Embolization of Nonliver Visceral Tumors

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ABSTRACT

Catheter-directed embolization of visceral tumors, with the exception of the liver, has received limited attention in the literature. The visceral arterial anatomy can be complex and its understanding is critical for procedure planning and limiting complications. Embolization of splenic neoplasms is exceedingly rare. Preoperative embolization for adrenal, renal, and gut tumors plays an important role in select patients. Embolization has been used successfully in the treatment of pancreatic insulinomas and in limited cases of unresectable pancreatic adenocarcinomas. Embolization of bleeding visceral tumors can be accomplished with a high likelihood of success.

KEYWORDS: Tumor, embolization, visceral

Objectives: Upon completion of this article, the reader should be able to list important anatomic variants, indications, and potential treatments for nonliver mesenteric tumors.

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Catheter-directed embolization is performed for a host of indications as varied as bleeding to palliative therapy for benign or malignant tumors. Most of the literature regarding embolization of visceral tumors is devoted to chemoembolization or radioembolization for primary and metastatic hepatic malignancies. Although much less common, embolization of nonliver visceral tumors can play an important role in appropriately selected patients. In this article, the authors provide a brief review of embolization for nonliver visceral tumors including anatomic considerations and a brief overview of indications and outcomes described in the literature.

ARTERIAL ANATOMY

A thorough understanding of the arterial anatomy and variants is critical to successfully embolize visceral tumors and limit complications. A detailed discussion is beyond the scope of this article, instead a few key points will be highlighted. This anatomy is highly variable with over 40% of patients demonstrating a variant. Eight variations of the hepatic artery have been described including a replaced common hepatic artery (10%), early bifurcation of the common hepatic artery with the gastroduodenal artery (GDA) arising from the right hepatic artery (RHA), replaced RHA (15%), replaced left hepatic artery (LHA) from the left gastric artery (23%), accessory RHA from the superior mesenteric artery (SMA) or pancreaticoduodenal trunk (31%), and accessory LHA from the left gastric (8%).[1]

The pancreas and duodenal anatomy is especially complex. Tumors in this region are typically supplied by several collaterals from the celiac and SMA. The posterior pancreaticoduodenal arcade typically arises from the

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GDA, but may receive feeding vessels from the hepatic artery and SMA. The anterior arcade often gives a pyloric branch and anastomoses with the SMA. The inferior pancreaticoduodenal artery is the first right-sided branch of the SMA. The tail of the pancreas is supplied by several branches of the splenic and gastro-epiploic arteries.[1,2]

The stomach has a rich network of collateral arteries originating from the celiac trunk, including branches of the splenic artery and the SMA. The jejunum and ileum are fed by 12 to 15 SMA branches and the ileocolic artery. It is important to note that the left colic and middle colic arteries infrequently arise from the anterior arcade or celiac trunk, thus necessitating celiac, SMA, and inferior mesenteric artery investigation in the setting of lower gastrointestinal (GI) tumor embolization. The marginal artery of Drummond and the arc of Riolan are important collateral pathways between the mesenteric arteries.[1,2]

Superior, middle, and inferior adrenal arteries typically arise from the inferior phrenic artery, the aorta, and the renal arteries. However, the middle adrenal artery can be replaced from the celiac artery or SMA in 2 to 5% of patients whereas the inferior adrenal artery can have variable origins from the superior capsular renal arteries, apical segmental renal artery, or inferior phrenic artery in two-thirds of patients.[2,3]

The renal parenchyma is typically supplied by a main renal artery with up to two accessory renal arteries frequently found. These arteries are terminal branches. Superior, medial, and inferior capsular branches arise from an adrenal artery, the main renal artery, or a gonadal branch.[1]

PANCREAS

The mainstay of treatment for pancreatic neoplasia remains surgical resection. Embolization, however, has been demonstrated to be a viable option in both malignant and benign pancreatic neoplasms when surgery is not an option, or as a method to reduce ischemic complications after distal pancreatectomy. Figure 1 highlights a case of upper GI bleeding secondary to renal cell metastasis to the duodenum and pancreas, which was successfully embolized with coils and particles.

Rott et al reported the successful treatment of a single patient with a symptomatic insulinoma who refused surgical resection.[4] Here, the authors super-selectively embolized the dorsal pancreatic artery with trisacryl gelatin microspheres. A computed tomography (CT) scan 3 days after the procedure demonstrated complete devascularization of the tumor, and the patient was without clinical or laboratory signs of recurrence one year after the procedure. Although there remains a paucity of articles dedicated to the use of embolization in insulinomas, similar findings were demonstrated by Urflacker and Moore.[5,6]

Embolization has also been reported as an option in advanced-stage pancreatic adenocarcinoma. The largest case series reported the use of chemoembolization in 31 patients with advanced pancreatic carcinoma. Embolization with arterial infusion achieved a response rate of 74% (9% complete response rate and a partial response rate of 65%). Overall median survival time was 22.86 months. The authors concluded that chemoembolization should be attempted as a last ditch effort in patients with advanced pancreatic carcinoma.[7]

Lastly, embolization has been demonstrated to be useful in the preoperative period in preparation for pancreatectomy. Kondo et al reported its use in four patients who underwent coil embolization of the common hepatic artery 1 to 7 days before distal pancreatectomy. Here the authors demonstrated that extensive collateralization immediately after embolization had a protective mechanism against ischemic damage from en bloc resection of the celiac artery during distal pancreatectomy.[8]

Nontarget embolization and incomplete treatment can be avoided with a thorough understanding of the complex vascular anatomy and the rich collateral networks about the pancreas.

SPLEEN

Metastatic and primary neoplasms of the spleen, with the exception of lymphoma and melanoma, are rare entities. Primary splenic neoplasms include sarcoma and melanoma. The mainstay of treatment for primary neoplasms is splenectomy with little attention given to the role of embolization. In fact, despite more than 1000 articles published on splenic angiography and embolization, no articles were found describing embolization of splenic tumors. The majority of the literature on splenic embolization is related to trauma and vascular abnormalities such as an aneurysm. Embolization is also a well-established technique to treat hypersplenism.[9–16] Although splenectomy is the gold-standard treatment for splenic tumors, embolization may play a select role in the preoperative setting.

STOMACH, SMALL AND LARGE BOWEL

Embolization involving stomach, small and large bowel tumors is largely reserved for preoperative management and tumors associated with GI bleeding. Due to the vascular nature of many GI neoplasms, preoperative embolization can reduce tumor size and subsequently reduce the extent of tumor resection.[17] This has been demonstrated most commonly with GI stromal tumors (GIST).[18,19] Kurihara et al reported a 60% reduction in tumor size following preoperative embolization of a

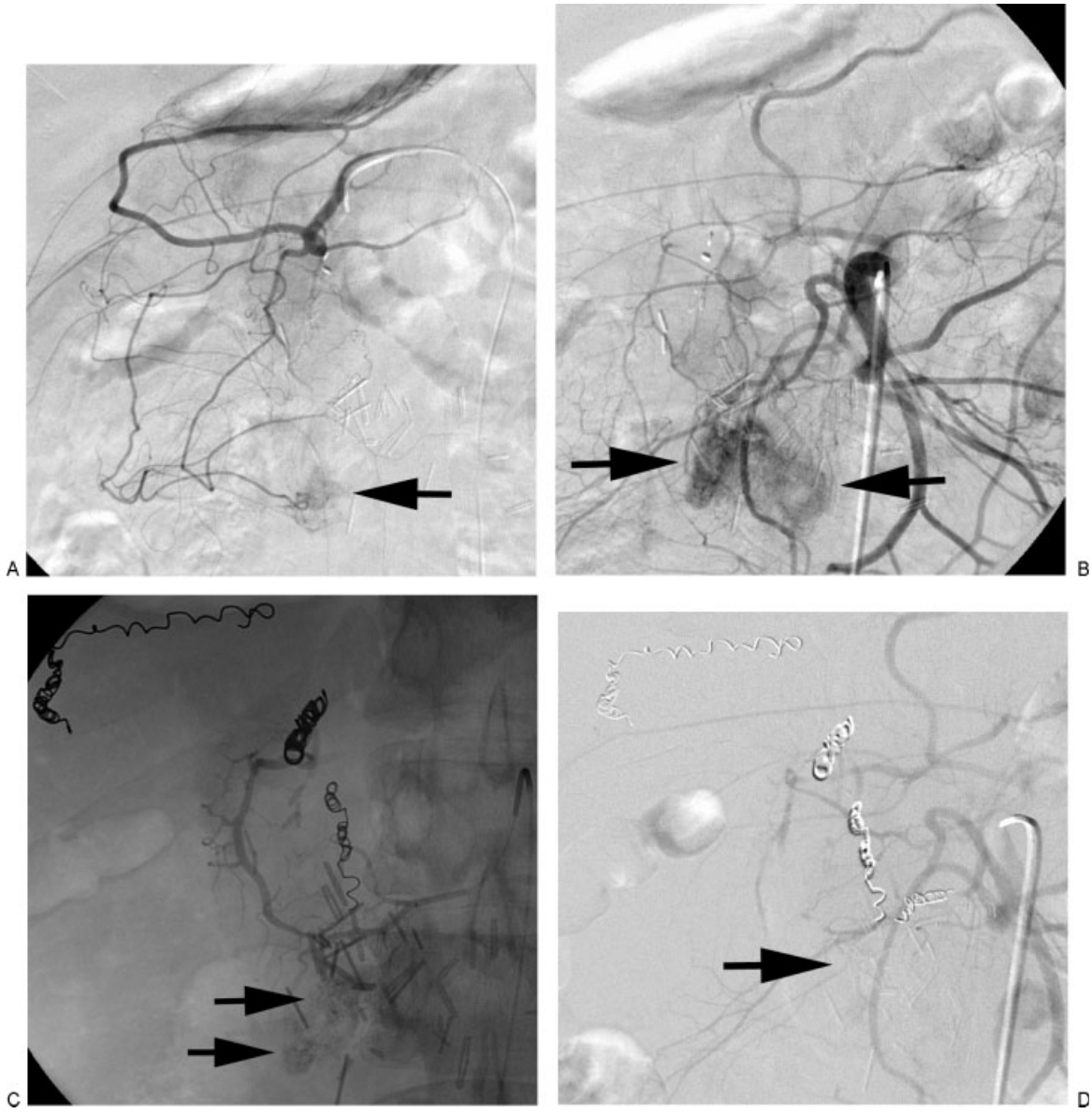

Figure 1 A 51-year-old woman with metastatic renal cell carcinoma to the duodenum and pancreas resulting in endoscopically confirmed upper gastrointestinal bleeding. (A) Gastroduodenal artery (GDA) injection shows tumor blush (arrow) from branches of the anterior pancreaticoduodenal arcade arising from the right gastroepiploic (RGE) and terminal GDA. The RGE was coil embolized to prevent recanalization and the anterior arcade was particle embolized, followed by coil embolization of the proximal GDA. (B) Superior mesenteric angiography (SMA) angiography shows dominant flow to the tumor (arrows). (C) Inferior pancreaticoduodenal arcade injection shows prominent tumor blush (arrows), which was successfully embolized with particles and coils. (D) Completion SMA angiography shows no residual tumor blush (arrow). This was also confirmed with celiac angiography.

duodenal GIST. Furthermore, preoperative embolization can decrease intraoperative blood loss. Joyce et al reported a case of VIPoma with colonic and duodenal invasion in which widespread resection was done following splenic artery embolization with a minimal operative estimated blood loss of ~500 mL.[20]

Embolization has utility in the case of GI bleeding secondary to tumor invasion/ulceration. Intestinal neoplasms are an uncommon cause of upper GI bleeding, but are responsible for 8 to 26% of cases of lower GI bleeding.[21] GI bleeding has been associated with several tumors including gastric and small bowel lymphoma, gastric carcinoma, intestinal adenocarcinoma, GISTs, metastatic disease, as well as benign lesions such as colonic adenomatous polyps (Fig. 2). Tumor-associated bleeding is often difficult to control with conservative measures.[22] The technical success rate of embolization of lower GI bleeding has been reported as high as 93 to 96% for bleeding from any cause, with a prolonged clinical success rate as high as 81%.[23] Embolization has

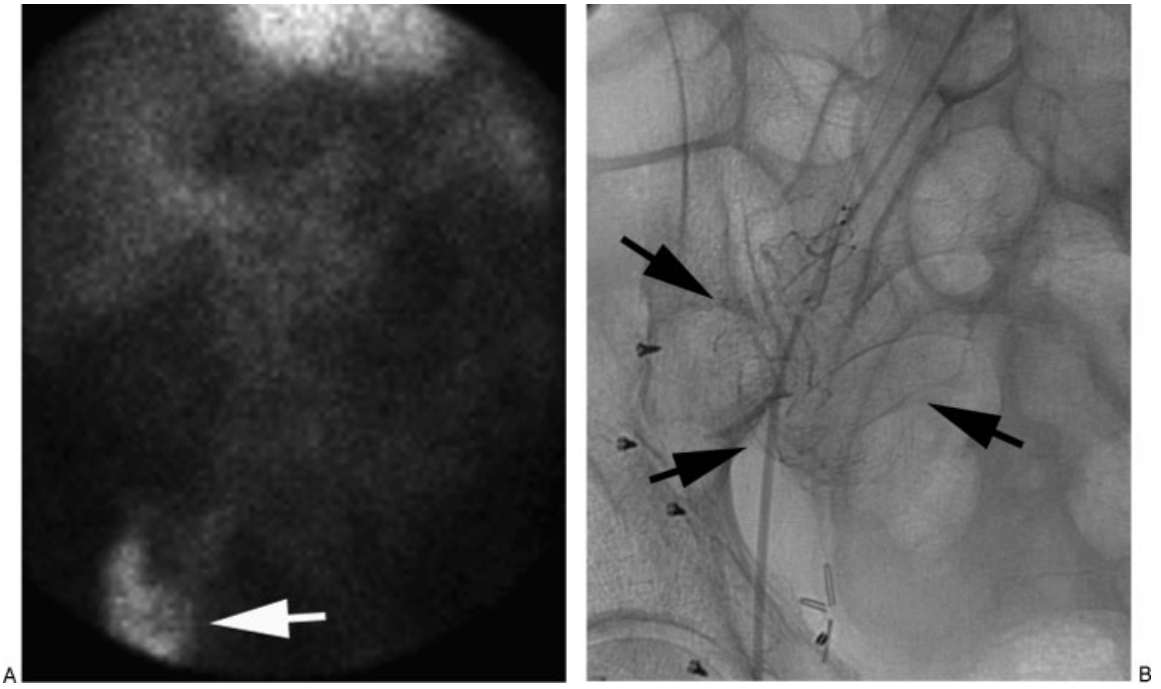

Figure 2 A 63-year-old man with metastatic hemangiopericytoma and lower gastrointestinal bleed. (A) A red blood cell (RBC) scan shows pooling in the right lower quadrant (arrow). (B) Selective angiography of an ileal branch shows tumor vascularity (arrows). This was embolized with polyvinyl alcohol (PVA) 500–700 μm particles with clinical success.

also been shown to be effective in the management of acute and recurrent GI bleeding associated with tumors.[22,24,25] However, an increased rate of rebleeding is expected and is most commonly attributed to tumor progression. Kikuth et al describes rebleeding in a patient secondary to progression of his widely metastatic pancreatic cancer with right colonic invasion.[23]

Acute ischemic complications following embolizations of GI bleeding from all causes is estimated as high as 22%. Recent data on super-selective coil embolization suggests a 6 to 7% incidence.[26] Selection of an embolization agent is somewhat controversial. Given the increased risk of rebleeding, we prefer long-term control with particles thus allowing for repeat treatment as necessary.

ADRENAL

Adenoma is the most common adrenal mass. Although most are clinically silent, adenomas may present as hyperfunctioning neoplasms. Commonly accepted treatment in these cases include open or laparoscopic-assisted adrenalectomy.[27] However, limited reports of embolization with alcohol have demonstrated success when treating patients with secondary hypertension.[28–30] Hokotate et al published a retrospective study of 33 patients with unilateral aldosteronomas who underwent embolization with ethanol or iohexol-ethanol.[28] In 27 of 33 patients (82%), embolization was successfully performed with 70% of patients experiencing good therapeutic result without long-term complications.[31] However, it should also be noted that several patients required multiple treatments for success and adrenalectomy.

Beginning in the 1980s, scattered case studies described successful embolization of pheochromocytoma to treat spontaneous hemorrhage or hypertension.[32–37] Successful use of Gelfoam® (Pfizer Pharmaceuticals, New York, NY), particles. and coils were all reported.

Case reports suggest that embolization may be useful in Cushing's syndrome secondary to hyperfunctioning adenoma, carcinoma, or adrenal hyperplasia.[38,39] O'Keefe et al reported a successful therapeutic response for hyperfunctioning adrenocortical carcinoma in 2 of 3 patients.[40] Blunt et al demonstrated the use of bilateral embolization with alcohol and coils to treat Cushing's syndrome from metastatic medullary thyroid carcinoma.[41] This resulted in adequate control of cortisol levels with additional medications to allow for bilateral adrenalectomy. A similar case was reported by Bourlet et al with successful treatment using particles.[42]

The adrenal gland is the fourth most common site of metastasis with almost 25% of cancer patients having adrenal involvement on autopsy. Consequently, embolization may play a role in the presurgical treatment plan.[43] Reported case studies described successful embolization prior to pheochromocytoma resection.[33,34,37] Furthermore, a recent case study reported embolization for tumor bed recurrence from metastatic adrenocortical carcinoma for palliation of pain.[44] Although embolization may provide pain relief, reduction in tumor size

should not be expected.[40] Recent retrospective studies have shown that management of adrenal metastasis from hepatocellular carcinoma with nonsurgical treatment provides short-term survival benefit similar to surgical resection but inadequate long-term survival. Current management strategies recommend surgical resection for adrenal metastasis as long as there is some residual hepatic function. When surgery is not indicated, transarterial catheterization or percutaneous chemoablation may be indicated to control the progression of the adrenal metastasis.[45,46]

Last, adrenal neoplasms have the propensity for spontaneous hemorrhage. Pheochromocytoma is the most common underlying tumor causing hemorrhage. Similarly, case studies have reported successful bleeding control in adrenocortical carcinoma, adrenal myelolipoma, and metastasis (Fig. 3).[47–49] Tumor embolization offers an alternative to emergent surgery for successful hemostasis in unstable patients.[48]

Adrenal tumor embolization carries significant risk because of the variable anatomy and risk of malignant hypertension. Close monitoring of vitals signs via an arterial line throughout the procedure is mandatory and anesthesia personnel should be involved in these cases. It has been suggested that slower injection rates (~1 mL/min) may help reduce the incidence of hypertension and tachycardia. Additionally, use of particles over alcohol may reduce this risk.[50] Alpha- and β-adrenergic blocker medications should be readily available to control any acute hypertensive crisis.[50] Other complications include postembolization syndrome, renal insufficiency, abscess formation, infarction of normal tissue, and sepsis.

RENAL

Embolization of renal neoplasms is controversial and is utilized primarily in two clinical scenarios: preoperative treatment to reduce hemorrhage risk and palliation. Preoperative embolization aims to decrease intraoperative blood loss and operative time. The procedure is typically performed 24 to 48 hours before the surgery,

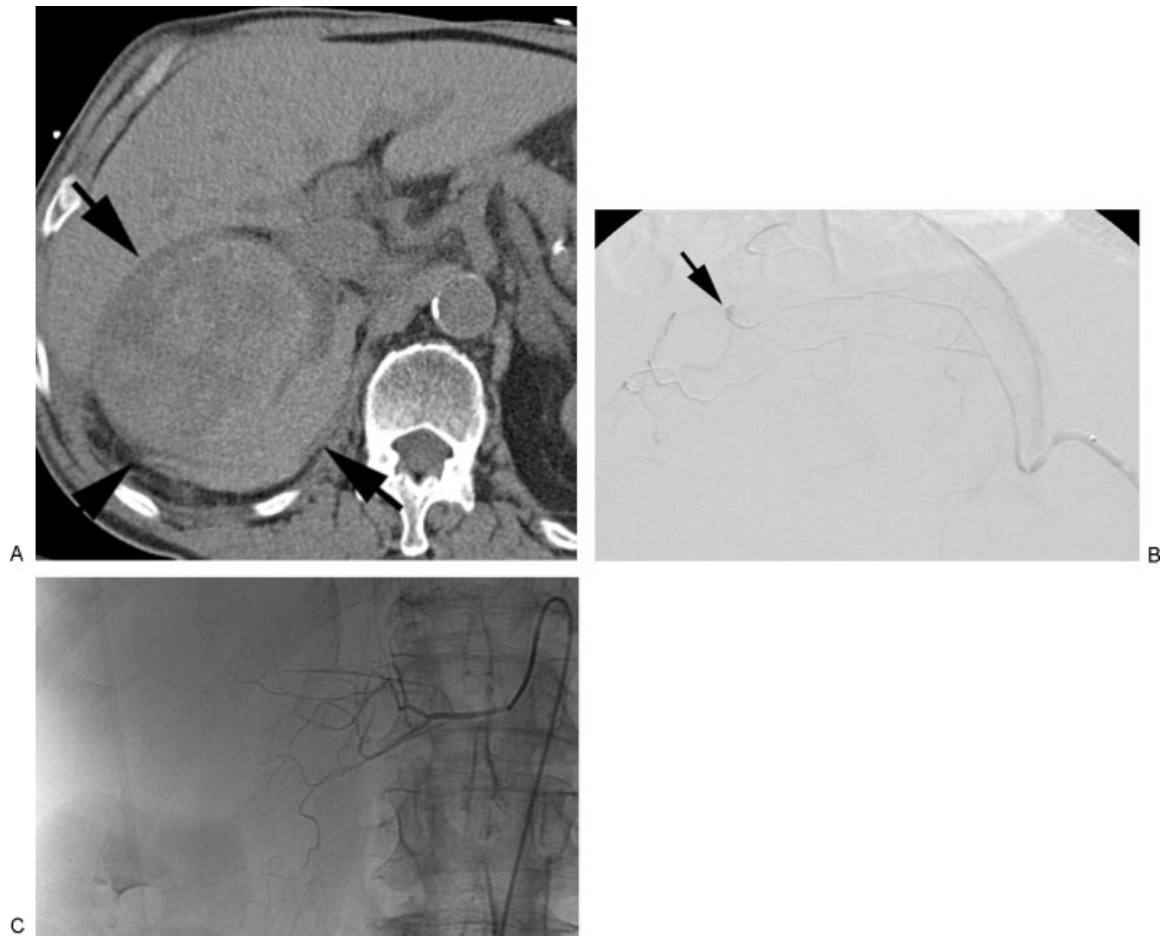

Figure 3 An 83-year-old man with known right adrenal adenoma. (A) A noncontrast computed tomography (CT) scan shows hyperdense hemorrhage (arrows) in the right adrenal, which resulted in pain and a decrease in hematocrit. (B) Superior adrenal artery angiography shows a pseudoaneurysm (arrow). This artery was embolized with polyvinyl alcohol (PVA) 250–350 μm particles. (C) The middle adrenal artery was selected and prophylactically embolized.

but can be completed up to several weeks prior to resection. In addition to decreasing arterial flow, embolization is theorized to result in vein collapse, facilitating safe resection of tumor thrombus and decreased blood loss.[51] In addition to decreased bleeding risk, preoperative embolization may impart a survival benefit. A recent retrospective cohort analysis of 118 preoperative embolization patients and 116 surgery-alone patients showed 5- and 10-year survival rates of 62% and 47% in the embolization cohort compared with 35% and 23% in nonembolization cohort ($p = 0.01$), respectively. Interestingly, survival benefit was observed in patients with stage II and III disease, as well as those with lymphatic metastases at surgery.[52]

Embolization of renal neoplasms may provide benefit in the patient with unresectable renal neoplasms including renal cell carcinoma and angiomyelolipoma (Fig. 4).[52,53] Nevertheless, palliative embolization of renal neoplasms has been decreasing in frequency over the past decade. This decline is theorized to be related to the better quality of diagnostic cross-sectional imaging with the resultant detection of neoplasms at an earlier stage. Regardless, embolization has been shown to be an effective treatment option for patients with unresectable stage IV neoplasm, widely disseminated disease, or those who are unable to tolerate surgery. Published results note improvement in hematuria and lumbar pain ranging between 75 to 100% and 50 to 75%, respectively.[54]

Published complication rates for renal tumor embolization are as high as 20% with prolonged hematuria being most common. The mortality rate reported is 3.3%.[55,56] Postinfarction syndrome, consisting of fever,

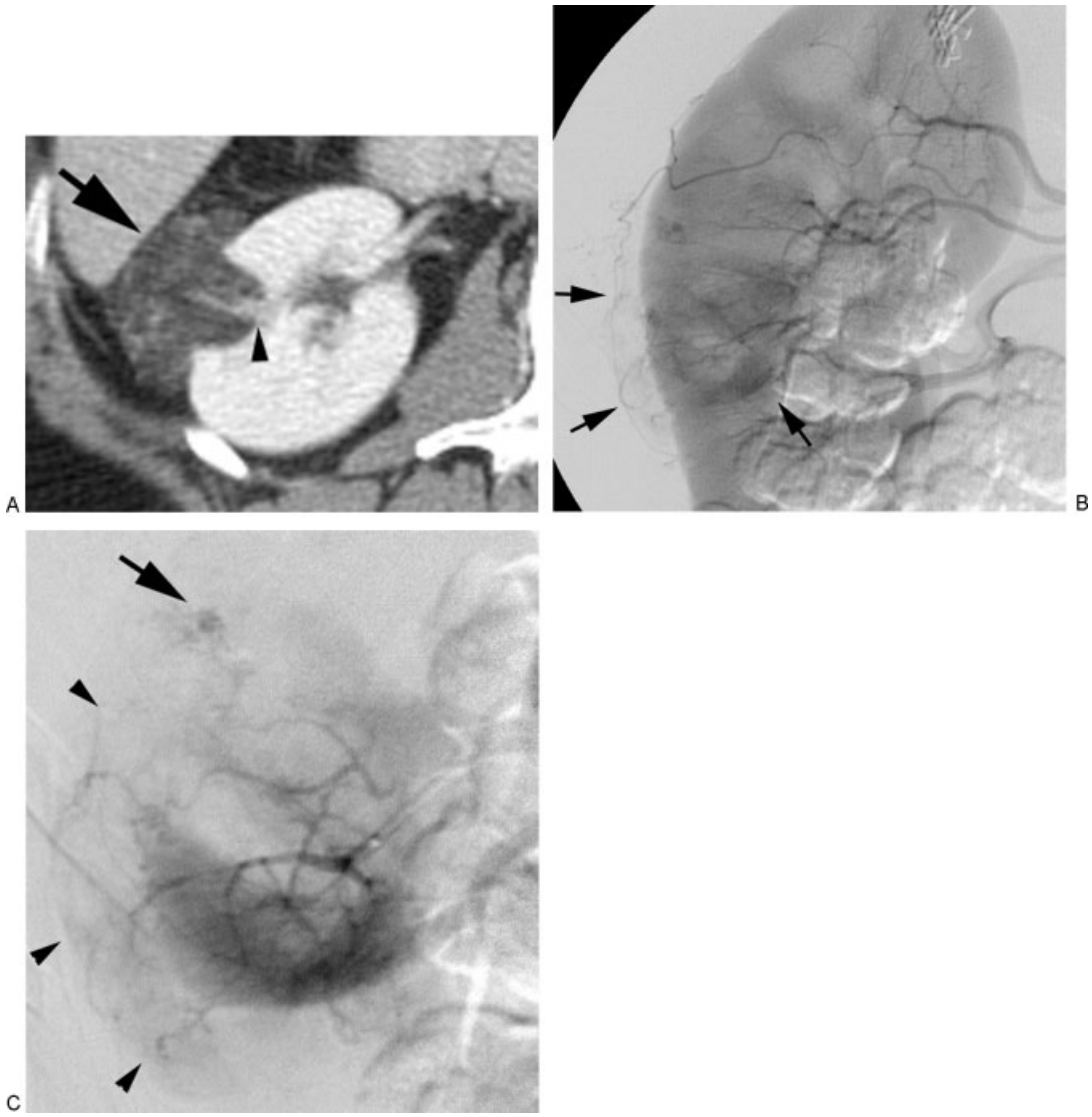

Figure 4 A 49-year-old woman with right angiomyolipoma (AML) causing flank pain. (A) Enhanced computed tomography (CT) scan shows a fatty mass arising from the right kidney (arrow) with a prominent feeding artery (arrowhead). (B) Right renal angiogram shows tumor vascularity (arrows). (C) Selective angiogram shows pseudoaneurysm (arrow) and tumor vascularity (arrowheads). Stasis was achieved with 45–150 μm polyvinyl alcohol (PVA) particles and ethanol mixture.

groin pain, and nausea, is common and occurs in nearly all patients. These symptoms typically resolve by 36 hours and are managed medically.[54,57]

DISCUSSION

Catheter-directed embolization of visceral tumors, with the exception of the liver, is an entity that has received little attention in the literature. In the above review, we discussed the various mesenteric organs and tumor types that may be amenable to embolization and the indications for its usage. Embolization for splenic tumors is an unexplored area with no articles to date discussing its efficacy. Small and large bowel tumors are rarely treated with embolization, but if so, embolization is primarily used prior to operative resection or in cases of tumor-induced GI hemorrhage. Embolization of pancreatic insulinoma and carcinoma has been described. In the adrenals, embolization is primarily used for preoperative debulking or for symptomatic relief from hyperfunctioning tumors. Embolization for renal cell carcinoma and angiomyelolipoma is mainly used in the preoperative setting to reduce blood flow prior to surgical resection. The embolization agents utilized were predominantly permanent including alcohol, particles, and coils.

In conclusion, catheter-directed embolization is an important technique in the treatment of nonliver mesenteric tumors, primarily in the setting of nonoperable neoplasms, preoperative tumor control, or tumor hemorrhage.

REFERENCES

1. Uflacker R. Atlas of Vascular Anatomy: An Angiographic Approach. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2007:905
2. Kadir S. Atlas of Normal and Variant Angiographic Anatomy. 1st ed. Philadelphia: WB Saunders; 1991:541
3. Kaufman JA, Lee MJ. Vascular and Interventional Radiology: The Requisites. 1st ed. Philadelphia: Mosby; 2004:510
4. Rott G, Biggemann M, Pfohl M. Embolization of an insulinoma of the pancreas with trisacryl gelatin microspheres as definitive treatment. Cardiovasc Intervent Radiol 2008; 31(3):659–662
5. Moore TJ, Peterson LM, Harrington DP, Smith RJ. Successful arterial embolization of an insulinoma. JAMA 1982;248(11):1353–1355
6. Uflacker R. Arterial embolization as definitive treatment for benign insulinoma of the pancreas. J Vasc Interv Radiol 1992;3(4):639–644; discussion 644–646
7. Homma H, Doi T, Mezawa S, et al. A novel arterial infusion chemotherapy for the treatment of patients with advanced pancreatic carcinoma after vascular supply distribution via superselective embolization. Cancer 2000;89(2):303–313
8. Kondo S, Katoh H, Shimizu T, et al. Preoperative embolization of the common hepatic artery in preparation for radical pancreatectomy for pancreas body cancer. Hepatogastroenterology 2000;47(35):1447–1449
9. Naritaka Y, Shiozawa S, Shimakawa T, et al. Transradial approach for partial splenic embolization in patients with hypersplenism. Hepatogastroenterology 2007;54(78):1850–1853
10. Shah R, Mahour GH, Ford EG, Stanley P. Partial splenic embolization. An effective alternative to splenectomy for hypersplenism. Am Surg 1990;56(12):774–777
11. Bárcena R, Gil-Grande L, Moreno J, et al. Partial splenic embolization for the treatment of hypersplenism in liver transplanted patients with hepatitis C virus recurrence before peg-interferon plus ribavirin. Transplantation 2005;79(11): 1634–1635
12. Chikamori F, Kuniyoshi N, Kawashima T, Takase Y. Short-term portal hemodynamic effects of partial splenic embolization for hypersplenism. Hepatogastroenterology 2007;54(78): 1847–1849
13. Firat A, Boyvat F, Moray G, Aytekin C, Karakayali H, Haberal M. Comparison of two different percutaneous splenic artery interventions in the treatment of hypersplenism: preliminary report. Transplant Proc 2005;37(2): 1094–1098
14. Sakata K, Hirai K, Tanikawa K. A long-term investigation of transcatheter splenic arterial embolization for hypersplenism. Hepatogastroenterology 1996;43(7):309–318
15. Sockrider CS, Boykin KN, Green J, et al. Partial splenic embolization for hypersplenism before and after liver transplantation. Clin Transplant 2002;16(Suppl 7):59–61
16. Zhu K, Meng X, Li Z, et al. Partial splenic embolization using polyvinyl alcohol particles for hypersplenism in cirrhosis: a prospective randomized study. Eur J Radiol 2008;66(1):100–106
17. O'Halpin D, Legge D, MacErlean DP. Therapeutic arterial embolisation: report of five years' experience. Clin Radiol 1984;35(2):85–93
18. Basile A, Certo A, Ascenti G, Lamberto S, Cannella A, Medina JG. Interventional radiology in the preoperative management of stromal tumors causing intestinal bleeding. Radiol Med (Torino) 2003;106(4):376–381
19. Kurihara N, Kikuchi K, Tanabe M, et al. Partial resection of the second portion of the duodenum for gastrointestinal stromal tumor after effective transarterial embolization. Int J Clin Oncol 2005;10(6):433–437
20. Joyce DL, Hong K, Fishman EK, Wisell J, Pawlik TM. Multi-visceral resection of pancreatic VIPoma in a patient with sinistral portal hypertension. World J Surg Oncol 2008; 6:80
21. Lee EW, Laberge JM. Differential diagnosis of gastrointestinal bleeding. Tech Vasc Interv Radiol 2004;7(3):112–122
22. Goldstein HM, Medellin H, Ben-Menachem Y, Wallace S. Transcatheter arterial embolization in the management of bleeding in the cancer patient. Radiology 1975;115(3):603–608
23. Kickuth R, Rattunde H, Gschossmann J, Inderbitzin D, Ludwig K, Triller J. Acute lower gastrointestinal hemorrhage: minimally invasive management with microcatheter embolization. J Vasc Interv Radiol 2008;19(9):1289–1296, e2
24. Lee HJ, Shin JH, Yoon HK, et al. Transcatheter arterial embolization in gastric cancer patients with acute bleeding. Eur Radiol 2009;19(4):960–965
25. Seya T, Tanaka N, Yokoi K, Shinji S, Oaki Y, Tajiri T. Life-threatening bleeding from gastrointestinal stromal tumor of the stomach. J Nippon Med Sch 2008;75(5):306–311

26. Funaki B, Kostelic JK, Lorenz J, et al. Superselective microcoil embolization of colonic hemorrhage. AJR Am J Roentgenol 2001;177(4):829–836
27. Townsend CMBR, Evers BM, Mattox KL. Sabiston Textbook of Surgery. 18th ed. Philadelphia: Saunders; 2008:2100
28. Inoue H, Nakajo M, Miyazono N, et al. Successful therapeutic embolization of aldosteronoma using absolute ethanol. Radiat Med 1993;11(6):256–259
29. Inoue H, Nakajo M, Miyazono N, et al. Treatment of aldosteronoma with superselective intraarterial injection of absolute ethanol. Nippon Igaku Hoshasen Gakkai Zasshi 1994;54(2):154–162
30. Inoue H, Nakajo M, Miyazono N, Nishida H, Ueno K, Hokotate H. Transcatheter arterial ablation of aldosteronomas with high-concentration ethanol: preliminary and long-term results. AJR Am J Roentgenol 1997;168(5):1241–1245
31. Hokotate H, Inoue H, Baba Y, Tsuchimochi S, Nakajo M. Aldosteronomas: experience with superselective adrenal arterial embolization in 33 cases. Radiology 2003;227(2): 401–406
32. Baguet JP, Hammer L, Tremel F, Mangin L, Mallion JM. Metastatic phaeochromocytoma: risks of diagnostic needle puncture and treatment by arterial embolisation. J Hum Hypertens 2001;15(3):209–211
33. Horton JA, Hrabovsky E, Klingberg WG, Hostler JA, Jenkins JJ. Therapeutic embolization of a hyperfunctioning pheochromocytoma. AJR Am J Roentgenol 1983;140(5): 987–988
34. Hrabovsky EE, McLellan D, Horton JA, Klingberg WG. Catheter embolization: preparation of patient with pheochromocytoma. J Pediatr Surg 1982;17(6):849–850
35. Park JH, Kang KP, Lee SJ, Kim CH, Park TS, Baek HS. A case of a ruptured pheochromocytoma with an intratumoral aneurysm managed by coil embolization. Endocr J 2003; 50(6):653–656
36. Pua U, Wong DE. Transarterial embolisation of spontaneous adrenal pheochromocytoma rupture using polyvinyl alcohol particles. Singapore Med J 2008;49(5):e126–e130
37. Bunuan HD, Alltree M, Merendino KA. Gel foam embolization of a functioning pheochromocytoma. Am J Surg 1978;136(3):395–398
38. Inoue H, Nakajo M, Miyazono N, et al. A case with Cushing's syndrome treated with arterial ablation of adrenal gland by absolute ethanol. Radiat Med 1993; 11(6):221–223
39. Ueno K, Nakajo M, Miyazono N, et al. Transcatheter adrenal arterial embolization of cortisol-producing tumors. Two cases of Cushing's syndrome. Acta Radiol 1999;40(1):100–103
40. O'Keeffe FN, Carrasco CH, Charnsangavej C, Richli WR, Wallace S. Arterial embolization of adrenal tumors: results in nine cases. AJR Am J Roentgenol 1988;151(4):819–822
41. Blunt SB, Pirmohamed M, Chatterjee VK, Burrin JM, Allison DJ, Joplin GF. Use of adrenal arterial embolization in severe ACTH-dependent Cushing's syndrome. Postgrad Med J 1989;65(766):575–579
42. Bourlet P, Dumousset E, Nasser S, et al. Embolization of hepatic and adrenal metastasis to treat Cushing's syndrome associated with medullary thyroid carcinoma: a case report. Cardiovasc Intervent Radiol 2007;30(5):1052–1055
43. Townsend CM, Beauchamp RD, Evers BM, Mattox KL. Sabiston Textbook of Surgery. 18th ed. Philadelphia: Saunders; 2008:2100
44. Li SH, Huang CH, Ko SF, Chou FF, Huang SC. Extended survival in a patient with recurrent and metastatic adrenal cortical carcinoma by aggressive transarterial embolization—a case report. J Surg Oncol 2005;90(2):101–105
45. Momoi H, Shimahara Y, Terajima H, et al. Management of adrenal metastasis from hepatocellular carcinoma. Surg Today 2002;32(12):1035–1041
46. Park JS, Yoon DS, Kim KS, et al. What is the best treatment modality for adrenal metastasis from hepatocellular carcinoma? J Surg Oncol 2007;96(1):32–36
47. Hendrickson RJ, Katzman PJ, Queiroz R, Sitzmann JV, Koniaris LG. Management of massive retroperitoneal hemorrhage from an adrenal tumor. Endocr J 2001;48(6): 691–696
48. Nakajo M, Onohara S, Shinmura K, Fujiyoshi F, Nakajo M. Embolization for spontaneous retroperitoneal hemorrhage from adrenal myelolipoma. Radiat Med 2003;21(5):214–219
49. Yang PW, Wang WY, Yang CH, Chou CC, Yen DH, Chou J. Treatment of massive retroperitoneal hemorrhage from adrenal metastasis of hepatoma. J Chin Med Assoc 2007; 70(3):126–131
50. Fink IJ, Girton M, Doppman JL. Absolute ethanol injection of the adrenal artery: hypertensive reaction. Radiology 1985;154(2):357–358
51. Bono AV, Caresano A. The role of embolization in the treatment of kidney carcinoma. Eur Urol 1983;9(6):334–337
52. Zielinski H, Szmigielski S, Petrovich Z. Comparison of preoperative embolization followed by radical nephrectomy with radical nephrectomy alone for renal cell carcinoma. Am J Clin Oncol 2000;23(1):6–12
53. Wallace S, Chuang VP, Swanson D, et al. Embolization of renal carcinoma. Radiology 1981;138(3):563–570
54. Serafin Z, Karolkiewicz M, Strzeniewski P, Lasek W, Bryczkowski M, Wolski Z. Palliative percutaneous kidney embolization with enbucrilate in patients with renal cell carcinoma: safety and symptom control. Med Sci Monit 2007;13(Suppl 1):98–104
55. Lammer J, Justich E, Schreyer H, Pettek R. Complications of renal tumor embolization. Cardiovasc Intervent Radiol 1985; 8(1):31–35
56. Roy C, Tuchmann C, Morel M, Saussine C, Jacqmin D, Tongio J. Is there still a place for angiography in the management of renal mass lesions? Eur Radiol 1999;9(2): 329–335
57. Munro NP, Woodhams S, Nawrocki JD, Fletcher MS, Thomas PJ. The role of transarterial embolization in the treatment of renal cell carcinoma. [see comment] BJU Int 2003;92(3):240–244