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TECHNICAL NOTE

Balloon-Occluded Carbon Dioxide Gas Angiography for Internal Iliac Arteriography and Intervention

Mitsuhiro Kishino[1] · Shuichiro Nakaminato[1] · Yoshio Kitazume[1] · Naoyuki Miyasaka[2] · Toshifumi Kudo[3] · Yukihisa Saida[1] · Ukihide Tateishi[1]

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Abstract

Introduction The usefulness of carbon dioxide (CO_2) gas digital subtraction angiography (DSA) has been reported for patients with renal insufficiency and allergy to iodinated contrast agents. However, CO_2 gas cannot replace the iodinated contrast agent in all cases owing to some disadvantages. We describe balloon-occluded CO_2 DSA (B-CO_2 DSA) as an improved CO_2 DSA procedure for interventions in the internal iliac artery (IIA) region and compare the quality of images obtained using conventional CO_2 DSA and B-CO_2 DSA.

Materials and Methods B-CO_2 DSA-guided embolization was performed for one case of genital bleeding with an acute anaphylactic reaction to the iodinated contrast agent and for three cases of type II endoleaks after endovascular abdominal aortic aneurysm repair with renal dysfunction. A 9-mm occlusion balloon catheter was placed just after the orifice of the IIA. Then, 10–15 ml of CO_2 gas was injected manually via the catheter with and without balloon occlusion. The quality of sequential digital subtraction angiograms was analyzed based on a scoring criterion.

Results In all four cases, image quality was improved with B-CO_2 DSA; the poor quality of images without balloon occlusion was because of reflux of the CO_2 gas.

Conclusions B-CO_2 DSA improves the image quality of CO_2 DSA in the IIA region and is useful for vascular intervention.

Level of Evidence Level IV.

Keywords Carbon dioxide gas · Balloon-occluded digital subtraction angiography · Anaphylactic reaction · Renal dysfunction · Internal iliac artery · Endoleak

✉ Mitsuhiro Kishino
ksnmrad@tmd.ac.jp

1 Department of Diagnostic Radiology and Nuclear Medicine, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan

2 Department of Perinatal and Women's Medicine, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan

3 Division of Vascular Surgery, Department of Surgery, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan

Introduction

Carbon dioxide (CO_2) gas digital subtraction angiography (DSA) was introduced in clinical practice in the 1970s [1]. Because it does not induce renal toxicity or allergic reaction, CO_2 gas has been used as an alternative contrast agent for vascular interventions in patients with allergy to iodinated contrast agents and renal insufficiency [2, 3]. Despite these significant advantages of CO_2, it cannot replace iodinated contrast agents because of its lower contrast, movement that differs from that of liquid, and rare ischemic complications [3–5].

We used balloon-occluded CO_2 (B-CO_2) DSA as an improved CO_2 DSA procedure for the internal iliac artery (IIA) region and used it in four cases of arterial embolotherapy. We compared the quality of images obtained using conventional CO_2 (C-CO_2) DSA and B-CO_2 DSA.

Materials and Methods

This was a single-center, retrospective observational study. All patients gave informed consent to undergo the relevant procedure.

B-CO_2 DSA

CO_2 gas was delivered through a 20-ml luer-lok syringe using a CO_2 delivery system (Gaster type G-1; Cathex, Tokyo, Japan) and a three-way stopcock. Using the ipsilateral femoral approach, CO_2 arteriography was performed in the external or common iliac artery to identify the IIA orifice. First, a 5-French (Fr) J-shaped catheter (RIM, Medikit, Tokyo, Japan) was placed into the orifice of the IIA, and 10–15 ml of CO_2 gas was manually injected for CO_2 DSA without balloon occlusion. The aim of the prior C-CO_2 DSA was to determine the necessity of B-CO_2 DSA and to confirm the catheter position and luminal diameter for the safe use of the balloon. Next, the catheter was exchanged for a 5.2-Fr occlusion balloon catheter with a 9-mm balloon (Selecon MP; Terumo, Tokyo, Japan). This is a double lumen catheter compatible with microcatheter use, and the balloon is made of natural rubber. The balloon was inflated in the orifice of the IIA, and 10–15 ml of CO_2 gas was injected manually for B-CO_2 DSA.

Image Quality Scoring

The quality of sequential digital subtraction angiograms was evaluated retrospectively by two interventional radiologists who reached a consensus based on the scoring criterion. The criterion focused on four imaging findings. Visualization of the trunk of the IIA, target artery (uterine artery and lumbar artery), and lesions (uterus and endoleak) was scored as 3 points (0 = no, 1 = faint, 2 = fine). Additionally, overflow from the IIA was scored as 2 points (0 = present, 1 = absent). The added scores for C-CO_2 DSA and B-CO_2 DSA were compared.

Case Presentations

Case 1: Uterine Artery Embolization

A 30-year-old woman admitted to our institution for cervical ectopic pregnancy was started on high-dose methotrexate (MTX) therapy. On day 7 of MTX therapy, massive genital bleeding occurred and emergency uterine artery embolization was performed. Immediately after left internal iliac and uterine arteriography using an iodinated contrast agent, angor pectoris and a rapid decrease in blood pressure developed; she was diagnosed as having anaphylactic shock due to the iodinated contrast agent. Soon after successful medical treatment, uterine artery embolization was resumed. Although the left uterine artery was already selected and embolized by gelatin sponge particles soaked with saline mixed with some ethiodized oil to confirm the decreasing blood flow, the right uterine artery was not identified. Therefore, right uterine artery embolization with CO_2 angiography was subsequently planned. The right uterine artery was barely detectable on right internal iliac C-CO_2 DSA owing to poor depiction of the peripheral arteries and reflux of CO_2 gas (Fig. 1A). However, subsequent B-CO_2 DSA improved visualization of the uterine artery (Fig. 1B). The right uterine artery was successfully selected using a microcatheter, and selective CO_2 DSA was performed. Compared with selective uterine CO_2 DSA without balloon occlusion (Fig. 1C), selective uterine CO_2 DSA with proximal balloon occlusion also improved the uterine staining and prevented the reflux of CO_2 gas (Fig. 1D). The right uterine artery was embolized by gelatin sponge particles as with the left uterine artery. After treatment, genital bleeding subsided.

Cases 2–4: Embolization for Type II Endoleak After Endovascular Abdominal Aortic Aneurysm Repair

Three patients showed continuous enlargement of the abdominal aortic aneurysm after endovascular abdominal aortic aneurysm repair. Two of the three patients had severe deterioration of renal function. The first patient (case 2) was a 50-year-old woman who had undergone renal transplantation and had a serum creatinine level of 4.01 mg/dl (normal range 0.5–0.8 mg/dl). The second patient (case 3) was a 60-year-old man with a serum creatinine level of 3.9 mg/dl (normal range 0.7–1.10 mg/dl). The third patient (case 4) was a 70-year-old woman with mild renal insufficiency and a serum creatinine level of 1.3 mg/dl (normal range 0.5–0.8 mg/dl). Therefore, contrast-enhanced computed tomography was avoided during the follow-up examination in these three patients; however, a type II endoleak from the lower lumbar arteries was suspected on the basis of ultrasonography findings. Therefore, trans-arterial embolization of the type II endoleak using CO_2 DSA was planned.

In the former two patients (cases 2 and 3) with severe renal dysfunction, the endoleak route and the branches of the IIA were not visualized using C-CO_2 DSA because of the massive reflux of CO_2 gas (Figs. 2A, 3A); however, B-CO_2 DSA revealed the route of the endoleak via anastomosis of the iliolumbar artery and lower lumbar artery

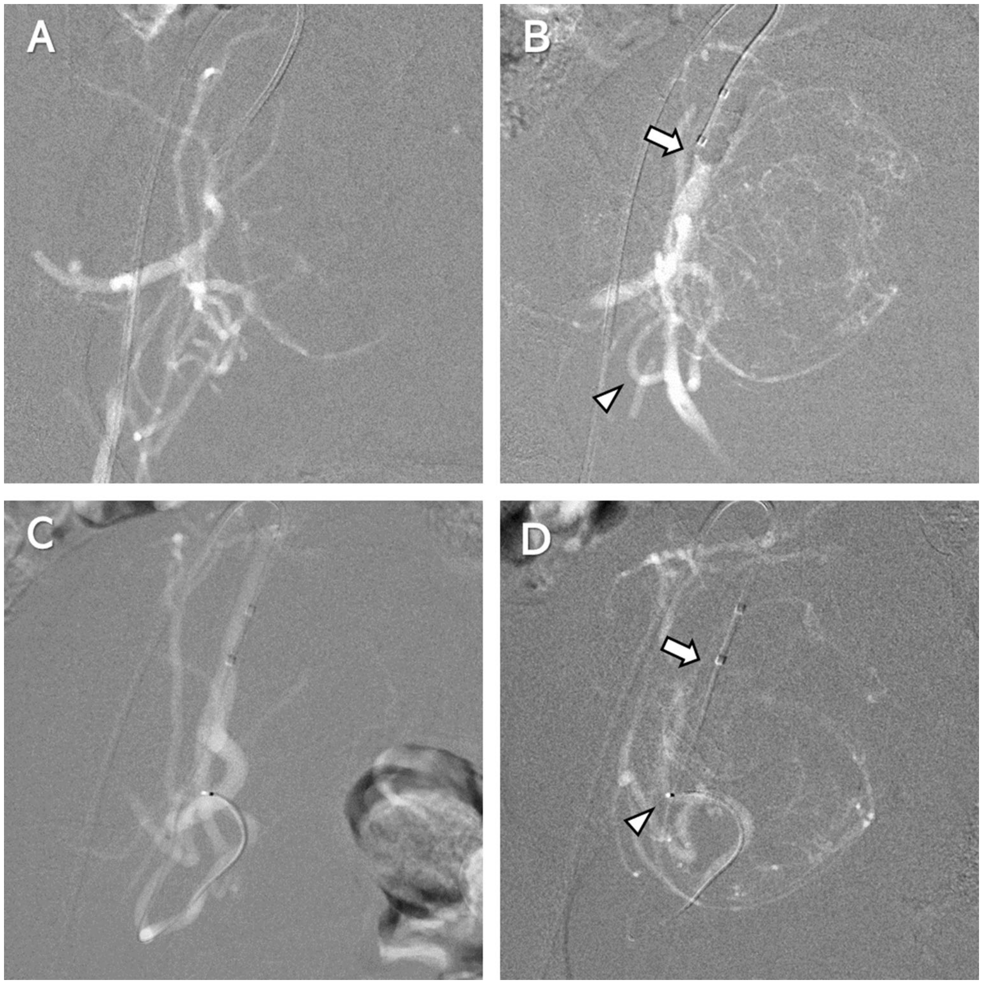

Fig. 1 Case 1. Uterine artery embolization with carbon dioxide (CO_2) gas digital subtraction angiography (DSA). **A** Conventional CO_2 DSA of the right IIA. The internal iliac artery (IIA) branches are visualized discontinuously and overlapping the branches outside of the IIA. **B** Balloon-occluded CO_2 DSA of the right IIA. The arrow indicates the tip of the balloon catheter. The uterus is stained, and the uterine artery is identified continuously (arrowheads). **C** Selective right uterine arteriography with CO_2 DSA (right oblique view) showing marked reflux of CO_2 gas and poor staining of the uterus. **D** Selective uterine DSA occluding the proximal balloon (arrow). The arrowhead indicates the tip of the microcatheter. The reflux is minimized, and the uterus is enhanced selectively

(Figs. 2B, 3B). Guided by B-CO_2 DSA, the microcatheter was advanced into the aneurysmal sac. Then, only 5 ml of the iodinated contrast agent was used to evaluate the aneurysmal sac volume and presence of outflow; subsequently, the sac and inflow route were embolized with glue and coils without any adverse events.

For the third patient (case 4) with mild renal insufficiency, compared with C-CO_2 DSA (Fig. 4A), B-CO_2 DSA of the right IIA (Fig. 4B) improved visualization of the anastomosis of the right IIA to the right lumbar arteries, although the endoleak was not detected. Therefore, left internal iliac CO_2 angiography was attempted via the left femoral approach; however, the balloon could not approach the orifice of the left IIA due to its severe tortuosity and rigidity of the balloon catheter. Finally, we changed our plan to use the iodinated contrast agent as little as possible. The possibility of using the iodinated contrast agent and the risk had been explained to the patient, who provided informed consent before treatment. Bilateral internal iliac DSA with the iodinated contrast agent was performed, but no obvious endoleak was found. The findings of right IIA angiography with the iodinated contrast agent (Fig. 4C) were the same as those before B-CO_2 DSA. Then, only coil embolization of the bilateral anastomosis of the iliolumbar artery and lumbar arteries was performed. No deterioration of renal insufficiency was noted after treatment.

Fig. 2 Case 2. Type II endoleak via the right internal iliac artery (IIA) treated with carbon dioxide (CO_2) gas digital subtraction angiography (DSA). **A** Conventional CO_2 DSA of the right IIA, right oblique view. The arrow indicates the tip of the balloon catheter. Peripheral visualization of the IIA is faint and discontinuous, whereas the reflux of CO_2 is marked (arrowhead). **B** Balloon-occluded CO_2 DSA of the right IIA. The type II endoleak root via the iliolumbar artery and lumbar artery is visualized clearly and continuously (arrowheads)

Fig. 3 Case 3. Type II endoleak via the left internal iliac artery (IIA) treated with carbon dioxide (CO_2) gas digital subtraction angiography (DSA). **A** Conventional CO_2 DSA of the left IIA. The arrow indicates the tip of the catheter. Most of the CO_2 gas was refluxed to the left iliac limb (arrowheads). **B** Balloon-occluded CO_2 DSA of the left IIA. The arrow indicates the occluding balloon catheter. The type II endoleak via anastomosis of the iliolumbar artery and lumbar artery is visualized (arrowheads)

Results

For all four patients, C-CO_2 DSA was insufficient for complete selective embolization because of reflux of the CO_2 gas and poor visualization of the peripheral IIA; therefore, B-CO_2 DSA was performed subsequently. Five B-CO_2 DSAs were attempted in four patients, and four of five procedures were accomplished. However, one B-CO_2 DSA failed because of severe bending of the iliac artery. B-CO_2 DSA improved visualization of the peripheral IIA and target artery, enabling selective embolization. The image quality scores of the sequential digital subtraction angiograms were higher in B-CO_2 DSA than in C-CO_2 DSA in all cases (Table 1).

Discussion

Buoyancy, surface tension, and low attenuation are major physical factors that affect the image quality of CO_2 DSA. The movement of CO_2 gas is subject to gravity and not just blood flow owing to its strong buoyancy. Sometimes, it moves against the blood flow in posterior-flowing vessels (direction of gravity). Therefore, CO_2 gas rarely runs peripheral to the IIA, because of its downward direction in

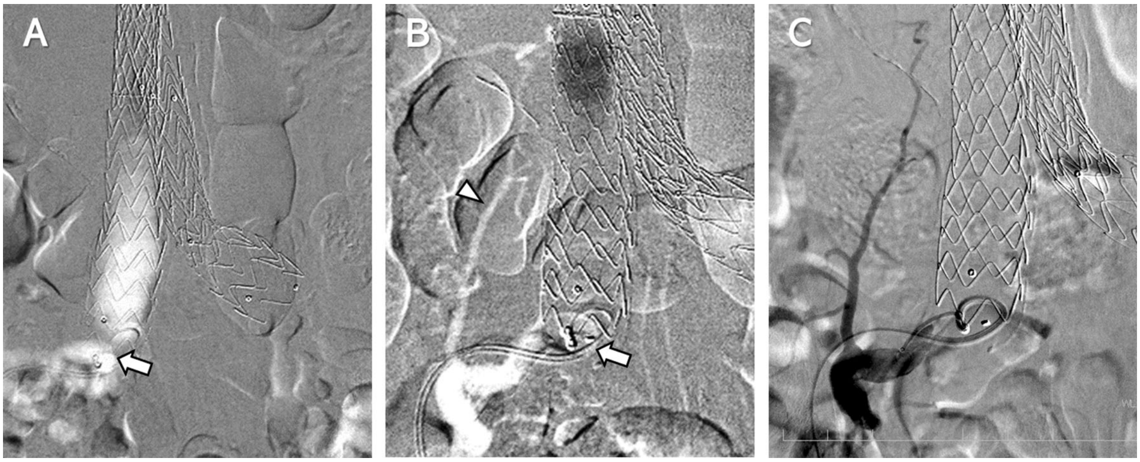

Fig. 4 Case 4. Evaluation of the endoleak using the carbon dioxide (CO_2) gas and iodinated contrast agent. **A** Conventional CO_2 digital subtraction angiography (DSA) of the right internal iliac artery (IIA). The arrow indicates the catheter tip. Most of the injected CO_2 gas is refluxed to the right iliac limb (arrowhead), and the IIA is not visualized. **B** Balloon-occluded (B)-CO_2 DSA of the right IIA. The arrow indicates the balloon catheter. Anastomosis of the iliolumbar artery and lumbar arteries is seen (arrowheads), but the endoleak of the aneurysm is not detected. **C** DSA of the right IIA with iodinated contrast agent. The endoleak is not detected as well as it was with B-CO_2 DSA

Table 1 Image quality score of each sequential digital subtraction angiogram

		IIA trunk	Target artery	Lesion	Overflow	Total
Case 1	C-CO_2	1	1	0	0	2
	B-CO_2	2	2	1	1	6
Case 2	C-CO_2	1	1	0	0	2
	B-CO_2	2	2	2	1	7
Case 3	C-CO_2	0	0	0	0	0
	B-CO_2	2	2	2	1	7
Case 4	C-CO_2	2	1	0	0	3
	B-CO_2	2	2	0	1	5

C-CO_2 conventional carbon dioxide digital subtraction angiography without balloon occlusion, B-CO_2 balloon-occluded carbon dioxide digital subtraction angiography, IIA internal iliac artery

the supine position, and easily overflows into the aorta or external iliac artery, which obstructs visualization of the target artery. Huang et al. [6] reported poor sensitivity and specificity of CO_2 DSA for detecting type II endoleaks compared with type I and type III endoleaks, and they postulated the reason for the posterior location of the endoleak root. Deep cannulation is one method of improving the image of the downward artery [7]. It will certainly improve visualization of the proximal vessels, but the effect is limited for the peripheral branch and for preventing reflux.

The low contrast of CO_2 DSA compared to the iodinated contrast agent is unavoidable because CO_2 gas is a negative contrast agent due to the small difference in X-ray absorption between the replaced blood and CO_2 gas. Moreover, partial localization of CO_2 gas in the vessel can reduce the contrast [5]. The CO_2 gas fills the anterior (nondependent) part of the luminal vessel due to its buoyancy and surface tension. Son et al. [8] reported that CO_2 gas only filled 65% of the lumen in a horizontal 15.9-mm-diameter vessel. Additionally, the formation of bubbles is attributed to the discontinuous vessel imaging. Therefore, complete and continuous filling of the vessel lumen with CO_2 gas is favorable for improving the CO_2 digital subtraction angiogram.

B-CO_2 DSA can fill the arterial lumen continuously, from the proximal to the peripheral direction, with CO_2 gas, especially in downward vessels. Furthermore, this prevents backflow of CO_2 gas to unexpected regions, helps to reduce the undesirable vascular overlap, and may reduce the risk of ischemic complications (such as bowel ischemia), which have been sporadically reported [3–5]. Balloon-occluded transvenous CO_2 portography was reported in 1999 by Tylor et al. [9], but its usefulness in arteriography has not been reported. Although our results were from a small number of patients, the image quality on using

B-CO_2 DSA was improved compared to that on using C-CO_2 DSA for all patients.

Conclusions

B-CO_2 DSA improves the image quality of CO_2 DSA in the IIA region and helps accomplish various complicated vascular interventions in the IIA region. It will be a useful option for patients with allergy to iodinated contrast agents or with renal dysfunction. However, the efficacy and appropriateness of B-CO_2 DSA use should be evaluated in larger case studies.

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.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Hawkins IF. Carbon dioxide digital subtraction arteriography. Am J Roentgenol. 1982;139:19–24.
2. Kessel DO, Robertson I, Patel J, Peters K, Taylor EJ, Denton LJ, et al. Carbon-dioxide-guided vascular interventions: technique and pitfalls. Cardiovasc Intervent Radiol. 2002;25:476–83.
3. Fujihara M, Kawasaki D, Shintani Y, Fukunaga M, Nakama T, Koshida R, et al. Endovascular therapy by CO_2 angiography to prevent contrast-induced nephropathy in patients with chronic kidney disease: a prospective multicenter trial of CO_2 angiography registry. Catheter Cardiovasc Interv. 2015;85:870–7.
4. Rundback JH, Shah PM, Wong J, Babu SC, Rozenblit G, Poplausky MR. Livedo reticularis, rhabdomyolysis, massive intestinal infarction, and death after carbon dioxide arteriography. J Vasc Surg. 1997;26:337–40.
5. Caridi JG, Hawkins IF. CO2 digital subtraction angiography: potential complications and their prevention. J Vasc Interv Radiol. 1997;8:383–91.
6. Huang SG, Woo K, Moos JM, Han S, Lew WK, Chao A, et al. A prospective study of carbon dioxide digital subtraction versus standard contrast arteriography in the detection of endoleaks in endovascular abdominal aortic aneurysm repairs. Ann Vasc Surg. 2013;27:38–44.
7. Cho KJ. Carbon dioxide angiography: scientific principles and practice. Vasc Specialist Int. 2015;31:67–80.
8. Song K, Cho D, Shinn K, Charlton E, Cho K. Gas dynamics in CO_2 angiography: in vitro evaluation in a circulatory system model. Invest Radiol. 1999;34:151–5.
9. Taylor FC, Smith DC, Watkins GE, Kohne RE, Suh RD. Balloon occlusion versus wedged hepatic venography using carbon dioxide for portal vein opacification during TIPS. Cardiovasc Interv Radiol. 1999;22:150–1.