the diaphragm and fixed to the diaphragm with appropriate strength. The liver for resection was lifted upward by the silicon band. When the right lobe was mobilized with the patient in the left lateral position, the right lobe naturally fell to the lower left, presenting a large space under the diaphragm.

variables were expressed as number or frequency (%) and analyzed using  $\chi^2$  test. Statistical significance was defined as  $P < 0.05$ . Statistical analysis was conducted with JMP version 15.1 (SAS Institute, Cary, NC).

**RESULTS**

Preoperative characteristics of patients.

Preoperative patient characteristics are summarized in Table 1. We compared the preoperative patient characteristics



**FIGURE 5.** The approach of the silicone band uplift technique—posterosuperior lesions: A, the silicone ring with needle; B, the silicone ring with needle was fixed using stay sutures; C, D, the needle was lifted up in the direction of the diaphragm (dotted yellow arrow) and fixed to the diaphragm with appropriate strength (yellow arrow); E, the elastic power of the silicone band retracted the liver appropriately and automatically exposed the transection plane (dotted yellow arrow).

TABLE 1. Patients' Baseline Characteristics

	Silicone Band Group (n = 125)	Conventional Group (n = 64)	P
Age, mean (SD)	67.4 ± 11.5	69.7 ± 8.6	0.1675
Sex, M:F	88:37	39:25	0.1898*
BMI, mean (SD)	23.4 ± 3.6	23.4 ± 3.6	0.9997
Disease, n (%)			0.2329*
Hepatocellular carcinoma	94 (75.2)	56 (87.5)	
Metastatic liver carcinoma	24 (19.2)	7 (10.9)	
Cholangiocellular carcinoma	1 (0.8)	0	
Others	6 (4.8)	1 (1.6)	
Hepatitis, n (%)			0.1085*
HCV-Ab positive	59 (47.2)	41 (64.1)	
HBS-Ag positive	17 (13.6)	8 (12.5)	
Alcoholic hepatitis	8 (6.4)	4 (6.2)	
None	41 (32.8)	11 (17.2)	
ICGR15 (%), mean (SD)	16.6 ± 11.6	19.7 ± 11.9	0.0862
Child-Pugh score (A:B)	123:2	62:2	0.4906*
Fibrosis on pathology (F4), n (%)	48 (38.4)	29 (45.3)	0.3600*
Previous liver resection, n (%)	13 (10.4)	2 (3.1)	0.0799
Tumor location, n (%)			
Segment 1	6 (4.8)	0	0.0749*
Segment 2	22 (17.6)	12 (18.7)	0.8456*
Segment 3	29 (23.2)	29 (45.3)	0.0018*
Segment 4	14 (11.2)	7 (10.9)	0.9567*
Segment 5	14 (11.2)	4 (6.2)	0.2726*
Segment 6	19 (15.2)	12 (18.8)	0.5328*
Segment 7	16 (12.8)	2 (3.1)	0.0320*
Segment 8	16 (12.8)	2 (3.1)	0.0320*

\*The Pearson  $\chi^2$  test.

BMI indicates body mass index; HBS-Ag, hepatitis B surface antigen; HCV-Ab, hepatitis C virus antibody; ICGR15, indocyanine green retention rate at 15 minutes.

between the silicone band (n = 125) and conventional (n = 64) groups (Table 1). The 2 groups were similar in terms of age, sex, body mass index, diseases, hepatitis infection, indocyanine green retention rate at 15 minutes, Child-Pugh score, presence of fibrosis on pathology, and previous liver resection. The details about the tumor location in the 2 groups are summarized in Table 1. Tumors located in segment 3 were predominant in the conventional group ( $P = 0.0018$ ), whereas tumors in segments 7 and 8 were predominant in the silicone band group ( $P = 0.0320$ ).

### Surgical Outcomes

Table 2 summarizes the surgical outcomes and the postoperative hospital course of both groups. There were no significant differences in the number of types of resections performed in the silicone band and conventional groups. Also, there were no significant differences in tumor size, resected lesion numbers, and surgical margin between both the groups. There was no positive surgical margin on microscopic examination in both groups. There were no significant differences in blood transfusion requirements between both groups. However, the silicone band group experienced significantly less blood loss than that by the conventional group ( $83.7 \pm 193.0$  vs.

TABLE 2. Operative Outcomes in 2 Groups

	Silicone Band Group (n = 125), n (%)	Conventional Group (n = 64), n (%)	P
Type of hepatectomy			0.1014*
Partial resection	96 (76.8)	42 (65.6)	
Left lateral sectionectomy	29 (23.2)	22 (34.4)	
Tumor size, cm (mean ± SD)	1.9 ± 0.9	1.9 ± 0.7	0.8044
Resected lesion numbers			0.7477*
One	115 (92.0)	60 (93.8)	
Two	9 (7.2)	4 (6.2)	
Three	1 (0.8)	0	
Surgical margin, cm (mean ± SD)	1.5 ± 1.0	1.4 ± 1.4	0.6340
Weight of resected specimen, g (mean ± SD)	94.1 ± 87.6	90.8 ± 87.8	0.8055
Blood loss, mL (mean ± SD)	83.7 ± 193.0	191.0 ± 357.3	0.0080
Blood transfusion	2 (1.6)	4 (6.3)	0.0844*
Operative time, minutes (mean ± SD)	231.3 ± 82.3	338.7 ± 103.4	< 0.0001
Conversion to laparotomy	1 (0.8)	5 (7.8)	0.0093*
Clavien-Dindo $\geq 3$	1 (0.8)	4 (6.3)	0.0271*
Bile leakage	1 (0.8)	1 (1.6)	
Abscess	0	1 (1.6)	
Pleural effusion	0	2 (3.1)	
Reoperation	0	0	—
Mortality	0	0	—
Postoperative hospital stay, days (mean ± SD)	9.1 ± 3.3	12.2 ± 7.0	< 0.0001

\*The Pearson  $\chi^2$  test.

$191.0 \pm 357.3$  mL,  $P = 0.0080$ ). Moreover, the mean operative time ( $231.3 \pm 82.3$  vs.  $338.7 \pm 103.4$  mL,  $P < 0.0001$ ) in the silicone band group was obviously shorter than that in the conventional group. There were 1 (0.8%) and 5 (7.8%) open conversions in the silicone band and the conventional group, respectively ( $P = 0.0093$ ). The main reason for open conversion was uncontrolled bleeding in both the groups. Only 1 patient with a tumor in segment 1 in the silicone band group underwent conversion to a hand-assisted laparoscopic procedure because of uncontrolled bleeding from the short hepatic vein. Five patients underwent conversion to a hybrid procedure because of bleeding from the hepatic vein or the liver parenchyma during transection in the conventional group. The major complication (0.8% vs. 6.3%,  $P = 0.0271$ ) rate was significantly lower in the silicone band group than that in the conventional group. One patient experienced bile leakage in the silicone band group following partial resection of segment 8, left lateral sectionectomy, and deroofting of multiple liver cysts. The bile leakage occurred because of an electric burn injury following the deroofting of liver cysts and was managed by percutaneous drainage. There were no morbidities requiring reoperation or perioperative mortality in both the groups. The length of postoperative hospital stay was significantly shorter in the silicone band group than in the conventional group ( $9.1 \pm 3.3$  vs.  $12.2 \pm 7.0$  d,  $P < 0.0001$ ).

## DISCUSSION

The success of LLR depends on stable and full exposure of the parenchymal transection plane, which is important to safely dissect the hepatic veins and the Glissonian pedicle and to control intraoperative bleeding. Our results show the 1-surgeon technique using a silicone band to be a safe and effective method of liver retraction for parenchymal transection in LLR. The silicone band retraction method creates sufficient exposure of the operative field and simultaneously provides adequate tension at the transection plane. The key characteristic of the silicone band retraction method is stable retraction with a constant countertraction, which facilitates easy exposure and safe dissection of hepatic vasculatures.

In the conventional group in this study, the operator dissects the hepatic parenchyma using the harmonic scalpel and CUSA and the assistant operates the SOFT COAG device. Traction by both operator's and the assistant's instruments are used to expose the transection plane. In the conventional laparoscopic approach for parenchymal liver transection, to achieve exposure of the operative field during the procedure, the operator needs to use his left hand along with the assistant's help. However, despite the involvement of 2 operators during the surgery, it is sometimes difficult to create adequate exposure because the visual field keeps changing during the ongoing procedure, particularly in instances of intraoperative bleeding. For these reasons, we suggested LLR using the silicone band retraction method. In this technique, under the stable exposure of the transection plane by the silicone band, the operator can safely perform liver transection, dissection, and division of the intrahepatic vasculature and achieve hemostasis, with both hands free. In our transection method, while the surgery is in progress, the surgeon can also use the suction and energy devices with the left hand to dry the operative field and obtain hemostasis at the required instant more easily than in the conventional technique. The use of silicone bands for exposing the operative field makes it possible for a single surgeon to perform liver dissection, suction, and hemostasis. There have been some reports on the use of silk or nylon stay sutures for exposure of the operative field; however, there is a risk of damage to the liver parenchyma of the sutured area under strong retraction. The use of elastic silicone bands did not cause excessive retraction and there was no damage to the liver parenchyma or injury to the hepatic vein during liver transection. In LLR, it is critical to maintain sufficient exposure of the operative field to perform appropriate procedures; however, only a few reports have evaluated the role of liver retraction in LLR.<sup>13</sup> Although there have been previous reports on the use of a rubber band, we used the silicone band for our procedure. The silicone band is composed of a radio-opaque and latex-free material, which addresses some major problems, such as the loss of the band during the surgery and allergic reactions to latex.

Performing LLR in the posterosuperior segments such as segments 7 and 8 is technically challenging because of the limited visibility and working space and because of the difficulty in controlling the bleeding.<sup>6,10-12</sup> Our results show that tumors located in segment 3 were predominant in the conventional group ( $P=0.0018$ ), whereas tumors in segments 7 or 8 were predominant in the silicone band group ( $P=0.0320$ ). Despite the fact that resections of posterosuperior lesions are difficult, the intraoperative and postoperative complications were not different between the posterosuperior and anterolateral lesions. Some authors have reported the usefulness of intercostal ports during LLR for tumors in segments 7 and 8.<sup>14-17</sup> However, the placement of ports in the intercostal spaces is associated with the risk of injury to the arteries or veins and specific adverse events, such

as a pneumothorax and other pulmonary complications.<sup>17</sup> We previously reported that the silicone band uplift technique is useful for accessing posterosuperior lesions.<sup>18</sup> During exposure of the operative field, the silicone band can be pulled out to the caudal side and fixed to the abdominal wall for accessing anterolateral lesions, whereas, conversely, the segment for resection needs to be retracted to the cranial side for posterosuperior lesions. Full mobilization of the right lobe is essential to access the posterosuperior part of the right lobe. When the right lobe is mobilized with the patient in the left lateral position, the right lobe naturally falls to the lower left, presenting a large space under the diaphragm. Silicone ring with needle was fixed to the diaphragm with appropriate strength. The silicone band provides stable upward retraction force of a constant strength. The elastic power of the silicone band retracts the liver and automatically exposes the transection plane. The uplift technique allows for clear visualization through the transection plane and also for easy dissection and division of the vasculature. Repositioning the silicone ring with needle to the diaphragm was easily performed with progression of the liver transection when necessary. The silicone ring with needle technique was used in 32 lesions for resections in segments 7 and 8, without any injury to the lung causing complications, such as a pneumothorax.

We evaluated the surgical outcomes in our patients and showed that we could perform LLR safely using the silicone band retraction method. In this technique, there were vast improvements in intraoperative blood loss, operative time, open conversion, major complication, and hospital stay. We performed the operation faster using the silicone band retraction method even when a single surgeon was operating, because of less stagnation during surgery, resulting in a favorable operative field. We speculate that the decrease in blood loss is attributable to the easier confirmation of the bleeding point, better hemostasis, and safe division of the hepatic vasculature, resulting from the stable exposure of the transection plane using silicone band retraction. Moreover, using this method can be expected to facilitate laparoscopic anatomical liver resections and robotic liver resections in future.

The limitations of our study include its retrospective nature, the most significant consequence of which is the lack of oncologic outcome data. In addition, the study sample included only partial resections and left lateral sectionectomies. Long-term follow-up of patients and evaluation of data from patients undergoing major hepatectomy with this technique in the future are warranted.

## CONCLUSIONS

The silicone band retraction method is a useful approach for a safe LLR. Appropriate exposure of a favorable operative field and adequate tension at the transection plane using silicone bands facilitate a smooth laparoscopic surgical procedure with relatively less blood loss and a short operative time.

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