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REVIEW ARTICLE

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Microballoon-related interventions in various endovascular treatments of body trunk lesions

Tomohiro Matsumoto[a,b]*, Kosuke Tomita[a], Satoshi Suda[a], Kazunobu Hashida[a], Shunto Maegawa[a,b], Toshihiko Hayashi[a], Takuji Yamagami[a,c], Tetsuya Suzuki[b] and Terumitsu Hasebe[a,b]*

[a]Department of Radiology, Tokai University Hachioji Hospital, Tokai University School of Medicine, Tokyo, Japan; [b]Center for Science of Environment, Resources and Energy, Graduate School of Science and Technology, Keio University, Kanagawa, Japan; [c]Department of Radiology, Kochi University, Kochi Medical School, Kochi, Japan

ABSTRACT
Occlusion balloon catheters of 5.2- or 6-French have been used for a few decades in various endovascular treatments of body trunk vascular lesions. However, these catheters may be difficult to place in cases of excessive vessel tortuosity, small vessels, and anatomic complexity. Recently, the introduction of the double lumen microballoon catheters for body trunk vascular lesions has allowed operators to advance them into more distal, smaller, and more tortuous vessels. Since the launch of the first generation microballoon catheters onto the market in Japan in 2011, the microballoon catheters have evolved and are now generally available for clinical use. The purpose of this article is to review the evolution and current clinical applications of the microballoon catheters in the field of interventional radiology.

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Microballoon catheter; flow control; occlusion microballoon; interventional radiology

Introduction

Occlusion balloon catheters of 5.2-French (Fr) with a 9-mm diameter or of 6-Fr with a 20-mm diameter have been used for a few decades in various types of endovascular treatment of body trunk vascular lesions. In balloon-occluded retrograde transvenous obliteration (B-RTO) for gastric varices, it has been normal practice to advance the balloon catheter through an 8-Fr sheath introducer into the gastrorenal shunt in a retrograde fashion [1]; likewise in transcatheter coil embolization for pulmonary arteriovenous malformations (PAVMs), especially high-flow type PAVMs [2,3], and *n*-butyl cyanoacrylate (NBCA) embolization in relation to the intrahepatic arterioportal shunt [4]. Balloon catheters have been used for flow control in embolization and for preventing procedure-related complications such as systemic migration of embolic materials. However, these balloon catheters may be difficult to place in cases of excessive vessel tortuosity, small vessels, or anatomic complexity. Recently, the introduction of double lumen microballoon catheters for treatment of body trunk vascular lesions has allowed operators to advance them into more distal, smaller, and tortuous vessels following the launch of the first generation of microballoon catheters (Attendant LP and Attendant 8 mm; Terumo, Tokyo, Japan) onto the market in Japan in 2011. Since then, the microballoon catheters have evolved and they are now generally available for various clinical uses. It is very important for the operator to become familiar with the features of microballoon catheters and to understand their clinical applications. The purpose of this article is to review the evolution and current clinical applications of microballoon catheters in the field of interventional radiology.

Double lumen microballoon catheters

First generation microballoon catheters *(Table 1)*

The first generation of microballoon catheters (Attendant LP and Attendant 8 mm; Terumo, Tokyo, Japan) was launched onto the market in Japan in 2011. The measured shaft diameters of Attendant LP and Attendant 8 mm are 3.0-Fr at the proximal part of the microballoon and 2.2-Fr at the catheter tip. The diameter of the guidewire lumen is 0.017 inch. A compliant microballoon made of polyurethane resin is 14 mm in length and 4.5 mm in inflation diameter

CONTACT Terumitsu Hasebe hasebe@tokai-u.jp Department of Radiology, Tokai University Hachioji Hospital, Tokai University School of Medicine, 1838 Ishikawa-machi, Hachioji, Tokyo 192-0032, Japan
*Both authors contributed equally to this work.

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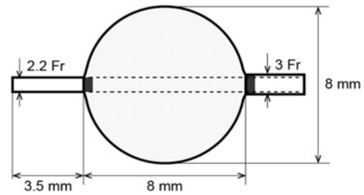
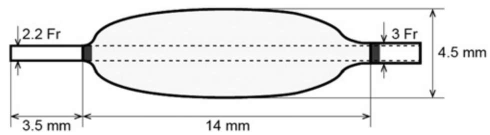
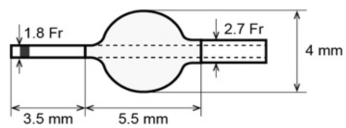
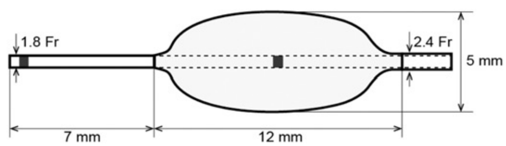
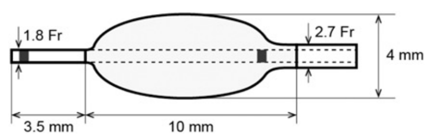
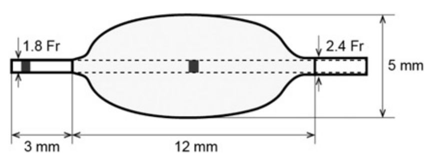
Table 1. Microballoon catheters.

Generation	Microballoon catheters	Microballoon segment	Key characteristics
First	Attendant 8mm (Terumo, Tokyo, Japan)		5-Fr guiding catheter compatible Purge hole at the tip
	Attendant LP (Terumo, Tokyo, Japan)		5-Fr guiding catheter compatible Purge hole at the tip
Second	Attendant delta (Terumo, Tokyo, Japan)		1.8-Fr tip microballoon catheter 4-Fr angiographic catheter compatible
	Logos (Piolax, Yokohama, Japan)		1.8-Fr tip microballoon catheter 4-Fr angiographic catheter compatible
Third	Attendant Nexus/Occlusafe (Terumo, Tokyo, Japan/Terumo Europe N.V., Leuven, Belgium)		1.8-Fr tip microballoon short tip catheter 4-Fr angiographic catheter compatible
	Logos ST (Piolax, Yokohama, Japan)		1.8-Fr tip microballoon short tip catheter 4-Fr angiographic catheter compatible

Fr: French.

with an injection volume of 0.2 ml of 150-mgI contrast agent (recommended limit volume) in Attendant LP, and is 8 mm in length and 8 mm in inflation diameter with an injection volume of 0.3 ml of 150-mgI contrast agent (recommended limit volume) in Attendant 8 mm. These microballoon catheters are compatible with a 5-Fr guiding catheter and have a purge hole at the tip. With the tip of the balloon catheter submerged in saline, all the air can be allowed to escape from the purge hole by adopting a slow injection technique.

Second generation microballoon catheters (*Table 1*)

Second generation microballoon catheters, launched in 2013, were developed to improve on the first generation microballoon catheter shaft to make it more flexible and thinner. There are two types of second generation microballoon catheters: Attendant Delta (Terumo, Tokyo, Japan) and Logos (Piolax, Yokohama, Japan) [5]. The diameter of the Attendant Delta is “2.7-Fr”; however, this is not the diameter of the actual microballoon catheter tip but the diameter of the more proximal part of the microballoon. The measured shaft diameter of Attendant Delta is tapered from 1.98-Fr at the distal part of the microballoon to 1.8-Fr at the catheter tip, and a radiopaque marker is located just proximal to the catheter tip. The diameter of the guidewire lumen is 0.017 inch. The compliant microballoon made of polyurethane resin is 5.5 mm in length and 4 mm in inflation diameter with an injection volume of 0.1 ml of 150-mgI contrast agent (recommended limit volume). Logos has a non-tapered 1.8-Fr catheter tip at the distal part of the microballoon. The diameter of the guidewire lumen is 0.018 inch. A compliant microballoon made of polyurethane resin is 12 mm in length and 3–5 mm in inflation diameter range, with a volume of <0.21 ml of 150-mgI contrast agent (recommended limit volume). The distal side of each catheter surface is coated with hydrophilic polymer. In addition, of particular note is the fact that both types of microballoon catheters are compatible with the diagnostic 4-Fr catheter. These comprise double lumen microballoon catheters; therefore, the proximal side consists of two ports: one is the microguidewire lumen and the other is the microballoon lumen.

Third generation microballoon catheters *(Table 1)*

Third generation microballoon catheters include two types: Attendant Nexus (in Japan)/Occlusafe (in Europe) (Terumo, Tokyo, Japan/Terumo Europe N.V., Leuven, Belgium), and Logos ST (Piolax, Yokohama, Japan) [6]. Attendant Nexus has the same characteristics as Attendant Delta except for microballoon length, which is 10 mm, and microballoon location, which is 3.5 mm from the microballoon catheter tip. Logos ST has the same characteristics as Logos except for microballoon location, which is 3 mm from the microballoon catheter tip.

As stated above, since the appearance of first generation microballoon catheters in the market, microballoon catheters have evolved and are now available for various clinical uses.

Clinical applications of microballoon catheters

Balloon-occluded transarterial chemoembolization (B-TACE)

Transarterial chemoembolization (TACE) for hepatocellular carcinoma (HCC) has been performed for more than 30 years [7]. Now, TACE is the most frequently used treatment for unresectable HCC, with proven improvement in survival in selected patients [8,9]. Conventional TACE (C-TACE) performed using Lipiodol (LPD) (Andre Guerbet, Aulnaysous-Bois, France) emulsion mixed with anticancer drugs followed by porous gelatin sponge particles, has been in mainstream use in Japan. Dense LPD accumulation after C-TACE is one of the significant prognostic factors affecting local recurrence [10,11]. Recently, Irie et al. noted that balloon-occluded TACE (B-TACE) using a first generation microballoon catheter (Attendant LP) induced dense LPD accumulation in HCC nodules in most treatments in which balloon-occluded arterial stump pressure (BOASP) was 64 mmHg or less [12]. B-TACE has rapidly become popular in Japan over the past few years since the emergence of reports that B-TACE has the potential to improve cancer nodule control locally, compared with C-TACE [13,14], and second and third generation microballoon catheters have come to the fore. In B-TACE, a new platinum-based anticancer agent, miriplatin hydrate (MPT) (Dainippon Sumitomo Pharma Co., Ltd., Osaka, Japan), which is easily suspended in Lipiodol, has been widely used as an anticancer drug [5,13–18]. MPT-LPD suspension deposited within HCC nodules will gradually release active platinum compounds into tumor tissues, thereby exerting prolonged antitumor effects; however, it is minimally transferred into the systemic circulation.

The B-TACE procedure was performed as follows: The microballoon was inflated to a diameter 5–10% larger than that of the occluded artery on DSA as described Irie et al. [12] (Figures 1(B,C)). LPD suspension infusion was continued under balloon occlusion until the HCC nodule was filled with LPD suspension or the portal venous branches were beginning to be filled with LPD suspension (Figures 1(A–D)). 1-mm gelatin sponge particles (Nippon Kayaku, Tokyo, Japan) were injected to obstruct the tumor-feeding branch under microballoon inflation [5]. As described, the double lumen microballoon catheters are always needed for B-TACE because LPD suspension and gelatin sponge particles must be injected into the guidewire lumen.

There may be some limitations to B-TACE. As a specific complication of B-TACE, aneurysmal dilatation (6.5%) due to overinflation of the microballoon catheter was confirmed in our previous study [5]. We profited from a helpful learning curve developed from the use of the microballoon catheter and found that careful inflation of the microballoon to a suitable size to occlude the target vessel under fluoroscopy guidance was important to avoid aneurysmal dilatation due to overinflation of the microballoon. There may be limitations to B-TACE. As treatment outcome of B-TACE, Matsumoto et al. reported that B-TACE at the lobar hepatic artery should be avoided for performing effective B-TACE and B-TACE at A1, 4, 8 and anterior segmental hepatic arteries may become less effective than at the other segmental or subsegmental hepatic arteries [6]. The results may explain that blood inflow through the communicating artery in the hilum, which is an anastomosis between the right and left hepatic arteries and originates mainly from A4 on the left side and from the anterior segmental hepatic artery or the right hepatic artery on

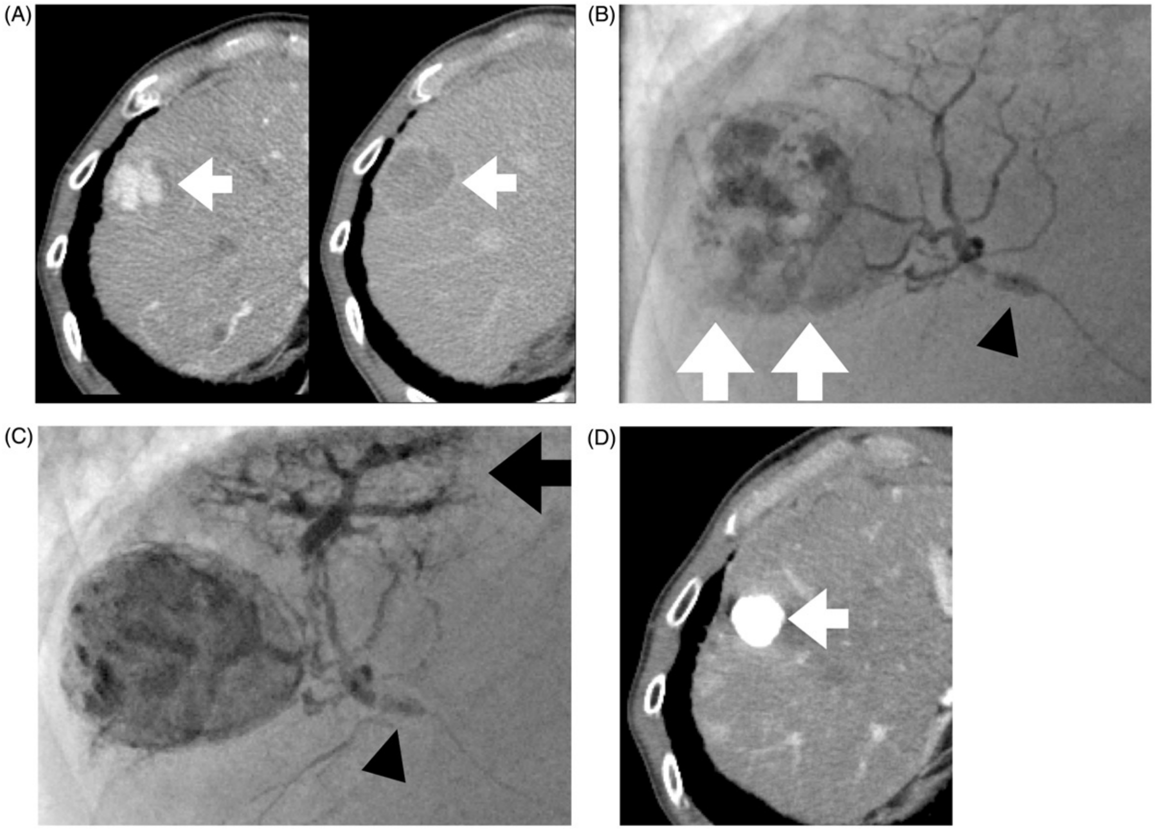


Figure 1. Balloon-occluded transarterial chemoembolization (B-TACE) for hepatocellular carcinoma (HCC) nodule in the anterior superior subsegment of the liver. (A) The nodule at the anterior superior subsegment of the liver shows hypervascularity on the arterial late phase image of CT and wash out on the delayed phase of CT. (B) Fluoroscopic image shows Lipiodol (LPD) emulsion mixed with miriplatin is accumulated in the HCC nodule (arrows) at the beginning of the injection under microballoon occlusion of the anterior superior subsegment artery (arrowhead). (C) Fluoroscopic image shows the portal vein (arrow) markedly demonstrated in the whole embolized area at the end of the injection under microballoon occlusion of the anterior superior subsegment artery (arrowhead). (D) Contrast medium-enhanced CT scan obtained 14 months after B-TACE shows dense LPD accumulation in the tumor (arrow) without local recurrence.

the right side [19], blocks decrease of the BOASP. Kawamura et al. reported the predictive factors were presence of portal vein visualization during B-TACE, tumor on the subcapsular portion and subsegmental artery embolization [17].

However, there has not been enough high quality evidence forthcoming to confirm the efficacy of B-TACE. Therefore, further prospective studies are needed to remedy this.

Coil embolization using microballoon catheters in parent vessels

Microballoon catheters create the benefit of flow control even in tortuous vessels, resulting in tight packing, which is more compact in parent vessel embolization (Figures 2(A,B)) and the avoidance of systemic migration of embolic materials [20,21]. For this clinical situation, both single and double lumen microballoon catheters can be used. However, we must advance another microcatheter into the target vessel for coil embolization in using a single lumen microballoon catheter for flow control.

Coil embolization using the microballoon catheter has some limitations; currently used microballoon catheters disable complete flow control in large vessels with diameters of $\geq$8 mm. Furthermore, microballoon catheters in current use are not always compatible with all microcoils because the diameter of the guidewire lumen is 0.017 or 0.018 inch. Therefore, development of a microballoon catheter with a larger microballoon or inner diameter may be desirable to circumvent this problem.

Liquid embolization using microballoon catheters

Liquid embolic agents include absolute ethanol, *n*-butyl-2-cyanoacrylate (NBCA) (Histoacryl;

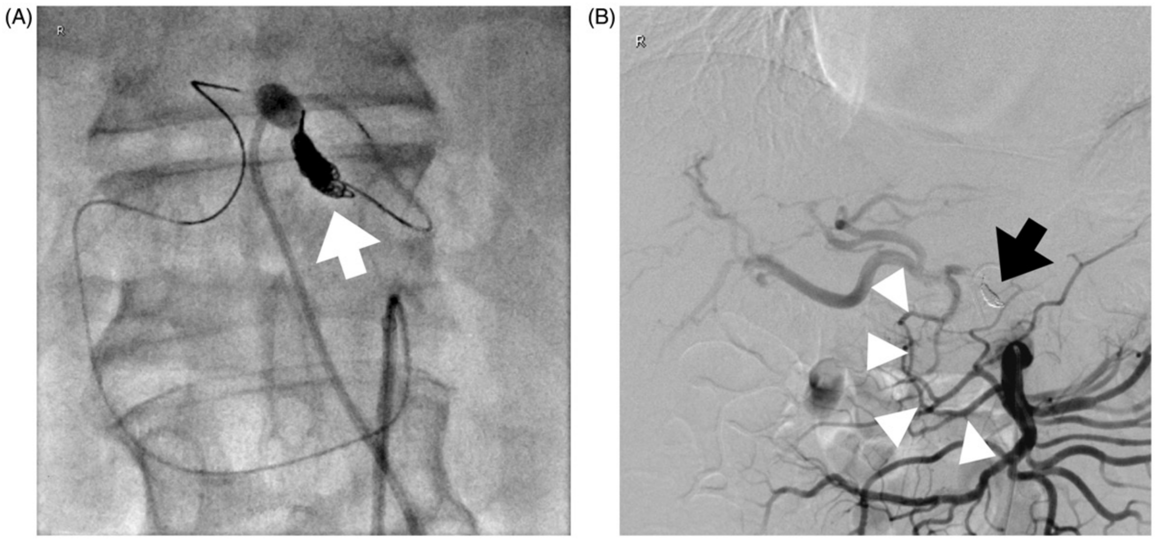


Figure 2. Preoperative coil embolization of the common hepatic artery (CHA) under distal microballoon inflation in a man in his 50 s with pancreatic adenocarcinoma at the pancreatic body. (A) Radiograph during coil embolization shows a tight widthwise frame. The microcatheter is inserted into the CHA via the celiac artery under microballoon inflation (white arrow). Note that a third generation microballoon catheter can be inserted into the distal CHA via the pancreatico-duodenal arcades from the superior mesenteric artery (SMA). (B) Superior mesenteric arteriography after coil embolization (arrow) shows blood flow from the SMA to the proper hepatic artery via the pancreatico-duodenal arcades (white arrowheads).

B. Braun, Aesculap, Tuttlingen, Germany) and non--adhesive liquid embolic agents (Onyx; Covidien, Irvine, CA, USA/Medtronic, Dublin, Ireland).

Ethanol causes tissue infarction by inducing denaturation of proteins with resultant acute thrombosis and subsequent fibrosis. The use of an occlusion balloon to prevent reflux in cases in which nontarget embolization is unlikely, such as in the kidney, has been recommended in ethanol embolization [22,23]. A microballoon catheter in current use can be selectively advanced into the branch of a renal artery because the catheter shaft is more flexible and thinner. Therefore, dedicated use of a microballoon catheter may be appropriate for ethanol embolization of renal angiomyolipoma (Figure 3(A)) to avoid reflux into the proximal renal artery or aorta (Figures 3(B–D)).

NBCA is an effective adhesive agent used for the management of small-arterial disorders when microcatheters cannot be cannulated. However, NBCA has been associated with various problems including proximal embolization, distal migration, fragmentation, reflux, catheter adhesion, and glue particle attachment during catheter pullback. Hamaguchi et al. have developed a microballoon-occluded NBCA embolization (B-glue) technique to overcome these problems [24]. The use of the B-glue technique may allow efficient control of NBCA delivery for a longer injection time without reflux. On the other hand, this technique may pose a heightened risk of microballoon catheter adhesion because microballoon catheters have a larger adhesion area with NBCA than microcatheters. This is a problem that needs to be taken into account.

Onyx is composed of ethylene vinyl alcohol (EVHO) copolymer dissolved in dimethyl sulfoxide (DMSO) mixed with micronized tantalum powder for radio-opacity. Microballoon catheters in current use must not be employed because they are not DMSO-compatible.

The double lumen microballoon catheters are always needed because ethanol or NBCA must be injected into the guidewire lumen.

Balloon-assisted technique for visceral artery aneurysms using microballoon catheters

Moret et al. initially described the balloon-assisted technique for wide neck intracranial aneurysms [25]. The technique consists of temporary balloon-inflation in front of the aneurysm neck during coil placement. The indication for endovascular treatment by using the technique has been increasingly extended to cases with an unfavorable anatomy. According to two large multicenter prospective series using the balloon-assisted technique in unruptured (Analysis of Treatment by Endovascular approach of Nonruptured Aneurysms [ATENA]) and ruptured (Clinical and Anatomical Results in the Treatment of Ruptured

Figure 3. Ethanol embolization under microballoon inflation for left renal angiomyolipoma (AML) in a woman in her 80 s. (A) CT image shows the 41-mm left renal AML (white arrow). (B) Left renal angiography shows that the AML is vascularized by two branches of the left renal artery (white arrowheads). (C) Ethanol–Lipiodol (LPD) (the ratio of ethanol to LPD was 3 to 1) for the AML embolization is injected under microballoon inflation (arrows) into each feeding branch of the renal artery by selectively advancing a third generation microballoon catheter. Total volume of ethanol–LPD is 10 ml (5 and 5 ml into each branch, respectively). (D) Post embolization angiography shows complete devascularization (white arrow).

Intracranial Aneurysms [CLARITY]) aneurysms, the balloon-assisted technique is as safe as the standard treatment with coils [26,27]. The technique using microballoon catheters in current use can be applied to visceral artery aneurysms. For this clinical situation, both single and double lumen microballoon catheters can be used. In particular, the technique should be used for embolization of wide-neck renal artery aneurysms (Figure 4(A)) because the parent artery must be preserved due to lack of collateral flow to the renal parenchyma (Figures 4(B,C)). However, development of a double lumen microballoon catheter with a longer microballoon may be desirable for this purpose because currently used microballoon catheters are up to 14 mm in length.

B-RTO using microballoon catheters

B-RTO has been widely accepted as an effective treatment for gastric varices. In this method, there are two main situations in which usage of microballoon catheters is useful. One is gastric varices without the gastrorenal shunt in which microballoon catheters may be applicable for B-RTO through the pericardiacophrenic or inferior phrenic vein [28]; Attendant 8 mm may be suitable for B-RTO through the

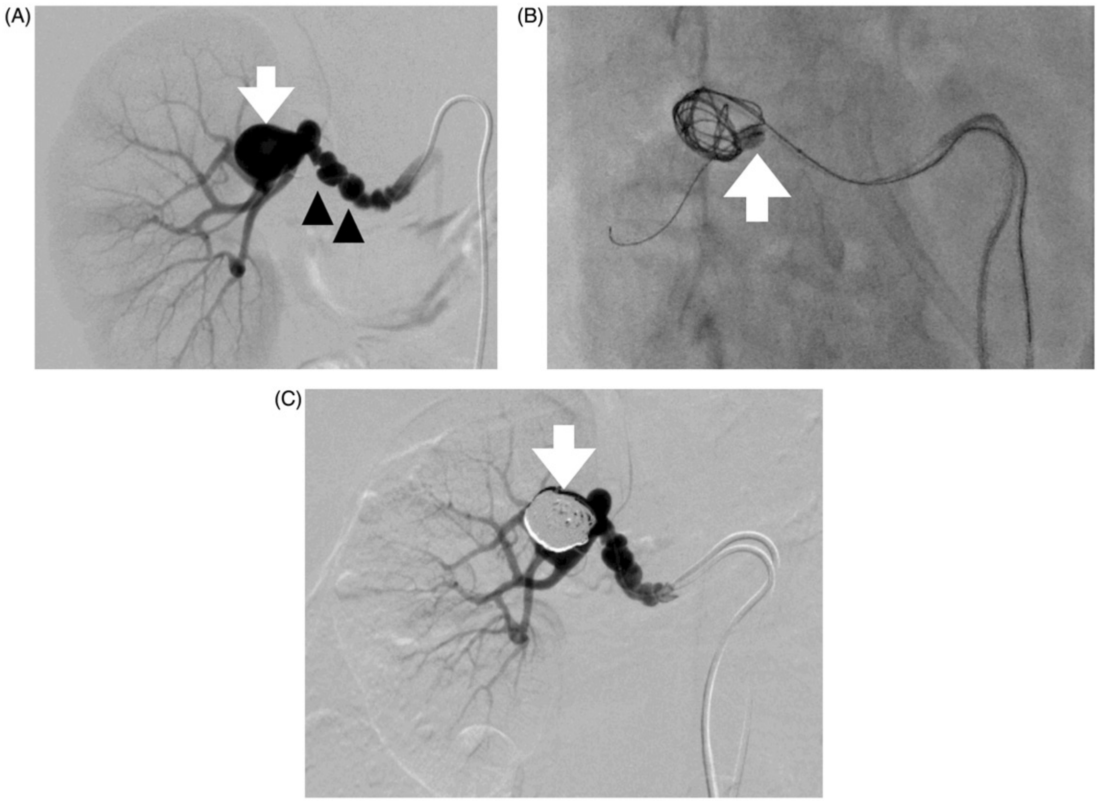


Figure 4. Balloon-assisted technique for renal artery aneurysm (RAA) with fibromuscular dysplasia (FMD) in a woman in her 60 s. (A) Right renal arteriography reveals 20 mm right main RAA (white arrow) associated with a radiographic appearance of a "string of beads (arrowheads)," which characterizes FMD. (B) A first generation microballoon catheter through a 5-Fr guiding catheter is placed along the aneurysm neck to protect branch arteries during the embolization procedure (white arrow). The RAA is embolized with detachable coils. (C) Completion angiography shows exclusion of the aneurysm by means of coil embolization (arrowhead). Flow to the right kidney has been preserved.

pericardiacophrenic or left inferior phrenic vein. Another is that gastric varix with the gastrorenal shunt and communication between gastric varices and systemic veins are also developing, whereupon the double balloon technique using a 5.2- or 6-Fr balloon catheter and 3- or 1.8-Fr microballoon catheter may be performed in B-RTO [28,29]. The double lumen microballoon catheters are acceptable for B-RTO because an embolic agent such as ethanolamine oleate iopamidole can be injected into guidewire lumen. Paralleling the development of microballoon catheters, opportunities to use this device would increase in the B-RTO procedure and microballoon catheters may produce a higher success rate of B-RTO [30].

Conclusions

Microballoon catheters are very versatile devices that allow interventional radiologists to treat safely and effectively various conditions in body trunk lesions including challenging vascular lesions such as those involving tortuous or small vessels. Becoming familiar with the features of the microballoon catheters, combined with meticulous technique to adapt the microballoon catheters to various clinical applications, are key points to ensure successful endovascular therapy.

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Declaration of interest

The authors report no conflict of interest.

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