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# Minimally invasive approach of hepatectomy and thrombectomy for hepatocellular carcinoma with right atrial tumor thrombus without sternotomy using percutaneous cardiopulmonary bypass

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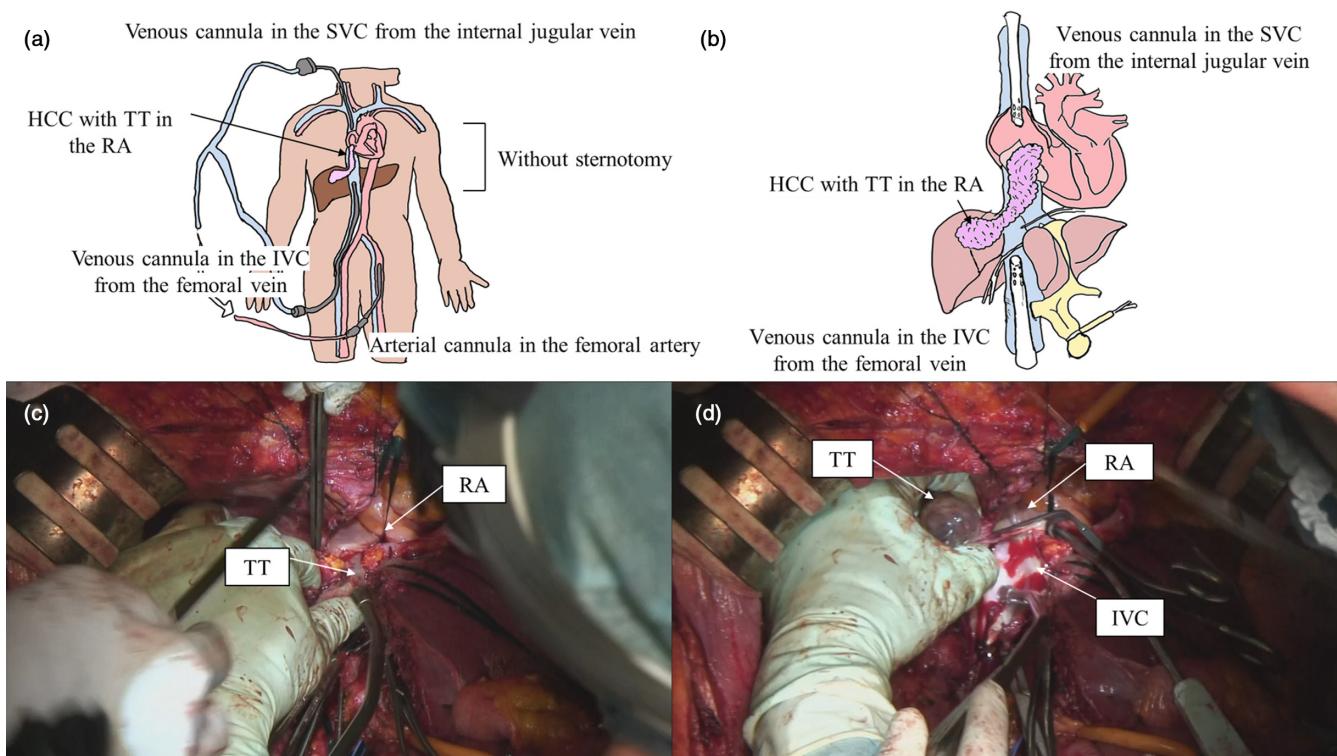
Management of hepatocellular carcinoma (HCC) with right atrial invasion poses a significant challenge,<sup>1</sup> necessitating surgical intervention to mitigate complications such as sudden death.<sup>2</sup> Traditional surgical approaches, including sternotomy and hepatectomy via laparotomy, are highly invasive.<sup>3</sup> We investigated a less invasive technique for resecting right atrial tumor thrombus (TT) without sternotomy and compared its outcomes with conventional methods with sternotomy.

The minimally invasive approach comprises several steps (Video S1). First, before the laparotomy, venous cannulation is performed with cannulas inserted into the hepatic inferior vena cava (IVC) and superior vena cava (SVC) (Figure 1a). Additionally, an arterial cannula is inserted into the femoral artery. Following hepatectomy, a vertical transdiaphragmatic pericardiotomy is executed,

providing access to the right atrium (RA) through an intraperitoneal approach alone. The subhepatic IVC is then retaped within the pericardial sac. Cardiopulmonary bypass (CPB) is initiated under cardiac pulsation, and total hepatic vascular exclusion is performed without the hepatic vein containing the TT (Figure 1b). The incision is extended from the anterior aspect of the IVC to the RA, allowing extraction of the TT (Figure 1c). The surgical field remains bloodless due to CPB facilitating blood removal from the SVC. Complete removal of the tumor thrombus is confirmed by firmly opening the atrium and removing the entire tumor thrombus with gross visual confirmation. After TT removal, the RA is temporarily closed using bite forceps (Figure 1d). The procedure is concluded with suturing of the IVC and reconstruction of the RA using a patch from the patient's own pericardial sac for its formation

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**FIGURE 1** Schematic representation and surgical scenes of the minimally invasive approach using percutaneous cardiopulmonary bypass while avoiding sternotomy with a vertical transdiaphragmatic pericardiotomy via an intraperitoneal route. (a) Illustration of percutaneous cardiopulmonary bypass setup. (b) Depiction of right atrial tumor thrombus removal during total hepatic vascular exclusion. (c) The incision extending from the inferior vena cava to the right atrium. (d) Extraction of the tumor. HCC, hepatocellular carcinoma; IVC, inferior vena cava; RA, right atrium; SVC, superior vena cava; TT, tumor thrombus.

due to the large defect in the atrial wall after TT removal. This approach helps avoid median sternotomy, thereby reducing associated risks such as deep sternal wound infections and enabling faster recovery.<sup>4,5</sup> In the cases reported here, this minimally invasive technique was performed in case 3, contributing to shorter operative time, less blood loss, and shorter hospital stay, leading to early initiation of systemic chemotherapy compared to cases 1 and 2 with sternotomy (Tables 1 and 2). There is no clear difference between the open abdominal and open thoracic approach. In theory, it should be possible to use the open abdominal approach in all cases except those where the tricuspid valve ring is directly involved and its freeing is poor, making it difficult to close the suture from the abdominal

cavity. However, the advantages of a sternotomy are that it allows the IVC within the RA to be secured safely, and that it allows a reliable approach even under cardiac arrest with a wide field of vision, so there is no clear difference in the criteria for resection, and each facility will make its own decision. This study had several limitations. Because of the differences of oncological background among patients, simple comparisons of outcomes should be made with caution. Moreover, case 3 was the first case of the minimally-invasive approach without a sternotomy, so whether this procedure and early introduction of recent systemic therapy for HCC with right atrial invasion leads to improved prognosis requires further analysis based on a larger number of cases.

TABLE 1 Patient characteristics.

Case	Age (years)	Sex	Tumor	Alcohol	HBs-Antigen	Anti-HCV antibody	Child-Pugh	Liver damage	ICG-R15 (%)	Vp	Va	B	Number of tumors	Tumor size (cm)	T	N	M	pStage (UICC 8th)
1	75	Male	HCC	+	+	—	A	B	17	1	0	0	1	8.2	3	0	1	IVB
2	50	Male	HCC	+	+	—	B	B	25	2	0	0	3	20.5	4	0	0	IIIB
3	80	Female	HCC	—	—	+	A	B	36	0	0	0	1	12	3	0	1	IVB

Abbreviations: HCC, hepatocellular carcinoma; ICG-R15, indocyanine green retention rate at 15 min; UICC, Union for International Cancer Control.

TABLE 2 Patient outcomes.

Case	Hepatectomy	Sternotomy	CPB	Weight of the resected liver (g)	Differentiation	Residual tumor classification	Operative time (min)	Blood loss (mL)	Postoperative stay (days)	Liver failure	Postoperative hemorrhage	Bile leakage	Pulmonary embolism	DSWI	Other postoperative complication	Postoperative chemotherapy	Overall survival
1	Left lobectomy	+	+	602	por	R2 (M1[PUL])	604	5700	40	—	—	—	Grade B	—	—	—	47 days (recurrence in the remnant liver)
2	Left lobectomy	+	+	2860	por	R1 (Positive pathological margin)	950	46 000	95	Grade B	—	—	Grade B	—	—	—	95 days (liver failure)
3	Right lobectomy	—	+	995	por	R2 (M1[PUL])	482	2110	15	—	—	—	—	—	Atezolizumab/Bevacizumab (started 60 days postoperatively)	390 days (alive/progression-free)	

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The authors have nothing to report.

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest for this article.

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