Cardiovasc Intervent Radiol (2019) 42:137–144
https://doi.org/10.1007/s00270-018-2105-y

TECHNICAL NOTE

Hydrodissection of the Retrohepatic Space: A Technique to Physically Separate a Liver Tumour from the Inferior Vena Cava and the Ostia of the Hepatic Veins

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Received: 28 September 2018 / Accepted: 27 October 2018 / Published online: 1 November 2018

Abstract
Objective To report a technique of percutaneous retrohepatic hydrodissection, highlighting its potential to physically separate liver tumours from the inferior vena cava (IVC) and the ostia of the hepatic veins (HV).
Materials and Methods Between December 2017 and April 2018, hydrodissection of the retrohepatic IVC was performed in 5 patients (5 females; mean age 64.5 years) undergoing percutaneous ablation of 5 liver metastases (mean size: 3.6 cm) located adjacent to the IVC. Number of hydrodissection needles, volume of hydrodissection, separation of tumour/liver parenchyma from IVC/HV post-hydrodissection; technical success of ablation; and complications were tabulated.
Results Two to three 22G spinal needles were required per case for adequate dissection. Mean volume to obtain sufficient hydrodissection was 410 ml on average. Physical separation of the IVC and tumour/hepatic parenchyma was successful in all cases, by 9 mm on average (range 5–12 mm). It also leaded to physical separation of the ostia of the right and middle HV in all cases. There was no early or delayed complication, notably no venous thrombosis in the post-operative period. All lesions but one were completely ablated after one session at 3-month follow-up. The patient with residual tumour was successfully retreated.
Conclusion Retrohepatic hydrodissection is a feasible technique to separate a tumour from the IVC and/or ostia of the HV. This could potentially limit the heat-sink effect/reduce the risk of thrombosis. Larger follow-up studies are required to assess efficacy on a long-term basis.

Keywords Thermal ablation · IVC · Hepatic vein · Hydrodissection · Heat-sink effect

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Introduction

Percutaneous imaging-guided ablation is an effective technique for the treatment of hepatic malignancies [1, 2]. However, lesions close to hepatic vessels may be subjected

to "heat-sink" effects, in which thermal energy is dissipated by flowing blood at the tumour periphery, resulting in higher local recurrence rates in some studies [3–5]. Because of this phenomenon, lesions adjacent to the inferior vena cava (IVC) are particularly at risk of incomplete ablation [6–8]. Various mitigating strategies have been proposed, including endovascular occlusion of the IVC during ablation and alternative ablation techniques [microwave ablation (MWA) and irreversible electroporation (IRE)], with limited success and/or application to paracaval tumours [4, 7, 9–14].

Hydrodissection is a well-established thermo-protective technique in which fluid is injected between the target lesion and vulnerable adjacent structures [15]. Hydrodissection can displace target lesions from heat sinks and therefore potentially improve ablation efficacy while reducing the risk of vascular injury [16].

We present our initial experience of using retrohepatic hydrodissection during ablation of liver tumours close to the IVC, highlighting technical feasibility/challenges, relevant hydrodissectional anatomy, and potential utility of this novel technique in optimising these challenging procedures.

Materials and Methods

All patients gave written informed consent for the procedure. Institutional review board approval was waived because of the retrospective descriptive design of the present study.

Study Population and Lesions

Initially, we inadvertently hydrodissected the retrohepatic IVC during ablation of a coeliac lymph-node metastasis, while attempting to separate the lesion from the retroperitoneal structures. We postulated that this could be reproduced to create an artificial distance between a hepatic tumour located in close vicinity to the IVC and/or the ostia of the hepatic vein(s) (HV). Between December 2017 and April 2018, retrohepatic hydrodissection was intentionally performed in 5 patients (all female; mean age 64.8 years; range 50–73 years) undergoing percutaneous ablation of 5 liver metastases (mean greatest axial diameter 3.6 cm; range 2–5.8 cm) located in the segment VII ($n = 1$) and VIII ($n = 4$), adjacent to the IVC ($n = 4$) and/or ostia of the right and/or middle HV ($n = 5$). The primary goal of the technique was to reduce the heat-sink effect phenomenon generated by the IVC without the need for an additional intravascular balloon deployment in 4 cases, and to limit the risk of HV thrombosis in one case.

Technique of Retrohepatic Hydrodissection

All procedures were performed under supine general anaesthesia using CT-guidance (Infinix-I 4DCT, Canon Medical Systems, Japan). Anticoagulants were stopped for 5 days and blood clotting parameters tested 24 h pre-procedure, ensuring minimum prothrombin time of 50% and platelet count of 50,000/mm^3 [17]. Hydrodissection was performed either prior to (Case 1) or following (Cases 2–5) probe placement, using 22G spinal needles (Becton–Dickinson, Franklin Lakes, USA) and 5% iodinated contrast-0.9% saline solution (Visipaque, GE Healthcare, Little Chalfont, UK; 270 mg I/ml) to optimise CT visibility and assess proper diffusion of saline injection [15, 18].

A first spinal needle was positioned at the highest part of the anteromedial para-caval fat, using a transhepatic ($n = 4$) or percutaneous transgastric approach ($n = 1$). 150–250 ml of hydrodissection fluid was injected, dissecting only the anterior and anteromedial para-caval space. To fully dissect the IVC in the retrohepatic space, one (= 4) or two ($n = 1$) additional spinal needles were positioned slightly more laterally, cranially and deeply in the anterolateral para-caval space (that was now depicted thanks to the first hydrodissection), using a suprahepatic ($n = 2$), transhepatic ($n = 2$) or transgastric (done percutaneously, $n = 1$) approach. A further 150–250 ml of fluid was injected until tumour-IVC separation was achieved. Figures 1 and 2 summarize the different steps of the technique in two different cases. Table 1 details the technical aspects of retrohepatic hydrodissection for each case.

Ablation

MWA was used in all cases. Details about ablation devices and protocols are summarized in Table 2.

Post-procedural Care and Follow-Up

After completion of the procedure, patients were transferred to a recovery ward and stayed overnight(s) for observation (mean hospital stay after intervention 2.8 days; range 1–6). Early follow-up was performed using immediate post-ablation contrast CT scan ($n = 3$) and/or contrast enhanced MRI the day after the intervention ($n = 3$). All patients completed the 1- and 3-month follow-up MRI and 2 patients the 6-month FU PET-CT.

Data Collection and Analysis

The following items were tabulated: minimal distance (on axial view) between the IVC and the tumour/liver parenchyma after hydrodissection; length (from their ostia to the liver parenchyma) and minimal thickness of the

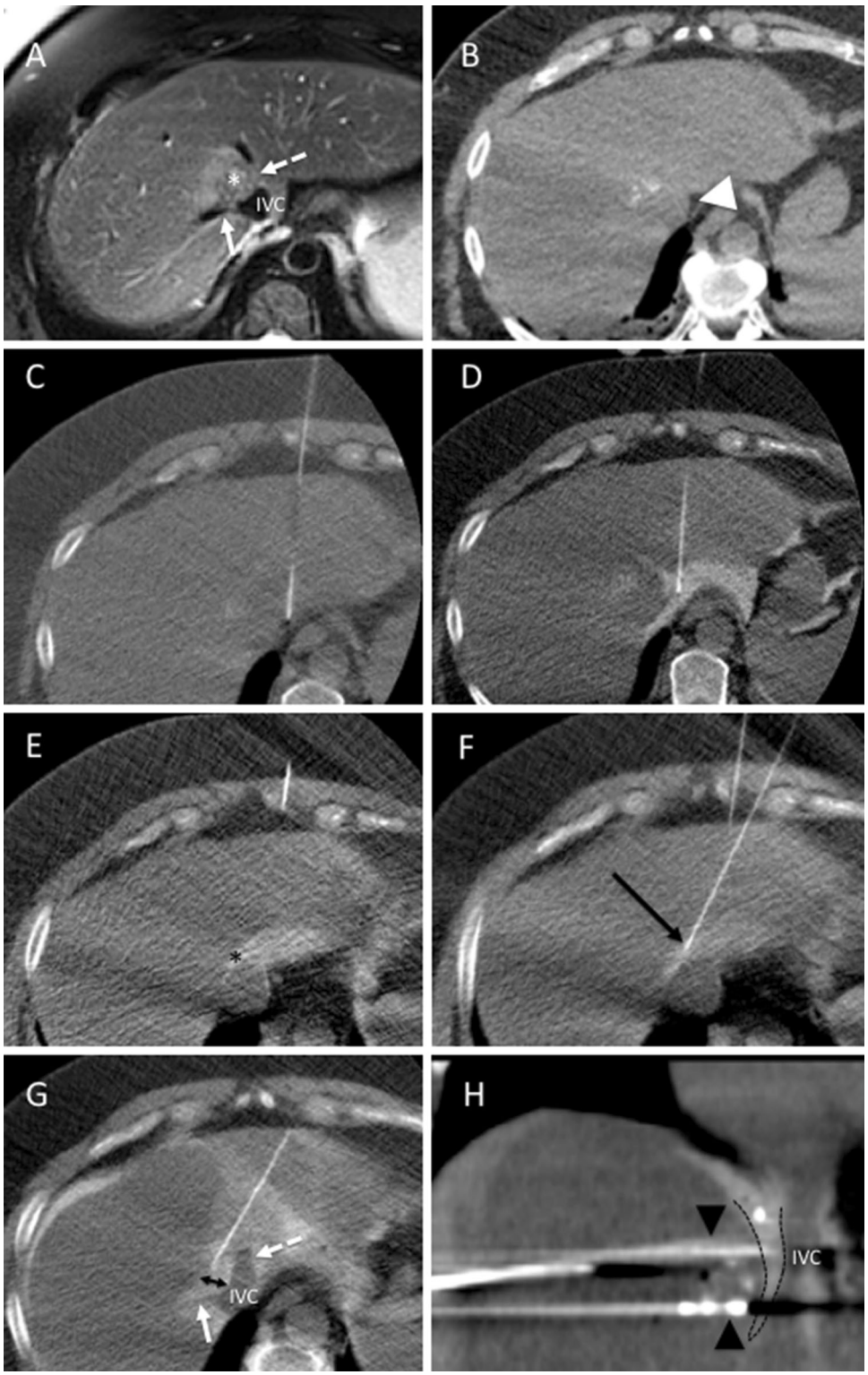

Fig. 1 Technique of retrohepatic hydrodissection (patient 4). **A** Axial T1W MRI shows a liver metastasis (asterisk) abutting the IVC, the right hepatic vein (arrow) and the middle hepatic vein (dotted arrow). **B** Planning Axial CT scan shows the para-caval fat (arrowhead) at the level of the ostia of the hepatic veins. **C** A 22G spinal needle is inserted through a transhepatic approach. **D** 200 ml of saline with contrast is injected in this location, which allows to depict the lateral para-caval space more cranially (**E**). This space is targeted transhepatically with a second 22G spinal needle (**F**). Additional injection of 250 ml allows to separate the lesion from the IVC, the RHV (arrow) and the MHV (dotted arrow), with a visible space on both axial (**G**, double black arrow) and coronal (**H**, dotted line)

dissection of the right and middle HV; the presence of residual fluid around the IVC/HVs 24 h after the intervention (if imaging was available), peri-procedural complications including patency of the IVC/HV at 24 h and one-month follow-ups, oncological result of last radiological examination available.

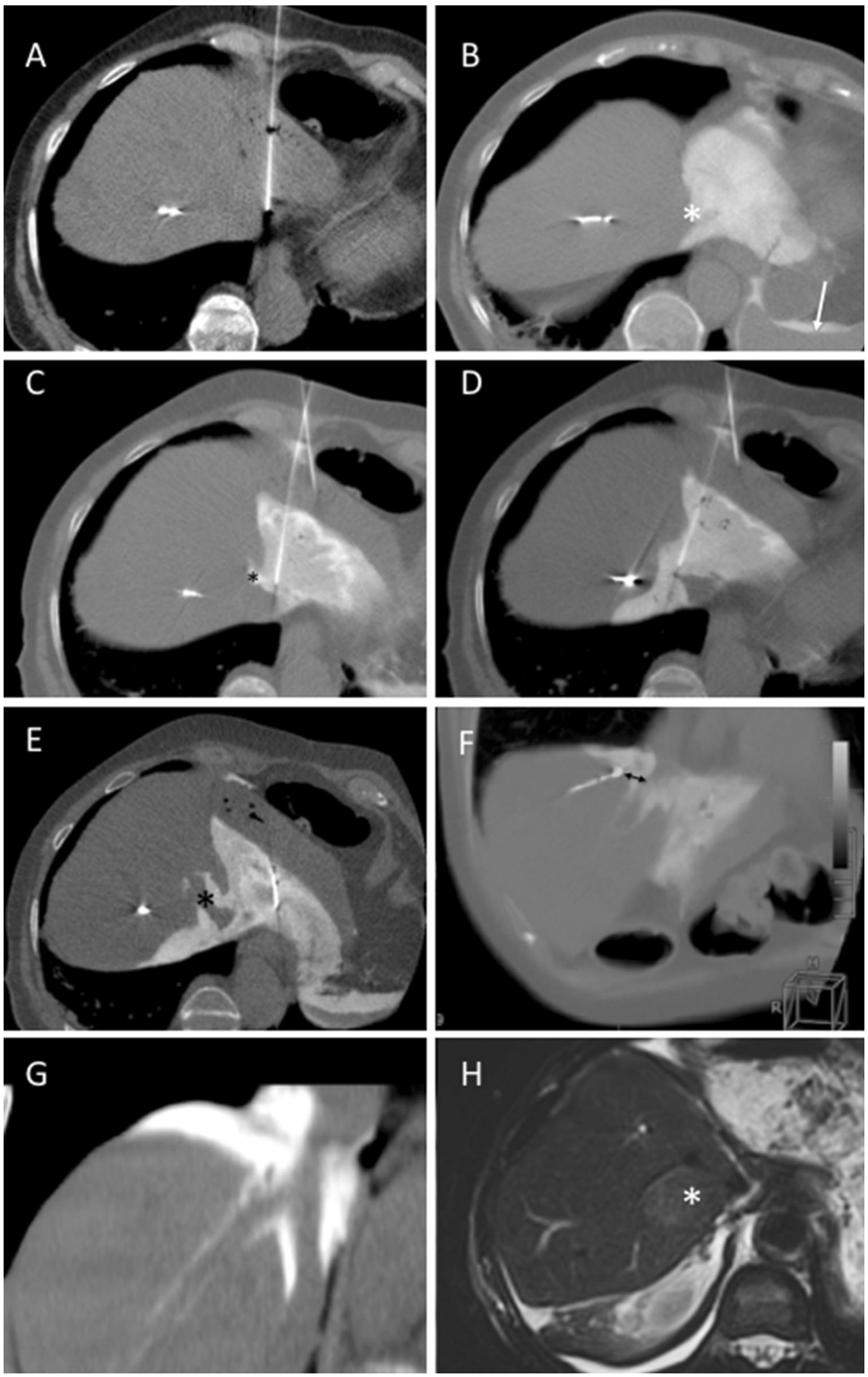

Fig. 2 Patient 2: hydrodissection of the retrohepatic IVC during para-caval colorectal metastasis ablation in a post-surgical liver with solitary RHV. **A** Using a transgastric approach, a 22G needle was positioned in the medial para-caval fat at the level of the RHV origin. **B** Initial hydrodissection resulted in enlargement of the anterior and medial part of the para-caval space (white asterisk), and some intra-peritoneal fluid around the spleen (arrow) likely due to distorted anatomy following left hemi-hepatectomy. **C** A second transgastric 22G needle was advanced more laterally adjacent to the IVC in the space created by the first hydrodissection. **D** After slight medial repositioning of the same needle, hydrodissection in this plane was successful, enabling wide expansion of the anterior/lateral retrohepatic tunnel, and displacement of the IVC away from the tumour (site of metallic artefact from MW probe). The right hepatic vein origin (black asterisk; **E** was also completely separated from the hepatic parenchyma on axial (**E**) and coronal (**F**) images. **G** Coronal oblique view shows complete dissection of the RHV from liver parenchyma. **H** Follow-up MRI 24 h post-MWA illustrates a post-ablation scar encompassing the prior lesion (white asterisk), and complete resorption of hydrodissection fluid. The RHV and IVC remained patent

Results

Retrohepatic hydrodissection was feasible in all cases. It resulted in full physical separation of the IVC and tumour/hepatic parenchyma in all cases ($n = 5$), by 9 mm on average (range 5–12 mm). It also leaded to physical separation of the ostia of the HV and tumour/hepatic parenchyma in all cases (Fig. 3). Length and minimal thickness of dissection were, respectively, 21 mm and 4 mm on average for the right HV ($n = 5$), and 12.5 mm

Table 1 Lesions characteristics and technical details of retrohepatic hydrodissection

Patient	Lesion size (cm)	Lesion localisation	Adjacent vessel	Intentional retrohepatic HD	Access to the anteromedial para-caval fat	Volume of HD (ml)	nb of additional needles to complete full retrohepatic HD	Volume of additional HD (ml)
1	4.2	Segt VIII	IVC/ RHV/ MHV	Yes	Transhepatic	150	2-Transhepatic suprahepatic	300
2	2	Segt VII	RHV	Yes	Transgastric	150	1-Transgastric	200
3	3.2	Segt VIII	IVC/ RHV/ MHV	Yes	Transhepatic	200	1-Transhepatic	250
4	3.5	Segt VIII	IVC/ RHV/ MHV	Yes	Transhepatic	200	1-Transhepatic	150
5	5.8	Segt VIII	IVC/ RHV	Yes	Transhepatic	250	1-Suprahepatic	200

HD hydrodissection

Table 2 Ablation devices and protocols

Patient	Ablation modality	Manufacturer	nb of antennas	Ablation protocol	Repositioning
1	mwa	Emprint, Medtronic	2	100 W—10 min	Yes (3X)
2	mwa	Emprint, Medtronic	1	100 W—10 min	No
3	mwa	Neuwave, Ethicon	3 (PR probes)	65 W—10 min	No
4	mwa	Neuwave, Ethicon	3 (PR probes)	65 W—10 min	No
5	mwa	Neuwave, Ethicon	3 (PR probes)	65 W—10 min	Yes (2X)

and 2 mm on average for the middle HV ($n = 4$, one patient having a previous left hepatectomy). Total volume of hydrodissection per patient was 410 ml on average (range 350–450). There was no residual fluid around the IVC at 24-h follow-up ($n = 3$). There was no significant drop of the level of haemoglobin at day 1 after intervention. There was no immediate or delayed complication, including no thrombosis of the IVC/HV in all cases ($n = 5$). Three-month follow-up MRI showed a 5-mm residual lesion at the superior part of the large MWA scar in one patient (patient 1), which was likely due to suboptimal MW antenna positioning on retrospective evaluation. The patient was successfully retreated since then. All other patients were free of disease at 3-month follow-up. The two patients who completed the 6-month follow-up are free of disease. Table 3 presents the results for each case.

Discussion

Anatomically, the retrohepatic IVC lies medially within the bare area, superiorly and lateral to the caudate lobe [19, 20]. It is separated from the hepatic parenchyma by a virtual space, the retrohepatic tunnel, which contains connective tissue and short hepatic veins [21]. Physical dissection of this minimally vascular plane has been well-described in the surgical literature ("liver hanging maneouvre") to optimize parenchymal transection and haemostatic control during hepatectomy [21, 22].

Retrohepatic hydrodissection targets the same anatomic compartment and appears technically feasible during ablation of para-caval liver tumours. In our experience, it is essential to use 5% iodinated contrast solution with intermittent CT-monitoring to delineate hydrodissection. Approximately 400–500 ml of fluid is required to fully dissect the retrohepatic space. A Tumour/liver parenchyma-IVC separation of minimum 5–10 mm appears achievable in a normal liver. Moreover, physical separation also involved the distal part of the right and middle HV in all cases. Finally, separation was possible in a post-operative case.

Even though MWA is less influenced than RFA by the heat-sink effect, it is still associated with a higher risk of incomplete treatment when the diameter of the neighbouring vessel is increasing [4, 7, 23]. In this small series, retrohepatic hydrodissection adequately separated the IVC/HV from previously abutting hepatic tumours in all cases. This safety distance can theoretically abolish the heat-sink effect generated by the IVC/HV [15, 16]. On the other hand, MWA can also induce vascular thrombosis, especially if the antenna is positioned close to and alongside a

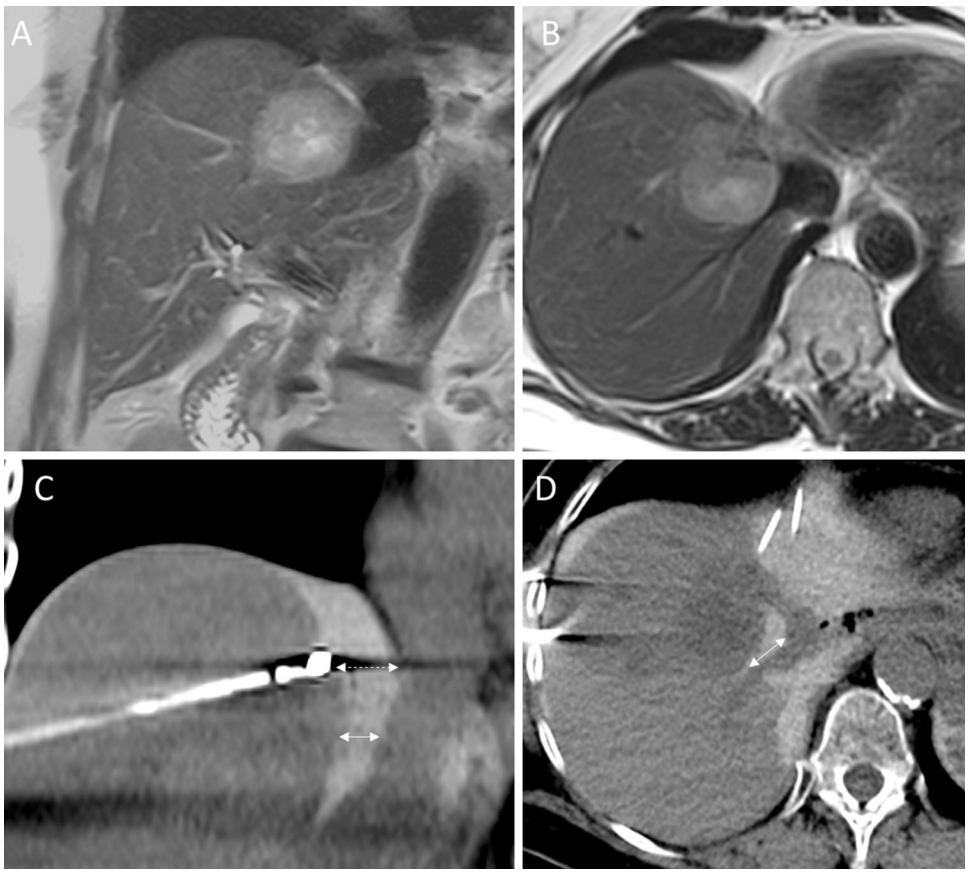

Fig. 3 Patient 1: coronal (**A**) and axial (**B**) T2W MRI show a 4.2 cm mass abutting the IVC and the origin of the RHV and MHV. **C** After hydrodissection, a wide physical separation of the IVC and the liver tumour has been achieved (dotted area). The minimal distance is 7 mm (double arrow). **D** Axial image also shows physical separation (dotted area) of the RHV (dotted arrow) and MHV (arrow). In this case, the length of dissection is measured at 25 mm for the RHV and 10 mm for the MHV

Table 3 Results of hydrodissection and early outcomes of procedures

Patient	Minimal distance tumour/liver—IVC after HD (mm)	Minimal length/thickness of HD of the RHV	Minimal length/thickness of HD of the MHV	Technical success	Residual fluid around the IVC at 24 h FU	Complications	Result of last imaging FU
1	7	25 mm/5 mm	10 mm/2 mm	Yes	No	No	Complete ablation (6 months), after treatment of a 5 mm residual disease seen at 3 months
2	12	30 mm/2 mm	– (left hepatectomy)	Yes	No	No	Complete ablation (6 months)
3	5	8 mm/2 mm	12 mm/2 mm	Yes	Not available	no	Complete ablation (3 months)
4	11	15 mm/5 mm	13 mm/4 mm	Yes	Not available	No	Complete ablation (3 months)
5	10	27 mm/8 mm	15 mm/3 mm	Yes	No	No	Complete ablation (3 months)

IVC inferior vena cava, *RHV* right hepatic vein, *MHV* middle hepatic vein

low-flow vessel [24, 25]. The hepatic veins are the second most frequent vessels at risk of thermally induced thrombosis in the liver after the portal veins [26, 27]. In an animal model, risk factors of hepatic veins thrombosis following ablation included a blood flow velocity inferior to 12.45 cm/s, a vessel diameter inferior to 5.1 mm and a vessel-antenna spacing inferior to 3.75 mm [28]. Physical separation between the ablation zone and the HV should therefore theoretically decrease this risk, although our study does not allow to support this assertion. In patient 2 with a single post-operative remnant HV, we used

retrohepatic dissection specifically to limit the risk of vascular thrombosis.

We experienced no complications, in particular no venous thrombosis. This is likely due to the excellent safety profile of hydrodissection, as fluid cannot induce compression [15]. It is also quickly reabsorbed [15]. Retrohepatic hydrodissection appears safe, relatively simple (no special equipment or vascular interventional expertise), and technically effective. To the best of our knowledge, the technique has not been described in the literature.

Major study limitations include the small sample (limiting generalisability and assessment of reproducibility), and absence of mid- and long-term oncological follow-up.

In conclusion, percutaneous hydrodissection of the retrohepatic IVC is technically feasible. Larger studies with clinical/radiological follow-up are required to further evaluate the role and efficacy of this adjunctive technique.

Compliance with Ethical Standards

Conflict of interest Julien Garnon is a proctor for Galil Medical and received fees for presentations for Canon and Medtronic. Roberto Luigi Cazzato received fees for oral presentation for Medtronic. Afshin Gangi is a proctor for Galil Medical.

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