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## Intrahepatic Collateral Supply to the Previously Embolized Right Gastric Artery: A Potential Pitfall for Nontarget Radioembolization

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### Editor:

Despite the promising therapeutic effects of hepatic radioembolization, serious gastrointestinal ulceration can result from nontarget deposition of radioactive microspheres through hepaticocentric anastomoses (1). One such anastomosis, the right gastric artery (RGA), shows extensive anatomic variability in its site of origin from the hepatic arteries and can be missed during angiography. Identifying and coil embolizing the RGA and other hepaticocentric anastomoses enable the angiographic equivalent of

vascular skeletonization, a technical end point the objective of which is to limit gastrointestinal complications arising from nontarget radioembolization. Herein, we report a series of five patients with an anatomic variant involving duplication of the proximal RGA, with an accessory vessel providing antegrade flow from within the liver to the main RGA in the lesser curvature of the stomach despite prophylactic embolization of the main origin of the RGA. The institutional review board approved this retrospective report. All data were handled in compliance with the Health Insurance Portability and Accountability Act.

All of the 187 consecutive patients undergoing radioembolization treatment underwent preparatory angiography and preemptive coil embolization of hepaticocentric anastomoses. A total of 136 patients (73%) underwent selection and embolization of the RGA. Patients who did not undergo RGA embolization included those that had prior surgical resection or ligation of the RGA and those who required only selective (segmental or lobar) treatment well distal to the origin of the RGA. Confirmation of skeletonization was performed using digital subtraction angiography and C-arm computed tomography (2).

The existence of a collateral vessel arising from a hepatic artery reconstituting the distal RGA, which we will refer to as the *accessory* RGA or aRGA, was discovered retrospectively in a patient in whom gastric ulceration developed despite successful coil embolization of the main RGA. Since then, four other cases of collateral reconstitution of an embolized RGA have been identified prospectively, and these patients have been treated successfully without gastrointestinal complications.

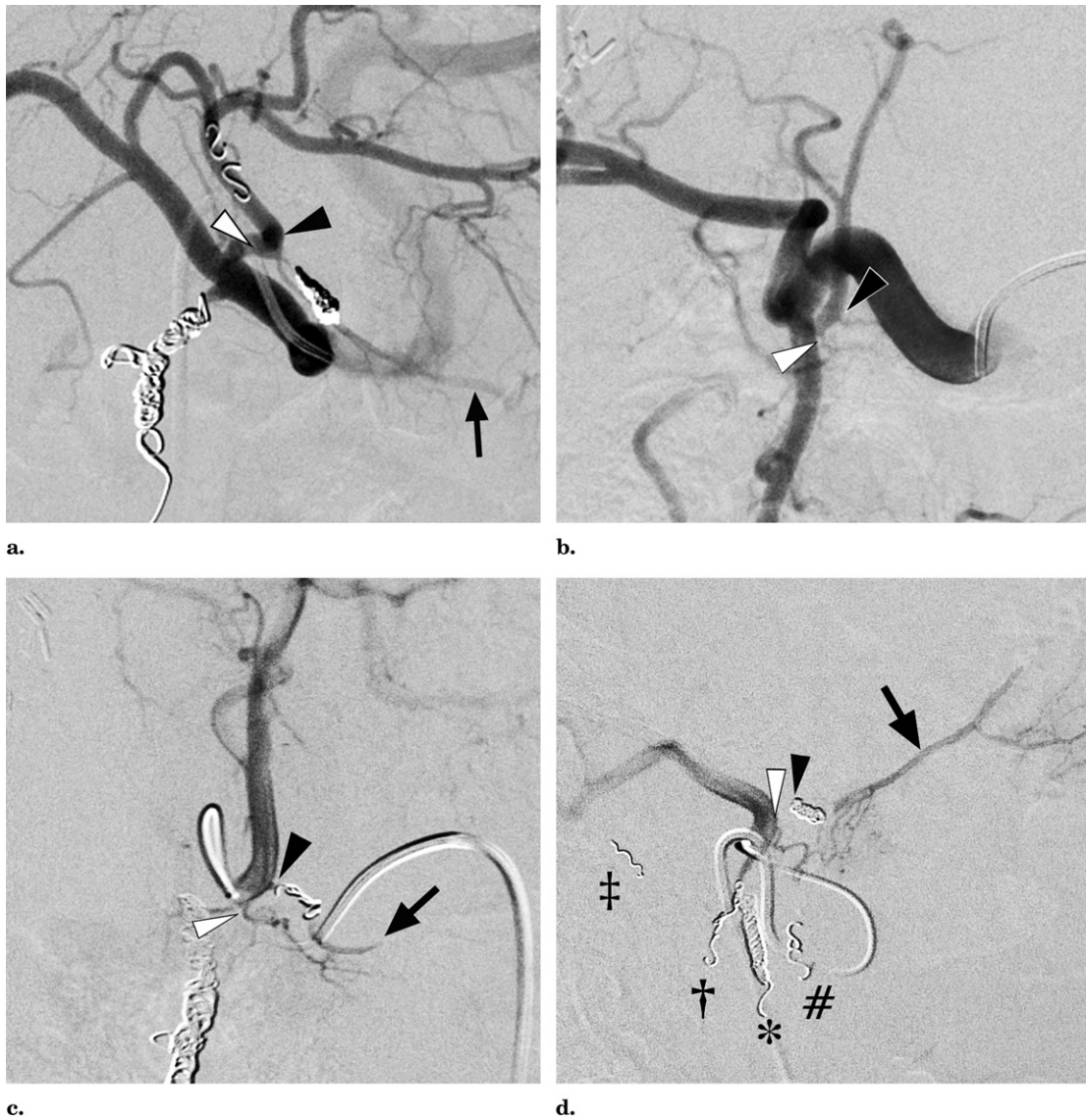
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**Table.** Clinical and Technical Summary

| Pt No | Age/<br>Sex | Diagnosis                           | Territory Treated by Radioembolization                | Origin of RGA | Origin of aRGA       | Treatment Method of aRGA  | Outcome   |
|-------|-------------|-------------------------------------|---|---------------|----------------------|---|---|
| 1     | 44/F        | Metastatic colon carcinoma          | Whole liver, single administration from PHA           | LHA           | LHA, distal to RGA   | None (aRGA was not recognized at the time of treatment)                 | Gastric antral ulcer, successfully treated with PPI |
| 2     | 57/F        | Metastatic neuroendocrine carcinoma | Whole liver, single administration from PHA           | LHA           | LHA, distal to RGA   | Coil embolized  | Uncomplicated                                       |
| 3     | 60/M        | Metastatic colon carcinoma          | Whole liver, single administration from PHA           | LHA           | Proximal RHA         | Intentional guide wire disruption                                       | Uncomplicated                                       |
| 4     | 54/F        | Metastatic colon carcinoma          | Whole liver, two lobar administrations                | LHA           | LHA, proximal to RGA | Two separate lobar treatments distal to origin of aRGA                  | Uncomplicated                                       |
| 5     | 74/F        | Cholangiocarcinoma                  | Segments IV-VIII, two lobar/segmental administrations | LHA           | LHA, distal to RGA   | Separate right lobar and segment IV treatments distal to origin of aRGA | Uncomplicated                                       |

Note.—PHA = proper hepatic artery, PPI = proton pump inhibitor.



**Figure.** (a) Common hepatic angiogram performed in patient 1 before administration of microspheres, 24 days after coil embolization of the GDA, RGA, and falciform artery, showed a branch (black arrowhead) of the proximal LHA with an origin distal to the RGA stump (white arrowhead). This collateral vessel is seen coursing around the RGA coils, faintly opacifying the distal RGA (black arrow). This finding was missed at the time of treatment, and the patient developed a gastric antral ulcer that contained radioembolic particles upon biopsy. (b) In patient 4, common hepatic arteriogram showed two branch arteries (black and white arrowheads) originating from the proximal LHA appearing to course toward the stomach. (c) The GDA and the larger and more distal RGA (black arrowhead) were selected and coil embolized. Completion LHA angiogram showed the more proximal accessory RGA (white arrowhead) filling the distal RGA (black arrow), whose opacification was incomplete because of competitive flow from the left gastric artery. Separate administrations of radioembolic material were performed into the RHA and into the LHA distal to this accessory RGA. (d) Right hepatic arteriogram was performed in patient 3 after successful coil embolization of two pancreaticoduodenal arteries (pound sign and dagger), the GDA (asterisk), and a supraduodenal artery (double dagger). The main RGA (black arrowhead), a branch of the proximal LHA, was coil embolized, but the distal RGA (black arrow) was reconstituted by a collateral branch of the right hepatic artery (white arrowhead). This arcade was too small to allow catheterization by a 1.8-F microcatheter but was eliminated by intentional wire disruption using a 0.014-inch guide wire.

## CASE 1

A 44-year-old woman with hepatic metastases from colon carcinoma underwent preparatory arteriography. The RGA, which arose from the proximal left hepatic artery (LHA), was selected with a microcatheter (J-tipped Prowler Plus; Cordis Neurovascular, Inc, Miami Lakes, Florida) and a shapeable 0.014-inch guide wire (Transend; Boston Scien-

tific, Natick, Massachusetts). The vessel was embolized successfully to stasis with three  $2 \times 3$ -mm diamond-shaped 0.018-inch coils (VortX; Boston Scientific). Angiography performed 24 days later immediately before administration of radioembolic microspheres portrayed a collateral branch of the proximal LHA adjacent to the origin of the main RGA, coursing around the RGA coils and faintly opacify-

ing the distal RGA (**Fig, a**). This finding was overlooked at the time of treatment, when the radioembolic material (SIR-Spheres; Sirtex, Inc, Wilmington, Massachusetts) was delivered from the hepatic artery bifurcation to the whole liver. The patient developed an antral ulcer, a biopsy of which showed embedded radioembolic microspheres. After 14 weeks of high-dose proton pump inhibitor (pantoprazole, 40 mg twice a day) and sucralfate therapy, her symptoms resolved, and the ulcer was found to be healed at follow-up endoscopy.

## CASES 2–5

Clinical and technical details are summarized in the **Table**. All four patients had RGAs originating from the LHA, but the collateral aRGAs originated from the LHA proximal to the RGA in one patient, distal in two patients, and from the proximal right hepatic artery (RHA) in one patient. After identification of collateral filling of the RGA either by angiography or by contrast-enhanced C-arm computed tomography, these vessels were either coil embolized ( $n = 1$ ), intentionally dissected with a guide wire ( $n = 1$ ), or circumvented by selective radioembolization distal to the origin of the aRGA ( $n = 2$ ).

The course of the RGA is known to vary substantially, arising from the proper hepatic artery in 51%–57% of patients, LHA in 17%–25%, gastroduodenal artery (GDA) in 3%–10%, RHA in 1%–9%, and common hepatic artery in 2%–9% (3). All five of our patients had main RGAs originating from the proximal LHA, but because the aRGA has not been described previously, there are no other data suggesting that this configuration is associated with duplication.

Despite the liver being an end organ, isolation of hepatic arterial perfusion is complex and difficult. Anatomic variants and distortion by neoplasm or prior surgery are extremely common in this vascular bed, and the ready formation of collateral pathways within the intricate network of hilar vessels can render the objective of skeletonization an elusive goal. Furthermore, neoplastic growth factors also encourage the formation of new collateral vessels and the parasitization of neighboring vessels.

Coil embolization of major branches such as the GDA and RGA may induce redistribution of flow and formation of new collateral or parasitized vessels (4). The interval between the preparatory angiogram and the administration of the radioembolic microspheres may allow previously unseen vessels to become more prominent. Our five patients each had the proximal 1–3 cm of the RGA filled with coils (**Fig, b–d**). We currently attempt to place a longer nest of coils, which should block more potential collateral pathways that could reconstitute the main RGA distally in the manner that occurred in our cases. In addition, the use of detachable coils may allow more pinpoint flush embolization of the RGA origin and occlusion of proximal branches that could provide collateral flow.

Collateral filling of the main RGA through duplication

at the origin, circumventing proximal coil embolization of the main origin, is a rare anatomic variant that needs to be recognized to avoid gastrointestinal complications in patients undergoing hepatic radioembolization.

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## Central Venous Catheter Insertion via the Vertebral Vein and the Sixth Transverse Foramen

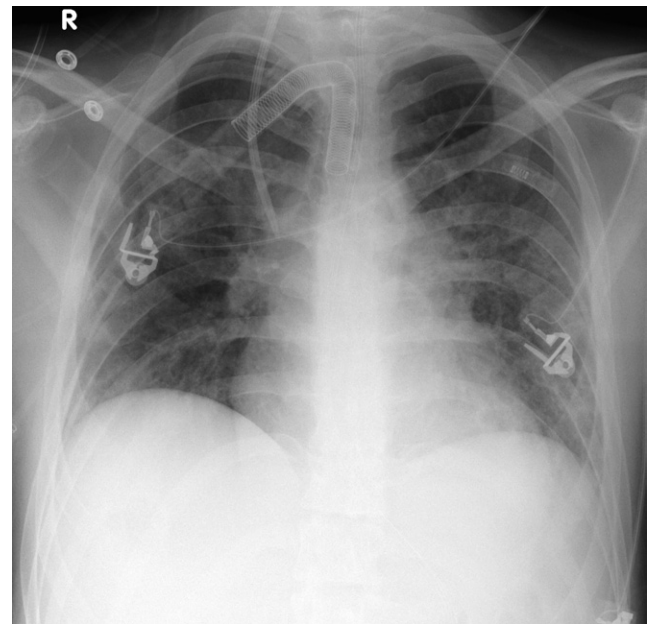
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**Figure 1.** Chest radiograph shows that the tracheal cannula and stomach tube project regularly. The lower end of the central venous catheter is inconspicuous as well, but its course shows a rather uncommon slight convexity to the right.