Abdominal Radiology (2019) 44:2699–2707
https://doi.org/10.1007/s00261-019-02033-z

INTERVENTIONAL RADIOLOGY

Coexistence of "extra-gastric afferent–efferent direct connection" with gastric varices: CT evaluation and clinical significance

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Published online: 27 April 2019

Abstract

Purpose To evaluate the prevalence of extra-gastric direct connection between afferent and efferent veins of gastric varices (GVs) (i.e., EAEDC) and its clinical significance during balloon-occluded retrograde transvenous obliteration (BRTO).

Materials and methods 57 patients who underwent BRTO for GVs obliteration were retrospectively enrolled in this study. Pre-procedural CT images were reviewed for the presence of EAEDC. Patients were categorized into group A (patients with EAEDC) and group B (Patients with no detectable EAEDC). Intraprocedural images were reviewed to see if EAEDCs could be seen and if additional techniques were used to preserve or occlude them. Post-procedural CT images were reviewed for GVs obliteration, portal/splenic vein thrombosis, EAEDC patency, and ascites exacerbation. Post-procedural esophageal varices aggravation was evaluated by upper endoscopy.

Results 39 EAEDCs were identified in CT images of 35 patients (i.e., group A = 61.4%). Among them, only 20 EAEDCs were visualized during BRTO. In the remaining 22 patients, EAEDC was not identified in CT images or during BRTO (i.e., group B = 38.6%). There was no statistically significant difference between *group A* and *B* regarding post-BRTO GVs obliteration and portal/splenic vein thrombosis. Use of additional techniques to preserve EAEDC patency had significantly reduced the incidence of ascites and esophageal varices exacerbation ($p = 0.036$ and 0.028, respectively). In patients with EAEDC diameter ≥ 5 mm, EAEDC preservation or obliteration by coils or balloon had significantly reduced the injected sclerosant volume ($p = 0.003$).

Conclusion CT is very useful for EAEDC detection. EAEDC preservation may decrease the incidence of post-BRTO ascites and esophageal varices exacerbation.

Keywords BRTO · Three-dimensional CT · Gastric varices · Extra-gastric afferent–efferent direct connection

Introduction

Gastric varices (GVs) are one of many portosystemic collateral routes developed due to portal hypertension to decompress portal pressure [1]. The blood is shifted from the portal circulation toward the GVs through feeding veins (left gastric, posterior gastric, short gastric, and/or gastroepiploic veins). Then, blood is drained into the systemic circulation by draining veins via the gastroesophageal venous system, gastrophrenic venous system, or both [2]. Balloon-occluded retrograde transvenous obliteration (BRTO) is an interventional radiological procedure introduced by Kanagawa et al. [3] which was then widely accepted as an effective and safe treatment option for isolated GVs [4–8]. The principle of BRTO is occlusion of the draining vein with a balloon catheter followed by retrograde filling of the entire GVs with a sclerosing agent [3]. Contrast-enhanced CT is routinely performed before BRTO to evaluate GVs afferent (feeding) veins and efferent (draining) veins. Kiyosue et al. [9] have classified the afferent venous anatomy of GVs into 3 types: Type 1 has only one afferent vein; Type 2 has two or more afferent veins; and Type 3 has a direct connection between afferent and efferent veins away from GVs. In this article, we used the expression "extra-gastric afferent-efferent direct connection (EAEDC)" for this direct connection in type 3 GVs. Detection of this EAEDC is essential due to the potential theoretical risk of sclerosing agent reflux into the portal

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venous system through it, resulting in incomplete GVs filling with sclerosant agent and/or portal venous thrombosis [10, 11]. Moreover, esophageal varices and ascites aggravation have been reported to develop after BRTO, mostly due to the sudden increase in portal pressure as a result of occlusion of the portosystemic shunt [12–15]. So, preservation of the EAEDC patency may have a protective effect against these post-BRTO portal hypertensive complications.

The purpose of our study was to evaluate the prevalence of this EAEDC by CT and its implication on BRTO procedure and outcomes.

Materials and methods

A total of 57 patients with GVs, who underwent BRTO in our department between October 2005 and October 2017, were retrospectively enrolled in this study. The indication for BRTO was either bleeding GVs or endoscopic signs of high-risk GVs for bleeding (i.e., F2 = nodular or F3 = tumorous varices form or had a red spot sign) [16, 17]. Two radiologists with 8 and 20 years of experience reviewed the pre-BRTO CT images, BRTO technique images, and post-BRTO CT images with consensus. Patients' baseline characteristics are summarized in Table 1.

CT technique and evaluation parameters

Pre- and post-BRTO CT images were acquired with a 32- or 64-MDCT scanner (Toshiba Medical Systems, Tokyo, Japan) with 120 kVp, 200–250 mA, 32 mm beam collimation, 0.8 pitch, 0.5 s rotation time, 27 mm table speed per rotation, and 1 mm slice thickness with 1 mm reconstruction interval. Arterial, portal, and equilibrium phases were acquired at 40, 70, and 150 s, respectively, after bolus injection of contrast medium (Iopamidol 370, Schering Japan; 1.7 ml/kg, 150 ml maximum volume) at a rate of 3 ml per second. For the pre-contrast, arterial, and equilibrium phases, the scan range was from 2 to 3 cm above the apex of the diaphragm to below the left renal vein, and was from the lung apex to the ischial tuberosity for the portal phase.

A Synapse Vincent V.5 (FUJIFILM Co., Japan) workstation was used to generate volume rendering (VR) images from the axial portal phase images. VR images (Fig. 1) were obtained by manual selection of the GVs and each afferent and efferent vein to obtain multiple and separate color-coded VR images. After that, these VR images were added to each other alternatively and collectively.

Pre-BRTO CT images were retrospectively evaluated for EAEDC presence, ascites grade, and portal/splenic vein thrombosis. Based on the presence of EAEDC, patients were classified into *group A* (patients in whom EAEDC was identified on CT) and *Group B* (patients in whom EAEDC was not identified on CT). Ascites grading was as follows: G0: no ascites, G1: minimal to mild ascites, G2: moderate ascites, and G3: marked ascites.

Table 1 Baseline characteristics of the total 57 patients and both study groups

	Total $n=57$	Group A $n=35$	Group B $n=22$	p value
Age (years)	66.8 ± 12.3	67.1 ± 11.6	66.4 ± 13.6	0.8
Sex				0.06
Male	33 (57.9)	24 (68.6)	9 (40.9)	
Female	24 (42.1)	11 (31.4)	13 (59.1)	
HCC	18 (31.6)	12 (34.3)	6 (27.3)	0.8
Bleeding GVs	8 (14)	6 (17.1)	2 (9.1)	0.5
Child–Pugh				0.7
A	40 (70.2)	25 (71.4)	15 (68.2)	
B	16 (28.1)	9 (25.7)	7 (31.8)	
C	1 (1.8)	1 (2.9)	0 (0)	
Disease				0.4
HCV/HBV	22 (38.6)	13 (37.1)	9 (40.9)	
Alcoholic	17 (29.8)	13 (37.1)	4 (18.2)	
NASH	5 (8.8)	3 (8.6)	2 (9.1)	
Cryptogenic	5 (8.8)	3 (8.6)	2 (9.1)	
Others	8 (14)	3 (8.6)	5 (22.7)	
Ascites				0.9
No	36 (63.2)	22 (62.9)	14 (63.6)	
Minimal-mild	19 (33.3)	12 (34.3)	7 (31.8)	
Moderate	2 (3.5)	1 (2.9)	1 (4.5)	
Co-existing Es.V.	40 (70.2)	24 (68.6)	16 (72.7)	0.8
Pre-PVT	6 (10.5)	5 (14.3)	1 (4.5)	0.4

Values between parentheses are in percentage of column value

HCC hepatocellular carcinoma, *HCV/HBV* hepatitis C or B virus, *Es.V.* esophageal varices, *NASH* non-alcoholic steatohepatitis, *Pre-PVT* pre-existing partial portal vein thrombosis

For description purpose and for correlation with management, EAEDCs were categorized according to their diameter and connection site into four types (Fig. 2): *Type I* small EAEDC connected to the proximal half of the draining vein (i.e., axial diameter < 5 mm measured at the site of connection between the afferent and efferent veins); *Type II* large EAEDC connected to the proximal half of the draining vein (i.e., axial diameter ≥ 5 mm); *Type III* small EAEDC connected to the distal half of the draining vein; and *Type IV* large EAEDC connected to the distal half of the draining vein.

CT images obtained 1 month after BRTO were retrospectively evaluated for GVs thrombosis, portal/splenic vein thrombosis, EAEDC patency, and ascites exacerbation. Complete GV thrombosis was defined as complete disappearance of contrast enhancement of the submucosal GVs.

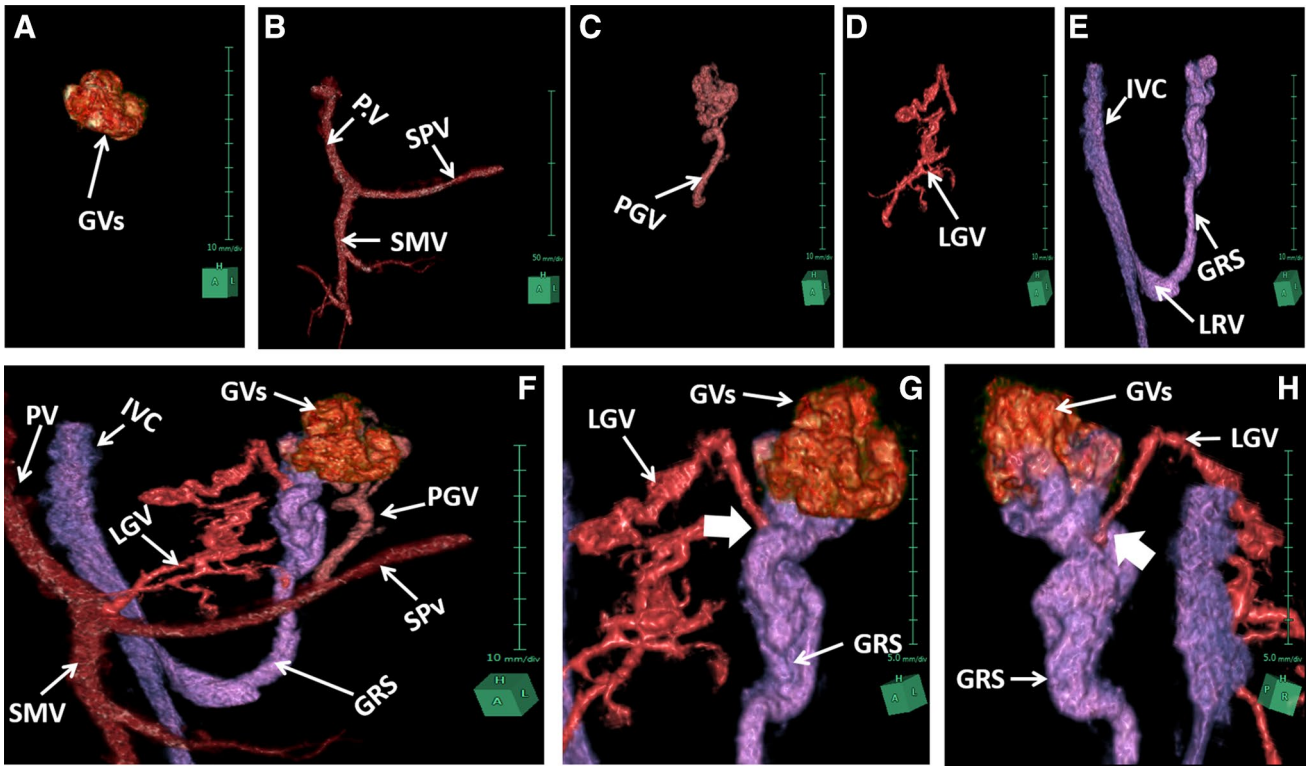

Fig. 1 Steps of volume rendering 3D images generation. **a** A color-coded separate image of the gastric varices (GVs). **b** A color-coded separate image of the splenic vein (SPV), superior mesenteric vein (SMV), and portal vein (P.V). **c** A color-coded separate image of the posterior gastric vein (PGV). **d** A color-coded separate image of the left gastric vein (LGV). **e** A color-coded separate image of the gastrorenal shunt (GRS), left renal vein (LRV), and inferior vena cava (IVC). All previous images were made by the manual selection of the desired vein in axial or coronal portal phase images. **f** A final volume rendering (VR) image made by collecting all previous images with each other shows the whole anatomy of the GVs. **g** An anterior oblique VR image of LGV, GRS, and GVs made by adding (**a**+**d**+**e**) images shows the site of the direct connection between LGV and GRS away from GVs (solid white arrow = EAEDC). **h** The same image as (**g**) but from oblique lateral view

BRTO-related portal/splenic vein thrombosis was defined as appearance of a newly formed thrombus within the portal/splenic vein or marked increase in size of a pre-existing partial thrombus. Based on EAEDC patency in post-BRTO CT images, group A patients were further subdivided into two subgroups: (a) *obliterated EAEDC subgroup* and (b) *patent EAEDC subgroup* (at least one EADC remained patent in patients with multiple EAEDCs).

Ascites exacerbation was defined as any increase in ascites grade compared to the baseline grade before BRTO.

BRTO technique and evaluation parameters

BRTO was performed by using a coaxial balloon catheter system (Medikit, Miyazaki, Japan), formed of an L-shaped or hook-shaped 9F guiding balloon catheter (balloon diameter up to 20 mm) and a 5F balloon catheter (balloon diameter up to 10 mm) [18]. After successful advancement of the 9F/5F coaxial catheters into the draining vein (i.e., gastrorenal or gastrocaval shunt), balloon-occluded venography (BOV) was performed with approximately 8 ml of liquid contrast medium (Iopamidol 370, Schering Japan) in all patients. Additional CO_2 BOV was done in 11 cases. In case of collateral draining veins visualization during BOV, the 5F balloon catheter was advanced as far as possible in the shunt beyond the collateral draining veins. Coil embolization of the collateral draining veins was performed when the 5F balloon catheter could not be advanced beyond them. A microcatheter (1.9F Excelsior 1018; Boston Scientific, Tokyo, Japan) with a 0.014-inch micro-guide wire (Chikai 14; ASAHI, Tokyo, Japan) was then advanced within or as near as possible to GVs for sclerosing agent injection. The routinely used sclerosing agent during BRTO in our institution was 5% ethanolamine oleate/iopamidol (EOI) which consisted of a mixture of 10% ethanolamine oleate (Oldamin, Grelan Pharmaceutical) and the same volume of contrast medium (Iopamidol 370, Schering Japan). Intravenous administration of 4000 units of human haptoglobin (Green Cross) was started prior to EOI injection to prevent renal damage [19]. Then, as much blood and EOI mixture as possible was aspirated via the microcatheter and balloon catheters after 40–60 min. In some patients, temporary balloon

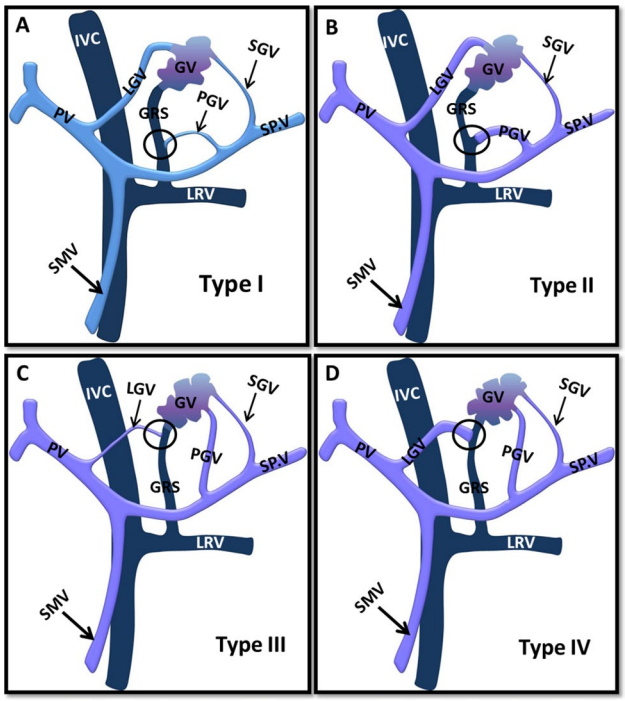

Fig. 2 Schematic drawing of EAEDC classification. **a** Schematic drawing shows *type I EAEDC* (black hollow circle), i.e., a small-sized (< 5 mm) connection between posterior gastric vein (PGV) and proximal half of the gastrorenal shunt (GRS). **b** Schematic drawing shows *type II EAEDC* (black hollow circle), i.e., a large-sized (≥ 5 mm) connection between PGV and the proximal half of GRS. **c** Schematic drawing shows *type III EAEDC* (black hollow circle), i.e., a small-sized (< 5 mm) connection between left gastric vein (LGV) and the distal half of GRS. **d** Schematic drawing shows *type IV EAEDC* (black hollow circle), i.e., a large-sized (≥ 5 mm) connection between LGV and the distal half of GRS. (*PV* portal vein, *SMV* superior mesenteric vein, *IVC* inferior vena cava, *LRV* left renal vein, *SP.V* splenic vein, *SGV* short gastric vein)

occlusion of the splenic artery was done in an attempt to reduce blood flow to the GVs during EOI injection [20].

We retrospectively reviewed BRTO images for EAEDC visualization during BOV and for additional techniques used for EAEDC preservation or obliteration. Additional techniques had been used for EAEDC management during BRTO in 13 patients (14 EAEDCs) including: (a) *selective BRTO* ($n = 11$ EADECs in 10 patients), performed by advancing the balloon catheter above the level of the EAEDC (Fig. 3); (b) *balloon occlusion of the EAEDC* ($n = 2$), performed by advancing a micro-balloon catheter inside the EAEDC (2.8F Masamune micro-balloon catheter, Fuji Systems Corp., Tokyo, Japan) (Fig. 4); and (c) *coiling of the EAEDC* ($n = 1$).

Esophageal varices evaluation

Upper endoscopy reports and images obtained before and within 3 months after BRTO were retrospectively reviewed

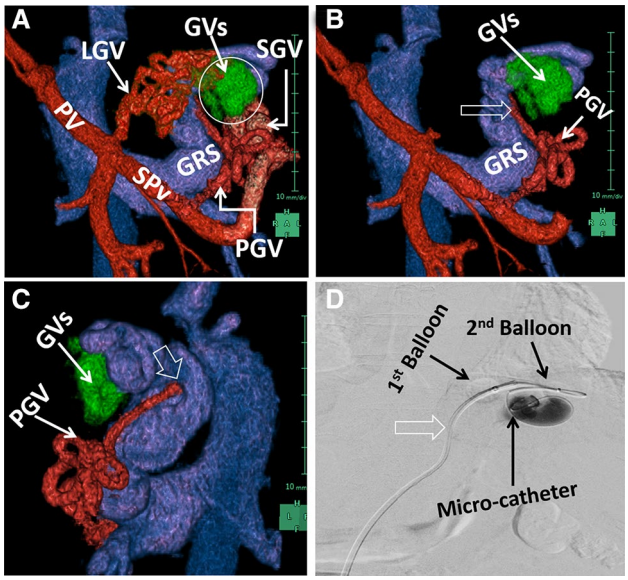

Fig. 3 Selective BRTO technique (i.e., advancement of the balloon catheter beyond EAEDC level). **a** An anterior view volume rendering (VR) image shows the gastric varices (GVs) supplied by short gastric vein (SGV) and left gastric vein (LGV). The posterior gastric vein (PGV) is directly connected to the gastrorenal shunt (GRS). **b** The same anterior view as shown in Fig. 3a but after subtraction of LGV and SGV to clearly visualize the connection (hollow white arrow) between PGV and GRS away from GVs. **c** A lateral oblique VR image shows the EAEDC (hollow white arrow). **d** A digital subtraction angiography image obtained during BRTO shows the 1st 9Fr balloon catheter high up in the GRS above the level of the EAEDC (hollow white arrow) and the smaller 2nd 5Fr balloon catheter near GVs, while the microcatheter is inside the GVs. (*PV* portal vein, *SP V* splenic vein)

for esophageal varices exacerbation, which is defined as any increase in varices size, appearance of a red color spot sign, or post-BRTO esophageal varices bleeding [16].

Statistical analysis

Chi-square test, Fisher's exact test, and *t* test were used to compare patients' characteristics and follow-up findings between study groups and subgroups. All statistical analyses were performed with IBM SPSS V.21 statistical software. The statistical level of significance was set at $p < 0.05$.

Results

EAEDC detection and management results

A total of 39 EAEDCs in 35 patients were identified in CT images (Group A = 61.4%; four patients had two EAEDCs). Among them, only 20 EAEDCs were visualized during

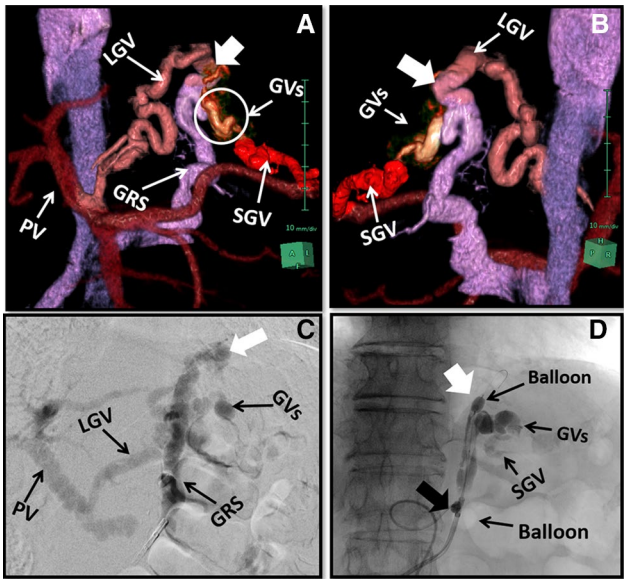

Fig. 4 Balloon occlusion of the EAEDC. **a** An anterior oblique volume rendering (VR) image shows the gastric varices (GVs) supplied by short gastric vein (SGV) and drained by gastrorenal shunt (GRS). The left gastric vein (LGV) is directly connected to the dome of the GRS (solid white arrow). **b** A lateral oblique VR image shows the EAEDC (solid white arrow). **c** A CO_2 balloon-occluded venography image during BRTO shows the direct connection between the GRS and LGV. **d** A fluoroscopic image obtained after EOI injection shows the opacified GVs and SGV after occlusion of the EAEDC by microballoon catheter (white solid arrow). The 9Fr balloon catheter (filled with air) occludes the GRS base. Temporary balloon occlusion of the splenic artery (solid black arrow) was done to reduce the blood flow and pressure within SGV. (*PV* portal vein)

BRTO after BOV. In the remaining 22 patients, EAEDC was not identified in CT images or during BRTO (i.e., Group B).

The left gastric vein (LGV) was the most common afferent vein connected directly to the draining vein (76.9% of the total EAEDCs, $n=30$), followed by the posterior gastric vein (PGV) (17.9%, $n=7$), and then the short gastric veins (SGV) (5.2%, $n=2$). Most of the distally located EAEDCs (Type III and Type IV) were from LGV (90.6%), while most of the proximally located EAEDCs (type I and type II) were from PGV (57.1%) and SGV (28.6%) (Table 2).

Regarding additional techniques used during BRTO for EAEDC management, selective BRTO technique was done in most of the proximally located EAEDCs (100% of type I and 75% of type II EAEDCs). However, no additional techniques were used in most of the distally located EAEDCs (94.1% of type III and 53.3% of type IV EAEDCs). Coiling and balloon occlusion of EAEDCs were performed only in 20% of type IV EAEDCs (Table 2).

The mean EOI volume used in all patients was 15.3 ± 8.3 ml. Among the 19 patients with large-sized EAEDCs (type II and IV), the mean EOI volume was significantly lower in patients ($n=10$) where additional techniques were used than in patients ($n=9$) where additional techniques were not used (i.e., 11.3 ml $\pm$ 5.6 ml and 22.2 $\pm$ 8 ml, respectively) ($p=0.003$, based on independent sample t test).

Follow-up results

GVs were completely thrombosed in 55 patients (96.5%) and partially thrombosed in 2 patients (3.5%). Partial portal/splenic vein thrombosis was identified in three patients (5.3%). Two of them had type IV EAEDCs from LGV and were obliterated without using any additional techniques. In the remaining patient, no EAEDC was detected in the pre-procedural CT images or during BRTO. However, there was no statistically significant difference between group A and B regarding complete gastric varices thrombosis and portal/splenic vein thrombosis after BRTO ($p=1$) (Table 3).

Regarding EAEDC patency (Table 4), 28 of the total 39 EAEDCs (71.8%) were obliterated (i.e., *Obliterated EAEDC subgroup*) whereas 11 EAEDCs (28.2%) remained

Table 2 Characteristics of the total 39 EAEDCs detected by CT correlated with additional techniques used during BRTO

	Total $n=39$	Type I $n=3$	Type II $n=4$	Type III $n=17$	Type IV $n=15$	*P* value*
EAEDC afferent vein						0.001
LGV	30 (76.9)	1 (33.3)	0 (0)	16 (94.1)	13 (86.7)	
PGV	7 (17.9)	1 (33.3)	3 (75)	1 (5.9)	2 (13.3)	
SGV	2 (5.2)	1 (33.3)	1 (25)	0 (0)	0 (0)	
Additional techniques						0.009
No	25 (64.1)	0 (0)	1 (25)	16 (94.1)	8 (53.3)	
Selective BRTO	11 (28.2)	3 (100)	3 (75)	1 (5.9)	4 (26.7)	
Balloon occlusion	2 (5.1)	0 (0)	0 (0)	0 (0)	2 (13.3)	
Coiling	1 (2.6)	0 (0)	0 (0)	0 (0)	1 (6.7)	

Values between parentheses are in percentage of column value

LGV left gastric vein, *PGV* posterior gastric vein, *SGV* short gastric vein

*χ^2 test

Table 3 Follow-up results of the 57 patients correlated with the study groups

	Total $n=57$	Group A $n=35$	Group B $n=22$	p value*
Portal/splenic vein thrombosis	3 (5.3)	2 (5.7)	1 (4.5)	1
GV thrombosis				1
Complete	55 (96.5)	34 (97.1)	21 (95.5)	
Partial	2 (3.5)	1 (2.9)	1 (4.5)	
Ascites exacerbation	14 (24.6)	9 (25.7)	5 (22.7)	1
Esophageal varices exacerbation	25 (43.9)	14 (40)	11 (50)	0.6

Values between parentheses are in percentage of column value

*Fisher's exact test

Table 4 Follow-up results and additional techniques used during BRTO correlated with "patent and obliterated EAEDC" subgroups

EAEDC	Obliterated ($n=28$ EAEDCs in 25 patients)	Patent ($n=11$ EAEDCs in 10 patients)	Total ($n=39$ EAEDCs in 35 patients)	p value
Additional techniques				<0.0005[a]
No	24 (85.7)	1 (9.1)	25 (64.1)	
Selective BRTO	1 (3.6)	10 (90.9)	11 (28.2)	
Balloon occlusion	2 (7.1)	0 (0)	2 (5.1)	
Coiling	1 (3.6)	0 (0)	1 (2.6)	
Ascites exacerbation	9 (36)	0 (0)	9 (25.7)	0.036[b]
Es.V exacerbation	13 (52)	1 (10)	14 (40)	0.028[b]

Values between parentheses are in percentage of column value

Es.V esophageal varices

[a]χ^2 test

[b]Fisher's exact test

patent (i.e., *Patent EAEDC subgroup*). Among the 28 obliterated EAEDCs, 24 EAEDCs were thrombosed by EOI alone without using any additional techniques. While the remaining four EAEDCs were obliterated by coils in one EAEDC, by EOI after using EAEDC balloon occlusion technique in two EAEDCs, and by EOI despite using selective BRTO technique in one EAEDC. Of 11 patent EAEDCs, 10 EAEDCs remained patent due to the use of selective BRTO technique, while only one EAEDC remained patent without using any additional technique.

Ascites exacerbation was noted in 14 patients (24.6%) with no statistically significant difference between group A and B ($p=1$) (Table 3). However, ascites exacerbation was significantly lower in *patent EAEDC subgroup* than in *obliterated EAEDC subgroup* (0% and 36%, respectively; $p=0.036$) (Table 4).

Esophageal varices exacerbation was noted in 25 patients (43.9%) with no statistically significant difference between group A and B ($p=0.6$) (Table 3). However, esophageal varices exacerbation was significantly lower in *patent EAEDC subgroup* than in *obliterated EAEDC subgroup* (10% and 52%, respectively, $p=0.028$).

Discussion

MDCT is an essential imaging technique to evaluate GVs anatomy before BRTO [2, 21]. Several reports have shown the usefulness of three-dimensional (3D) CT images in the evaluation of portosystemic collaterals and GVs in cirrhotic patients [22–26]. Detection of EAEDCs in CT images requires meticulous tracking of each afferent and efferent vein along their entire course in the axial or coronal images. Obtaining a separate color-coded VR image of each vein can simplify the complex GVs anatomy resulting in easier and more accurate assessment with different view angles. Also, VR images can be used as reference or vascular map images during BRTO procedure. Obtaining VR images is a time-consuming process and depends on the software used and the experience of the operator [25]. However, VR images can be simultaneously obtained during the routine assessment of the axial images by the operator using our described VR technique.

LGV was the most common afferent vein connected directly to the main draining vein and was characterized

by its long and tortuous course before connecting with the distal part of the draining vein in most cases (i.e., type III or IV EAEDCs), in contrast to the relatively shorter and straighter course of PGV and SGV with a proximally located connection (i.e., type I or II EAEDCs).

EOI reflux into the portal circulation may depend on EAEDC type, i.e., in type I and II EAEDCs, the proximally located EAEDC is nearer to the EOI injection site (i.e., catheter tip) than to the GVs, so EOI may reach the portal circulation early before complete filling of the GVs. Fortunately, type I and II EAEDCs were infrequent (7.7% and 10.3% of total EAEDCs, respectively) and could be easily bypassed by using selective BRTO technique as shown in our results.

Up to 45% of patients have been reported to have ascites after BRTO when minimal ascites detected only by imaging was included [27–29]. Development of ascites may be related to the sudden increase in portal pressure and/or hepatic dysfunction [13, 30, 31] and it is usually transient and occurs in the early post-BRTO period (within 30–60 days) [32]. The incidence of ascites worsening in our study was within the reported incidence (24.6%) and it was significantly lower in patients with patent EAEDCs than those with obliterated EAEDCs. Saad et al. [27] reported that transjugular intrahepatic portosystemic shunt appears to have a protective value against ascites exacerbation. Similarly, EAEDC preservation appears to have the same protective effect.

The rate of esophageal varices aggravation has been reported to be 11.6–66% [5, 6, 12, 17, 33]. This wide range appears to be due to variable follow-up periods and aggravation criteria between studies. In our study, the incidence of esophageal varices exacerbation within 3-month follow-up period was 43.9% and it was significantly lower in patients with patent EAEDCs than those with obliterated EAEDCs. Tanihata et al. [13] reported that esophageal varices aggravation was significantly related to the increased portal venous pressure, which was significantly related to the shunt occlusion and collateral veins coiling. So, EAEDC preservation appears to have a protective effect against esophageal varices aggravation.

The most serious reported complications related to EOI injection were renal dysfunction, pulmonary edema, and disseminated intravascular coagulopathy [8, 15, 29]. Renal dysfunction is not rare, so intraprocedural administration of haptoglobin and injection of a limited dose of EOI are necessary [19]. In our study, the volume of EOI used in patients with large-sized EAEDCs was significantly lower when additional techniques were used to obliterate or bypass the EAEDCs. Obliterating or bypassing large EAEDCs may save the injected EOI from being wasted in them; hence, the entire injected EOI will be concentrated into GVs, resulting in complete GVs filling with smaller amount of EOI.

Portal/splenic vein thrombosis had developed in 5.3% of our patients, which is within the reported (1.1–11.5%) incidence [15, 29, 34]. The low incidence of portal/splenic vein thrombosis after BRTO, despite the frequent presence of EAEDC, can be attributed to the high pressure, long and tortuous course, distal location and small size of the EAEDCs, careful EOI injection by the operators, and the use of additional techniques. The high pressure within EAEDC resists and delays the sclerosant from reaching the portal circulation. The long and tortuous course of EAEDCs (usually the distally located type III and IV) requires a large volume of EOI so that it can reach the portal circulation. Moreover, small-sized EAEDCs can be obliterated early during EOI injection especially by using the stepwise injection technique [10]; consequently, no more EOI will be refluxed into portal circulation through it.

In this study, there was no statistically significant association between the presence of EAEDC and post-BRTO portal/splenic vein thrombosis. However, the operator should be aware of the EAEDC type, especially the large-sized and proximally located EAEDCs, to avoid excessive EOI reflux through them. For this purpose, correlation between 3D CT images and fluoroscopic images during BRTO is very helpful.

In conclusion, CT images with 3D reconstruction are very useful for EAEDC detection. Preservation of EAEDC patency may decrease the incidence of ascites and esophageal varices exacerbation. Using additional techniques for preservation or obliteration of large-sized EAEDCs may reduce the needed volume of sclerosant agent.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent This retrospective study was approved by our institutional review board, and the requirement to obtain written informed consent was waived.

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