ORIGINAL ARTICLE

Efficacy of carbon dioxide for diagnosis and intervention in patients with failing hemodialysis access

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Background: Carbon dioxide (CO_2) is the only proven safe intravascular contrast agent in renal failure and contrast allergy. The use of CO_2 as a contrast agent for the evaluation of failing dialysis fistulas has the potential to preserve residual renal function by eliminating the use of contrast material or decreasing the amount used for fistulograms.
Purpose: To evaluate the feasibility of fistulography using CO_2 for diagnosis and intervention in patients with failing hemodialysis access.
Material and Methods: Dialysis access failure occurred in 94 patients (54 men, 40 women; mean age, 65 years; range, 32–89 years) on 146 occasions. CO_2 was used as the first-choice contrast agent for fistulography and PTA. Fistulography was performed with the injection of CO_2 in the brachial artery using a power injector.
Results: Interventional treatment was indicated in 141 accesses. In 115 of these 141 cases, intervention was performed using CO_2 fistulography alone. When the access flow stopped or decreased very much due to an occlusion and severe stenosis, we could not visualize the access by CO_2 fistulography, or could not perform CO_2 fistulography. For those cases, iodinated contrast fistulography was performed. When the vascular rupture, dissection, or clot formation occurred during intervention, iodinated contrast fistulography was performed. In three patients with arteriovenous fistula, manual injection of CO_2 into the brachial artery resulted in reflux of the gas into the thoracic aorta causing transient loss of consciousness.
Conclusion: CO_2 is a useful contrast agent in the diagnosis and intervention of failing hemodialysis access, eliminating or limiting the use of iodinated contrast material. Caution should be exercised to prevent CO_2 reflux into the aorta when injecting the gas into the brachial artery.

Key words: Contrast agents; vascular access; dialysis; angiography; CO_2; PTA

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The use of iodinated contrast agents in hemodialysis patients with residual renal function may threaten that function (1–3). Delayed excretion of iodinated contrast agents in patients with renal insufficiency has led to concerns over increased toxicity after radiographic procedures using iodinated contrast agents (4).

Waybill et al. recommended using carbon dioxide (CO_2) in patients at moderate to high risk of contrast nephropathy, with minimal usage of iodinated contrast agent (1). Iodinated contrast agents cannot be used in patients who are allergic to iodinated contrast agents. In such cases, CO_2 or a gadolinium-based contrast agent may be used. Several studies have used gadolinium-based contrast agents instead of iodinated contrast agents in interventions (5–10). However, recent reports have suggested that the use of gadolinium-based contrast agents in patients with decreased renal function may induce nephrogenic systemic fibrosis (11).

CO_2 can be used as a contrast agent instead of iodinated contrast agents for angiography, as this gas is not nephrotoxic, does not cause allergic reactions, and is inexpensive. If CO_2 is used for percutaneous transluminal angioplasty (PTA) in hemodialysis patients, the dosage of iodinated contrast agent can be decreased or eliminated, potentially contributing to the conservation of residual renal function. The purpose of this study was to evaluate the feasibility of fistulography using CO_2 for diagnosis and intervention in patients with failing hemodialysis access.

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Material and Methods

Patients and indications

The study protocol was approved by the institutional ethics committee, and written informed consent was obtained from all participants.

A total of 94 consecutive patients (54 men, 40 women; mean age, 65 years; range, 32–89 years) with 146 hemodialysis access failures for whom interventional treatment was considered necessary between May 2003 and September 2004 were enrolled in the study. Types of hemodialysis access were native fistula at the forearm in 87 cases, native fistula at the elbow in 14 cases, forearm loop grafts in 31 cases, upper arm loop grafts in 12 cases, native fistula at the forearm with straight graft in 1 case, and native fistula at the upper arm with straight graft in 1 case. Informed consent for CO_2 fistulography and interventions was obtained from patients for all 146 hemodialysis access failures that needed fistulography, and fistulography was performed using CO_2 as the first-choice contrast agent. Interventions including PTA, thrombolysis, thrombectomy, and stent placement were performed using CO_2 as the first-choice contrast agent in fistulography. When CO_2 could not move the intravascular by much decreased access flow due to an occlusion and severe stenosis, we could not visualize the access by digital subtraction angiography (DSA), we could not visualize the access. For those cases, iodinated contrast (370 mgI/ml of Iopamiron; Nihon Schering, Osaka, Japan) fistulography was performed. When vascular rupture, dissection, or clot formation also occurred during intervention, iodinated contrast fistulography was performed.

The indication for interventional treatment was ≥50% stenosis with clinical/physiological abnormalities or thrombosis, according to Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines (12). All judgments regarding clinical or physiological abnormalities were made by interventional radiologists and access surgeons. Reports regarding access blood flow, stenotic location, and diameter of stenosis on ultrasonography by clinical technologists were referred to for judgments if necessary. For all treatments, we selected interventional or surgical procedures after discussion with interventional radiologists and access surgeons. In all patients electrocardiogram (ECG) and percutaneous SpO_2 were consecutively monitored and blood pressure was automatically monitored every 5 min during the procedure. In addition, blood pressure was monitored when necessary.

Fistulography

Ultrasonography was not used to evaluate the inflow artery, anastomosis, and venous outflow for fistulography. For the initial diagnostic fistulography, with all native fistulae, CO_2 was injected manually into the brachial artery at the elbow through a 22-gauge intravenous catheter, and with all graft accesses, CO_2 was injected manually into the graft through a 16-, 18- or 22-gauge intravenous catheter. With all native fistulae, a 22-gauge intravenous catheter was inserted toward the venous outflow as far as possible in the brachial artery. However, when it was difficult, the catheter was inserted toward the subclavian artery. The direction of insertion was not limited in the graft. During the interventional procedure, CO_2 was injected into the brachial artery at the elbow through a 22-gauge cannula, into the outflow vein, or into the graft (Figs. 1 and 2). In particular, when stenosis was detectable on antegrade fistulography through a sheath introducer, a balloon catheter, or a 5-French straight catheter, CO_2 was injected from those devices to obtain better detection. Ultrasonography was not used during the interventional procedure. Iodinated contrast agent was used to inflate the angioplasty balloon.

For initial CO_2 fistulography regardless of site of CO_2 injection, the field of view included the upper arm, and CO_2 was injected by the manual method, with imaging performed using the digital subtraction technique. The injection rate was adjusted manually referring to the digital subtraction images at the same time so that CO_2 did not flow in a retrograde fashion through the brachial artery into the subclavian artery. The purpose of this injection was to identify an injection rate at which CO_2 did not flow in a retrograde fashion into the subclavian artery. Reflux of CO_2 into the cerebral vessel was associated with neurological

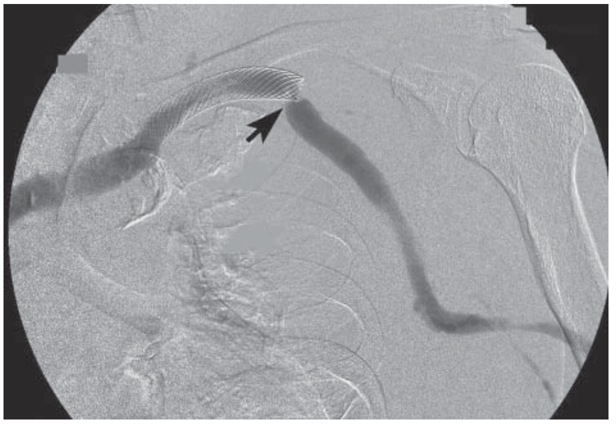

Fig. 1. During the interventional procedure, CO_2 digital-subtraction angiography in a patient who had a left loop graft with venous anastomotic stenosis in the forearm demonstrates a second stenosis (*black arrow*) due to stent shorting at the subclavian vein. CO_2 was injected using a power injector through a sheath introducer placed in the graft. Total volume and rate of CO_2 injection programmed for power injection were 40 ml and 20 ml/s, respectively. This type of image can be obtained with a hand injection into the outflow vein with a smaller volume.

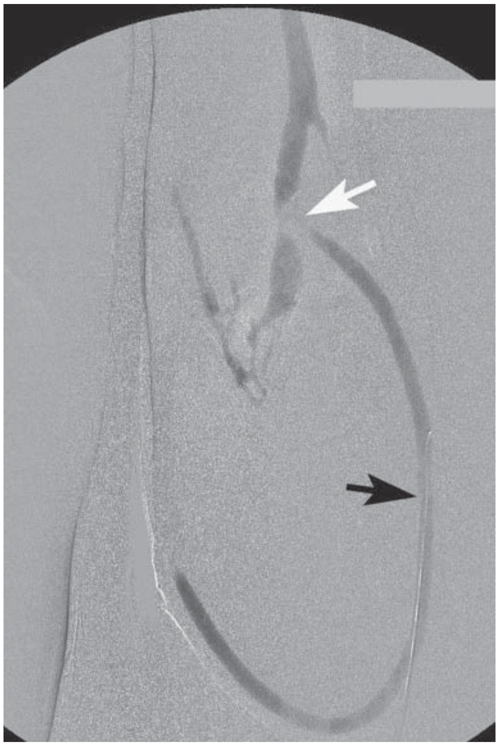

Fig. 2. During the interventional procedure, CO_2 digital-subtraction angiography in a patient with a left loop graft in the forearm demonstrates a stenosis (*white arrow*) at the venous anastomosis. CO_2 was injected using a power injector through a sheath introducer (*black arrow*) placed in the graft. Total volume and rate of CO_2 injection programmed for power injection were 40 ml and 20 ml/s, respectively.

sequelae, including seizures, in a previous study (13). In subsequent manual CO_2 injections, when we confirmed CO_2 flowing in retrograde fashion through the brachial artery, the injection rate was adjusted as in the first fistulogram. However, when we could not confirm CO_2 flowing in a retrograde fashion through the brachial artery, CO_2 was injected without exceeding the injection rate and dose for the first fistulogram. When the CO_2 injection rate and volume needed to be changed because access flow changed during interventional procedures and when we could not confirm CO_2 flowing in a retrograde fashion through the brachial artery, we performed fistulography in the initial manner to again determine the injection rate and dose.

When an indication for PTA (≥ 50% stenosis) was confirmed on initial fistulography, a repeat fistulography was performed by injecting CO_2 using a power injector (Injection System Mark V Pro Vis; Medrad, Pittsburgh, Pa., USA) in order to record the injection rate, duration, and total volume per run as numerical values, and to measure percent stenosis before PTA. CO_2 injection time and volume for programming power injection were determined based on values obtained from previous manual injections. When the power injector was used, dose and injection rate were determined not to exceed those in previous manual injections, and were selected from volumes of 10, 20, 30 or 40 ml, and from rates of 5, 10, 15, 20, 30 or 40 ml/s. The amount of CO_2 in the chamber of the power injector was adjusted to be equal to the amount of CO_2 programmed for power injection. The total dose of programmed CO_2 was thus injected. CO_2 runs were always operated using a closed circuit sealed with cock valves, and contamination by air was prevented. Before injection, the entire connector tubing was filled with CO_2. Pressure was always maintained above atmospheric pressure in the circuit.

Fistulography was performed in a retrograde manner only when observing the arterial anastomosis of grafts during PTA (Fig. 3). In retrograde fistulography, while occluding the venous anastomosis or graft using a balloon, CO_2 was gradually injected manually through a sheath introducer or balloon catheter, and fistulography was carried out until arterial anastomosis. CO_2 injection was discontinued when arterial anastomosis was visualized. All other fistulography procedures were performed in an antegrade manner.

When CO_2 injection was performed manually, injection was monitored by DSA, and was discontinued after sufficient CO_2 was injected for diagnostic purposes. It was decided that a total injecting volume of CO_2 per 60 s period was $<$ 60 ml. With all hemodialysis accesses, the entire access circuit from arterial anastomosis to the superior vena cava was evaluated by fistulography. In fistulography using iodinated contrast agent, the agent was diluted threefold using heparinized physiological saline solution. All CO_2 fistulography images were obtained with DSA. Acquisition

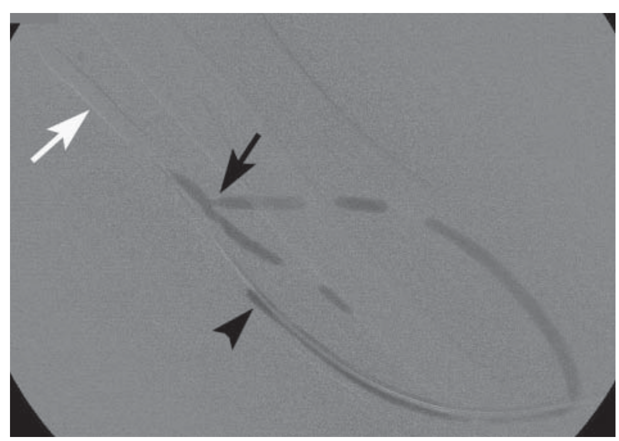

Fig. 3. Retrograde fistulography by CO_2 digital-subtraction angiography demonstrates an arterial anastomosis (*black arrow*). The patient had a left loop graft in the upper arm with stenosis at the venous anastomosis. Balloon (*white arrow*) angioplasty was performed for the stenosis. While occluding the venous anastomosis due to balloon angioplasty, CO_2 was gradually injected manually through a sheath introducer (*black arrowhead*), and fistulography was performed until the arterial anastomosis was identified.

rate was five frames per second. An angiography machine (Ultimax; Toshiba Medical Systems, Tochigi, Japan) was used. Vessel diameter was measured using a workstation (Digital Image System ADR-2000A; Toshiba Medical Systems, Tochigi, Japan) connected to the angiography machine.

A power injector was used for the iodinated contrast agent, and was used off-label for injecting CO_2; CO_2 taken out of the CO_2 gas dispenser (Gaster Cathex, Kanagawa, Japan) was typically used to inflate an occlusion balloon catheter, and was not used as a contrast medium. Our institutional review board was aware of this off-label use.

Study definitions and statistical analysis

For the endpoint of PTA, we used improvement in access flow visualization as assessed by fistulography and the conversion of continuous palpable thrill at the outflow vein in native fistulae and at the distal (venous) end of grafts. The clinical success rate was then calculated. Clinical success was defined as the resumption of normal dialysis for at least one session, in accordance with published Society of Interventional Radiology guidelines (14). Primary patency rates were calculated for all first-time PTA and for first-time PTA using only CO_2. Primary patency was calculated using the Kaplan–Meier method. For state of access, type of access, and presence of past fistulogram, the probability of performing intervention using only CO_2 fistulography was analyzed using the χ^2 test or Fisher's exact test for 2×2 tables. All complications were recorded and categorized as minor or major, as defined by SIR criteria (15).

Results

As a result of fistulography using CO_2 as the first-choice contrast agent, 5 of the 146 hemodialysis accesses were judged as untreatable by intervention, and surgical reconstruction was performed. A total of 141 interventional treatments were indicated in 89 patients with ≥50% stenosis or thrombosis. These occurred in 52 men and 37 women (mean age, 65 years; range, 32–89 years). Table 1 shows the access characteristics. Mean percentage stenosis before PTA was 80.3±12.9% (graft access, 77.5±14.8%; native fistula, 81.8±11.6%).

A power injector was used for CO_2 fistulography immediately before intervention in 130 of 141 procedures. Table 2 shows the injection program using the power injector. A power injector could not be used before intervention due to the risk of clot migration into the inflow artery in 11 accesses with thrombosis.

The clinical success rate for the total subject population was 98.6% (139/141 accesses). Postintervention primary patency rates are shown in Table 3. CO_2 was used in all fistulograms and during the intervention. Table 4 shows the probability of performing intervention using CO_2 fistulography alone. Table 5 shows the dose of contrast agent and the number of CO_2 runs per procedure. A maximal total amount of injecting CO_2 for any 60 s period was 60 ml.

Among the 141 PTA procedures, 8 major and 3 minor complications occurred. The eight major complications all involved balloon dilation causing vessel rupture. In these cases, hemostasis was achieved by prolonged balloon dilation, and clinical success was achieved, but iodinated contrast fistulography was required to confirm the details of the vessel wall. In one minor complication, the tip of a cannula placed in the brachial artery became dislodged, and iodinated contrast agent was injected around the brachial artery. The cannula was replaced into the brachial artery, and the procedure was continued. In three minor complications,

Table 1. Characteristics of access and intervention.

Characteristics	No. of accesses (%) (n=141)
Type of access	
Native fistula at forearm	83 (59)
Native fistula at elbow	14 (10)
Forearm loop graft	30 (21)
Upper arm loop graft	12 (9)
Native fistula at forearm with straight graft	1 (1)
Native fistula at upper arm with straight graft	1 (1)
Location of stenosis caused access failure	
Vein-to-graft anastomosis*	33 (23)
Intragraft*	2 (1)
Outflow vein	
Upper arm	21 (15)
Forearm	71 (50)
Cephalic arch	7 (5)
Central vein	4 (3)
Arteriovenous anastomosis	2 (1)
Inflow artery	1 (1)
State of access	
Without occlusion	115 (82)
Occlusion	
Nonthrombosis	15 (11)
Thrombosis	11 (8)
Type of access	
Native fistula	99 (70)
Graft	42 (30)
Presence of past fistulogram†	
–	60 (43)
+	81 (57)
Type of intervention	
PTA alone	137 (97)
PTA with stent placement	4 (3)

PTA, percutaneous transluminal angioplasty.
*All grafts are loop type.
†Patient had undergone previous fistulography, against which we could compare images from the present intervention.

Table 2. Program for power injector in CO_2 fistulography before intervention.

Type of access	Injection site	No. of accesses	Injection rate (ml/s)*	Injection volume (ml/injection)*	Injection duration
Native fistula at forearm	Brachial artery	78	10.0 ± 6.2 (5–40)	28.1 ± 7.6 (10–30)	3.5 ± 1.8 (1–6)
	Outflow vein	3	20.0 ± 0 (20–20)	40.0 ± 0 (40–40)	2.0 ± 1.8 (2–2)
Native fistula at elbow	Brachial artery	8	10.6 ± 9.0 (5–15)	27.5 ± 7.1 (10–30)	3.9 ± 2.3 (1–6)
	Outflow vein	5	17.0 ± 12.5 (5–30)	30.0 ± 0 (30–30)	3.2 ± 2.3 (1–6)
Forearm loop graft	Outflow vein	26	25.6 ± 10.5 (5–40)	33.5 ± 5.6 (20–40)	1.7 ± 1.1 (1–6)
Upper arm loop graft	Graft	10	24.0 ± 8.8 (5–30)	32.0 ± 4.2 (30–40)	1.8 ± 1.5 (1–6)

Numbers in parentheses represent ranges.
*Data represent mean ± standard deviation.

during the initial diagnostic fistulography, transient neurological symptoms lasting 15–30 s occurred. Two patients (nos 1 and 3) showed left arteriovenous fistula in the forearm (patient 1) and upper arm (patient 3), and one patient (patient 2) had right arteriovenous fistula in the forearm. In patient 1, access flow was reduced due to stenosis of an arteriovenous anastomosis and an outflow vein close to the anastomosis. In patients 2 and 3, flow was reduced due to stenosis of an outflow vein close to the arteriovenous anastomosis. In all three cases, 20 ml of CO_2 was injected via the brachial artery with manual injection, and CO_2 moved in a retrograde fashion up to the aorta, entering the carotid artery (Fig. 4). These events occurred at the first fistulography. One patient (no. 1) experienced loss of consciousness and nausea and two patients (nos 2 and 3) experienced only nausea. These complications occurred early in our experience. All complications were treated conservatively without any medication or therapy, and no sequelae or abnormal findings on neurological examinations were noted after intervention. No major complications were encountered.

Discussion

Ehrman et al. studied a total of 32 patients who underwent fistulography, including 28 patients who were scheduled for routine imaging, and compared the results of CO_2 with those using iodinated contrast agent (13). They documented that the image quality of CO_2 fistulography was sufficient for making therapeutic decisions. The present results support that conclusion, but we did not schedule for routine fistulography without access failure. As we perform fistulography on patients with clinical and physiological abnormalities, PTA was indicated in most patients. We conducted the present study because we believed that the usefulness of CO_2 guidance for PTA needed to be determined to confirm the overall utility of CO_2 fistulography in hemodialysis patients. In addition, clinical investigations of the methods and clinical results of CO_2 fistulography in native fistulae have been insufficient.

In our study, clinical success and 6-month primary patency rates were comparable to published data (16–22). These results suggest that, without assessment by iodinated contrast images, the clinical success of PTA for hemodialysis access can be predicted, and a satisfactory primary patency rate can be achieved based on PTA endpoint assessment, i.e. improvement of access flow visualization by CO_2 fistulography, and conversion of a continuous palpable thrill extending from the arterial anastomosis. Trerotola et al. advocated the use of a thrill as the procedural endpoint, and we support this notion (23).

Iodinated contrast agent was needed for all cases of intervention for thrombosis. Thrombosis under fluoroscopic guidance must be visualized, and as a result, thrombosis cannot be delineated by CO_2 fistulography, which requires digital subtraction. The probability of performing intervention using only CO_2 for stenosis without nonthrombotic occlusion was higher than that for stenosis with nonthrombotic occlusion. With non-

Table 3. Postintervention primary patency rates in patients without past intervention for present vascular access.

Category	No. of accesses	Primary patency rate (%)*		
		3 months	6 months	12 months
All interventions	58	89.2 ± 4.2 (49)	76.3 ± 5.7 (41)	51.3 ± 6.9 (26)
CO_2 alone	39	86.8 ± 5.5 (33)	73.7 ± 7.1 (28)	54.4 ± 8.2 (19)

Primary patency after intervention was calculated by Kaplan–Meier analysis. Numbers in parentheses represent at-risk accesses at start interval.
*Data represent primary patency rates ± standard error.

Table 4. Probability of performing intervention using only CO_2 fistulography.

	Probability	
Characteristics	%	*P* value
All interventions	82	
Type of access		
Native fistula at forearm	82	
Native fistula at elbow	86	
Forearm loop graft	87	
Upper arm loop graft	75	
Native fistula at forearm with straight graft	0	
Native fistula at upper arm with straight graft	0	
Location of stenosis caused access failure		
Vein-to-graft anastomosis	76	
Intragraft	100	
Outflow vein		
Upper arm	86	
Forearm	82	
Cephalic arch	100	
Central vein	75	
Arteriovenous anastomosis	100	
Inflow artery	0	
State of access		
Without occlusion	95	
Occlusion		< 0.01†
Nonthrombosis	40	
Thrombosis	0	< 0.01†
Type of access		
Native fistula	81	
		0.72†
Graft	83	
Presence of past fistulogram*		
–	65	
		< 0.01†
+	94	
Type of intervention		
PTA alone	83	
PTA with stent placement	25	

PTA, percutaneous transluminal angioplasty. Numbers in parentheses indicate percentage of interventions performed using CO_2 fistulography alone.

*The patient had undergone previous fistulography, against which we could compare findings from the present intervention.

†Data are from χ^2 test or Fisher's exact test.

thrombotic occlusion, an outflow vein proximal to the occlusion could not be identified, and iodinated contrast agent was used. We guessed that CO_2 could not enter the main outflow vein from collateral pathways because CO_2 was less likely to enter branch vessels. In all such patients, the main outflow vein proximal to occlusion could be visualized by fistulography using iodinated contrast.

After thrombolysis or recanalization of nonthrombotic occlusions, balloon dilatation was performed in the same manner as in patients without occlusion. As a result, CO_2 can be used in fistulography. In addition, CO_2 fistulography was sufficient for observing hemodialysis access segments that were not involved with lesions. Therefore, even in patients with thrombosis, the usage of iodinated contrast agent can be reduced.

Among the patients with past fistulogram, the present intervention was performed using only CO_2 in 94%. When we were able to refer to a previous fistulogram, performing PTA using CO_2 fistulography alone became much easier, even if fistulography was inadequate due to access failure.

With a native fistula, CO_2 was injected at least once from the brachial artery to assess anastomosis. Caution was exercised to prevent CO_2 from flowing in a retrograde fashion into the subclavian artery. However, because CO_2 was compressed in a syringe and then injected explosively, some practice was required to inject CO_2 while avoiding retrograde flow into the subclavian artery. We injected CO_2 while attempting to prevent flow into the subclavian artery, but CO_2 flowed in a retrograde fashion into the subclavian and aortic arch in three native accesses, and reached the cerebral vessels to cause neurological symptoms. Although neurological symptoms were mild in our study, major complications may result if a large quantity of CO_2 enters the cerebral vessel. Caution must be exercised when injecting CO_2 through the brachial artery. In particular, when CO_2 is injected from the brachial artery of a native fistula with low access flow, extreme caution is warranted.

In patients with graft access, Ehrman et al. reported that when they attempted to evaluate arterial anastomosis using the "reflux" technique, three of five patients showed significant, if transient, neurological sequelae. They noted that if evaluation of arterial anastomosis is necessary, extreme caution should be used (13). In the present study, to assess arterial anastomosis in a graft access, fistulography was performed by injecting CO_2 in a retrograde fashion under balloon occlusion. With this technique, CO_2 could be gradually injected manually, and retrograde CO_2 flow into the subclavian artery did not occur. Likewise with native fistula, we considered the "reflux" technique as unsafe and injected CO_2 via the brachial artery to evaluate the anastomosis.

The present study shows several limitations. The size of the patient population was small. We used a power injector to show CO_2 injection status as a numerical value. We determined the rate for power injection based on injection time of CO_2 during manual injection, and this measurement was based on the perceptual skill of the operator. This is inaccurate, as the compressibility of gas results in an explosive injection. For the same reason, injection rate was also inaccurate on power injection. Use of a dedicated CO_2 injector may overcome some of these problems, but we did not have access to such a device.

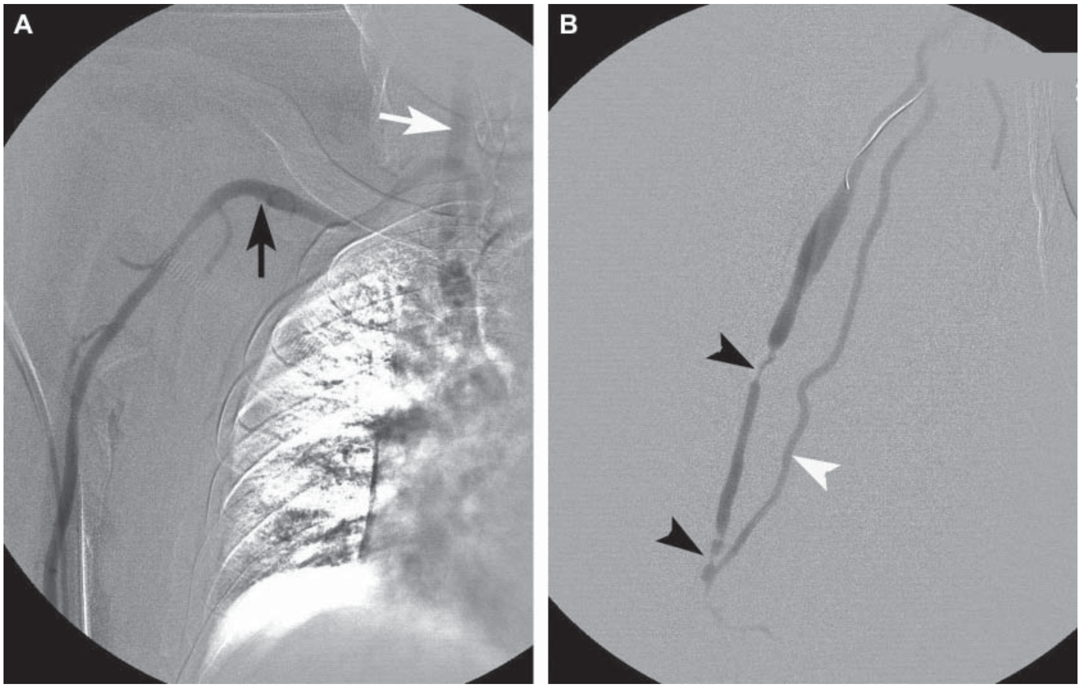

Fig. 4. Patient 2, an 84-year-old man. The patient had a right arteriovenous fistula in the forearm with stenosis of an outflow vein. The patient experienced transient neurological symptoms. (A) CO_2 digital-subtraction angiography (DSA) demonstrates the right subclavian artery (*black arrow*) and right carotid artery (*white arrow*). Fistulography was performed by manually injecting only 20 ml of CO_2 from the right brachial artery using a 50 ml syringe filled with 40 ml of CO_2. CO_2 moved in retrograde fashion up to the brachiocephalic artery, and entered the carotid artery. (B) CO_2 DSA demonstrates stenosis of an outflow vein (*black arrowheads*) and the radial artery (*white arrowhead*).

CO_2 is a gas, and thus does not mix with blood, so the entire vessel must be filled with CO_2 to avoid underestimation of the vessel diameter (13, 24). Ehrman et al. reported that, on average, the percentage stenosis seen on CO_2 images was 16% higher than on corresponding iodinated images (13). In the present study, all patients showed clinical and physiological abnormalities, and the mean percent stenosis for accesses where PTA was indicated was high, at 80.3±12.9%. However, the ≤50% stenosis in the present study could have been assessed as ≥50% stenosis in that study.

In conclusion, diagnosis and intervention could be performed using CO_2 fistulography alone in 82% of cases. CO_2 could be used for fistulography in all diagnoses and interventions if used together with iodinated contrast. When injecting CO_2, especially from the brachial artery, caution must be exercised to prevent CO_2 from flowing in a retrograde fashion into the cerebral circulation. This is extremely important when injecting CO_2 from the brachial artery.

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Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Table 5. Dose of contrast agents and number of CO_2 runs per procedure.

Intervention	No. of accesses	Total dose of CO_2 per procedure (ml)		Number of CO_2 runs per procedure	Total dose of iodinated contrast agent per procedure (ml)	
		Mean	Range	Mean*	Mean	Range
All interventions	141	192	70–560	5.5±2.5	–	–
Using only CO_2	115	194	105–560	5.5±2.7	0	0
Using CO_2 and iodinated contrast agent	26	183	70–385	5.2±2.7	27	6–60

*Data represent means ± standard deviation.

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