LETTER TO THE EDITOR

Balloon-Assisted Blood Pressure Reduction in the Downstream Vascular Compartment to Avoid Nontarget Embolization during Transarterial Chemoembolization from the Inferior Phrenic Artery

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Editor:

Conventional transarterial chemoembolization is a mainstay of locoregional therapy for unresectable liver tumors. Occasionally, small, innumerable, or sharply angulated vessels preclude a safe and effective approach, increasing the risk of nontarget embolization. By altering the local hemodynamic environment to decrease downstream pressures within tumors, balloon-assisted transarterial chemoembolization has been demonstrated to allow for improved accumulation of the chemoembolic emulsion with potential to reduce nontarget embolization (1).

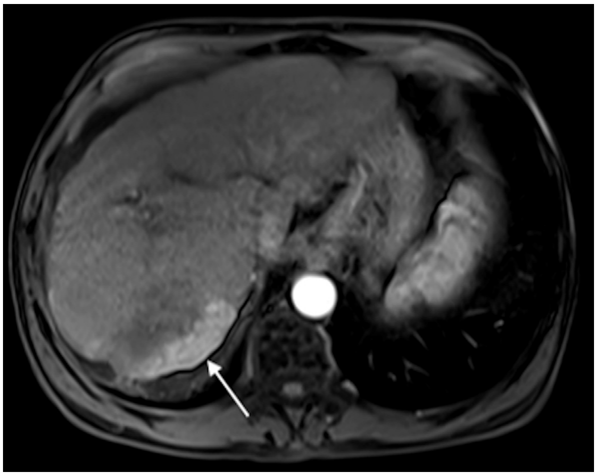

Figure 1. Subtracted axial postcontrast magnetic resonance imaging 1 month after conventional transarterial chemoembolization in a patient with multifocal hepatocellular carcinoma demonstrates residual enhancement in a treated segment 7 mass posteriorly (white arrow) measuring 6.9 cm.

Low-pressure and antireflux catheters commonly used for hepatic arterial interventions include the Sniper (Embolx, Inc, Sunnyvale, California) and Surefire Infusion System (TriSalus Life Sciences, Westminster, Colorado). Most microballoon catheter systems have a compliant balloon that can be inflated via a sideport. Introduced via a microwire, the balloon is inflated proximally, causing a reduction in pressure distally with subsequent reversal of flow from high-pressure nontarget tissues into the rich vasculature supplying a tumor (2). Pressure-measurement before, during, and after balloon occlusion provides a quantifiable metric the operator can rely on during the procedure and has been demonstrated as a proof of concept of balloon-assisted transarterial chemoembolization in the literature (2). This letter provides angiographic support to this phenomenon.

Institutional review board approval was not required for this case report. A 75-year-old man with a past medical history of hepatitis C and cirrhosis presented for evaluation and management of a large infiltrative and multifocal hepatocellular carcinoma. After previous locoregional therapies, including conventional transarterial chemoembolization, residual enhancement in a segment 7 tumor suggested the development of extrahepatic supply (**Fig 1**).

At presentation to interventional radiology, the patient's Model for End-Stage Liver Disease score was 8. Arteriography via a 5-F Mikaelsson catheter (AngioDynamics, Inc, Latham, New York) confirmed a hypervascular mass within segment 7 supplied by the right inferior phrenic artery with anterograde flow within the right ascending and diaphragmatic branches (**Video 1** [available online on the article's Supplemental Material page at *www.jvir.org*], **Fig 2a**). Using a 2.9-F microcatheter with a compliant occlusion balloon (Sniper) and 0.016-inch microwire, the proximal right inferior phrenic artery was catheterized. Balloon occlusion of the proximal right inferior phrenic artery before embolization caused reversal of flow of contrast material in the right diaphragmatic branch and persistent anterograde flow through the ascending (anterior) right inferior phrenic branch (**Video 2** [available online on the article's Supplemental Material page at *www.jvir.org*], **Fig 2b**). Before and after balloon inflation, digital subtraction angiography was performed with iohexol at a rate of 2 mL/s for a total of 6 mL with an injection pressure of 700 psi. After confirmation of the flow of contrast agent only to target vessels, the chemoembolic emulsion of 50 mg doxorubicin and 10 mL ethiodized oil (Lipiodol; Guerbet, Roissy, France) and 0.2 mL of 100–300 μm trisacryl gelatin microspheres (Embosphere; Merit Medical Systems, Inc, South Jordan, Utah) were delivered with the balloon inflated with 0.2 mL of contrast agent (**Fig 3a, b**). On fluoroscopy, retrograde flow of the embolic material from the right diaphragmatic branch occurred with persistent anterograde flow through the ascending right inferior phrenic branch to the tumor

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D.C.M. is a paid consultant for Embolx (Sunnyvale, California). The other author has not identified a conflict of interest.

Videos 1–3 can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

https://doi.org/10.1016/j.jvir.2018.12.010

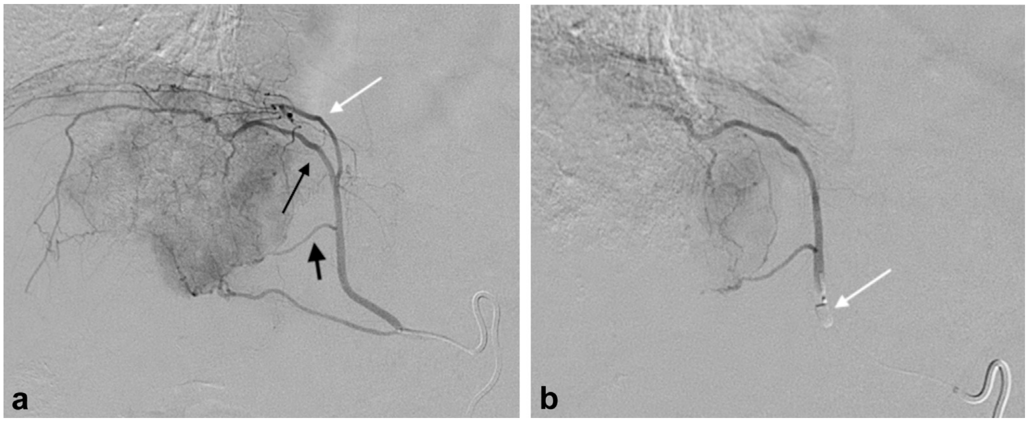

Figure 2. Angiographic images from balloon-assisted transarterial chemoembolization procedure targeting segment 7 residual disease. **(a)** Digital subtraction angiography before balloon inflation demonstrates the inferior phrenic branches supplying the tumor. The white arrow indicates the diaphragmatic branch, the long black arrow indicates the ascending (anterior) right inferior phrenic artery, and the short black arrow indicates the descending (posterior) right inferior phrenic artery branch. **(b)** Once the balloon is inflated (white arrow), flow of contrast favors the right inferior phrenic artery branches supplying the tumor, and contrast cannot be seen filling the diaphragmatic branch. Refer to **Videos 1** and **2** (available online on the article's Supplemental Material page at *www.jvir.org*) for cine clips of right hepatic segmental artery injection without and with balloon inflation, respectively.

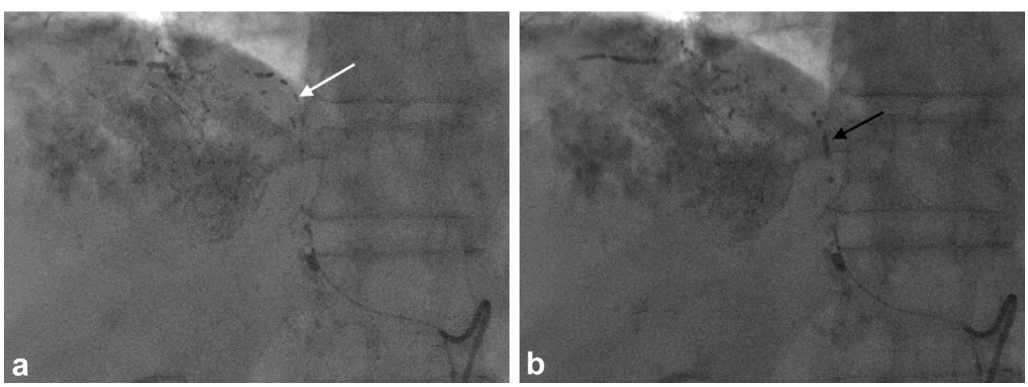

Figure 3. **(a)** Segment 7 tumor staining with the chemoembolic emulsion after early balloon occlusion, which is visualized entering the diaphragmatic branch (white arrow). **(b)** Subsequent fluoroscopic image with balloon inflation demonstrates the same droplets of embolic material that were in the diaphragmatic branch having reversed course and traveled into the ascending branch of the right inferior phrenic artery (black arrow). Refer to **Video 3** (available online on the article's Supplemental Material page at *www.jvir.org*) for cine clip demonstrating this progression.

(**Video 3** [available online on the article's Supplemental Material page at *www.jvir.org*]). Transarterial chemoembolization was performed until near-stasis of flow was achieved. Imaging performed 1 month after the procedure showed no contrast enhancement within the treatment zone (**Fig 4**). On clinical follow-up, there was no evidence of abdominal or shoulder pain or diaphragmatic weakness to suggest nontarget embolization of critical inferior phrenic artery branches.

Using balloon occlusion at a proximal arterial branch decreases arterial stump pressure distally, helping redirect flow away from nontumoral tissues into the tumor (3). Rose et al (2) produced demonstrable downstream pressure differences and twice the microparticle uptake after balloon occlusion in a porcine model. Maruyama et al (4) published a case-control study that demonstrated a statistically significant increase in ethiodized oil uptake at the subsegmental level in patients undergoing balloon-assisted transarterial chemoembolization, yet increased risk of abscess and/or infarction in patients with biliary ductal dilatation. Irie et al (3) studied the survival of patients after conventional transarterial chemoembolization versus balloon-assisted transarterial chemoembolization in a single-center retrospective study and demonstrated that balloon-assisted transarterial chemoembolization improved primary tumor control rates and was an independent factor prolonging overall survival in patients with 1 or 2 hepatocellular carcinoma tumors. However, larger scale multi-institutional studies are warranted to establish if and how balloon-assisted transarterial chemoembolization may fit into established treatment algorithms as well as to provide long-term survival data.

This case provides direct angiographic evidence of reversal of flow from nontarget vessels (**Video 2** [available online on the article's Supplemental Material page at

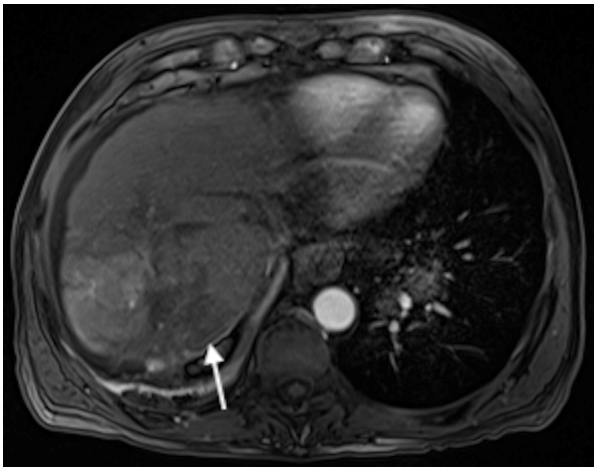

Figure 4. Magnetic resonance imaging after balloon-assisted transarterial chemoembolization of hepatic arterial branches supplying the segment 7 mass demonstrates minimal residual enhancement in the treatment cavity (white arrow).

www.jvir.org]) after balloon inflation. The chemoembolic emulsion administered into the diaphragmatic branches reversed direction, and nontarget embolization of vital structures was averted.

In conclusion, this case provides angiographic support for the utility of balloon-assisted transarterial chemoembolization in the treatment of liver tumors. The pressure-directed reversal of flow away from nontarget vessels can be a useful tool to navigate complex anatomy and preserve vital structures during transarterial chemoembolization. When used in the appropriate clinical setting, this pressure-directed technique could impact management of difficult-to-access tumors and may improve safety.

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