Original Report

Noboru Tanigawa[1]
Atsushi Komemushi
Shuji Kariya
Hiroyuki Kojima
Satoshi Sawada

Intraosseous Venography with Carbon Dioxide Contrast Agent in Percutaneous Vertebroplasty

OBJECTIVE. Our objectives were to ascertain whether CO_2 can be used as a contrast agent in venography during percutaneous vertebroplasty and to evaluate whether it might be capable of replacing nonionic iodinated contrast agents.

CONCLUSION. Intraosseous venography with CO_2 contrast agent was slightly inferior to iodine venography in terms of its ability to visualize the vertebral bodies and perivertebral veins, but it remains a useful technique because no interference with optimal visualization of bone cement occurs during the cement injection when CO_2 remains within the fracture cleft.

Percutaneous vertebroplasty has an excellent pain-relieving effect on compression fracture due to various causes [1–7] and has therefore attracted much attention as a new therapeutic technique for this condition. It is a relatively simple technique that involves advancing a needle through the skin and into the affected vertebral body, into which cement is injected. However, the method adopted varies according to the operator and the center at which it is performed. The situation is similar for imaging guidance, with some centers using bilateral fluoroscopy and others using a combination of CT and fluoroscopy [8, 9]. One current focus of technical concern is the necessity of using intraoperative venography, with arguments both in favor and against appearing in the research literature [10–14]. One drawback of venography is the potential pooling of contrast agent in the fracture cleft, which interferes with the optimal visualization of bone cement during the cement injection. We have therefore experimented with the use of CO_2 as a contrast agent, an inexpensive alternative that does not interfere with the optimal visualization of bone cement when it remains in the cleft after venography during vertebroplasty. A further advantage is that CO_2 can also be used in patients with iodine hypersensitivity.

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Subjects and Methods

This study was approved by the institutional review board. All patients gave informed consent in writing.

The study population consisted of 26 consecutive patients who underwent 47 vertebroplasties at our institute between May and June 2003. Mean age was 71.2 years, and subjects comprised five men and 21 women. Vertebroplasty was performed on 47 vertebral bodies, of which 22 were thoracic and 25 were lumbar. Forty-seven intraosseous venographies with CO_2 and iodine contrast medium during vertebroplasty were evaluated. The cause of compression fracture was osteoporosis in all cases.

Vertebroplasty was performed under combined CT and fluoroscopic guidance (Advantex LCA and ACT, GE Healthcare). Thirty minutes preoperatively, morphine hydrochloride ([10 mg] Sankyo), atropine sulfate ([0.5 mg] Tanabe), and hydroxyzine hydrochloride ([25 mg] Pfizer Japan) were administered intramuscularly. Local anesthesia with 1% lidocaine ([10 mL] AstraZeneca) was per-

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[1]All authors: Department of Radiology, Kansai Medical University, 10-15, Fumizono, Moriguchi, Osaka 570-8507, Japan. Address correspondence to N. Tanigawa (tanigano@takii.kmu.ac.jp).

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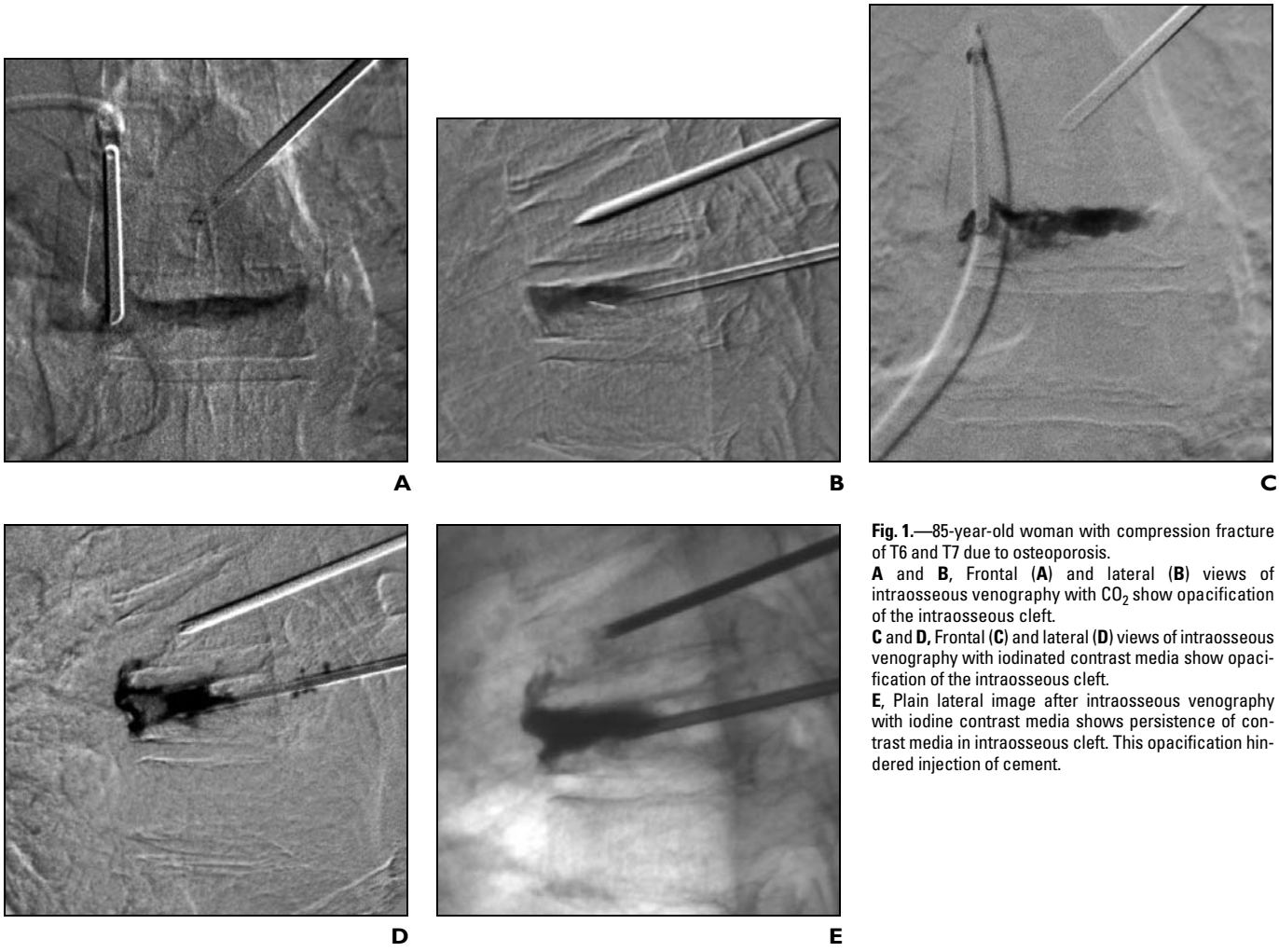

Fig. 1.—85-year-old woman with compression fracture of T6 and T7 due to osteoporosis.
A and **B**, Frontal (**A**) and lateral (**B**) views of intraosseous venography with CO_2 show opacification of the intraosseous cleft.
C and **D**, Frontal (**C**) and lateral (**D**) views of intraosseous venography with iodinated contrast media show opacification of the intraosseous cleft.
E, Plain lateral image after intraosseous venography with iodine contrast media shows persistence of contrast media in intraosseous cleft. This opacification hindered injection of cement.

formed from the shin to the periosteum of the pedicle by using a 22-gauge Cathelin needle (Terumo Europe) under fluoroscopic guidance. After orientation of the puncture needle was confirmed on CT and aligned with the Cathelin needle, a 13-gauge bone biopsy needle (Osteo-Site, Murphy M2, Cook) was advanced into the pedicle of the vertebral arch. CT was repeated, and after the orientation of the biopsy needle was confirmed, the visualization technique was changed to lateral fluoroscopy and the bone biopsy needle was advanced to the anterior third of the vertebral body close to the midline under lateral fluoroscopic guidance. Venography was then performed using CO_2 as a contrast agent. CO_2 was drawn through a sterile filter into a 10- or 20-mL syringe from a CO_2 generator (Gaster, Asahi Keiki). The syringe containing CO_2 was connected to the bone biopsy needle via extensible tubing. Then CO_2 was injected manually, and frontal and lateral venograms were obtained using digital subtraction angiography. The amount of CO_2 used in venography was 10 mL for thoracic and 20 mL for lumbar vertebrae. Data collection for digital subtraction angiography was performed with a 12-inch (31-cm) image intensifier and nine frames per second. Venography using a nonionic iodine contrast agent was then performed. The nonionic iodine contrast agent (Iopamidol [300 mg I/mL], Schering Japan) was injected manually at a volume of 3–5 mL, and venography using digital subtraction angiography (frontal and lateral) was performed under the same conditions as those used for CO_2 venography.

CO_2 venograms were evaluated relative to the gold standard of iodine venography, with evaluations performed separately for the vertebral body region and the perivertebral vein region. In evaluating venograms of the perivertebral veins, we judged the most central drainage vein leading from the vertebral body visualized under iodine venography to be the same vein visualized on CO_2 venography. Two interventional radiology specialists independently evaluated the CO_2 and iodine venograms and negotiated agreement if the two opinions differed. Reversed positive-negative images were used for CO_2 venography.

Results

Vertebral Body Region

CO_2 venography could be performed for all patients, and no complications were documented. We compared CO_2 and iodine venographic findings for the vertebral body region.

With iodine venography, the venographic pattern was evaluated as bilateral marrow blush for 32 vertebrae. On CO_2 venography of these 32 vertebrae, 26 images showed bilateral marrow blush, similar to that seen with iodine, whereas the venographic pattern was evaluated as unilateral marrow blush in two cases. In the remaining four subjects, evaluation with CO_2 venography was not possible because of the absence of contrast enhancement of the vertebral body itself. With iodine venography, the venographic pattern was evaluated as unilateral marrow blush in seven

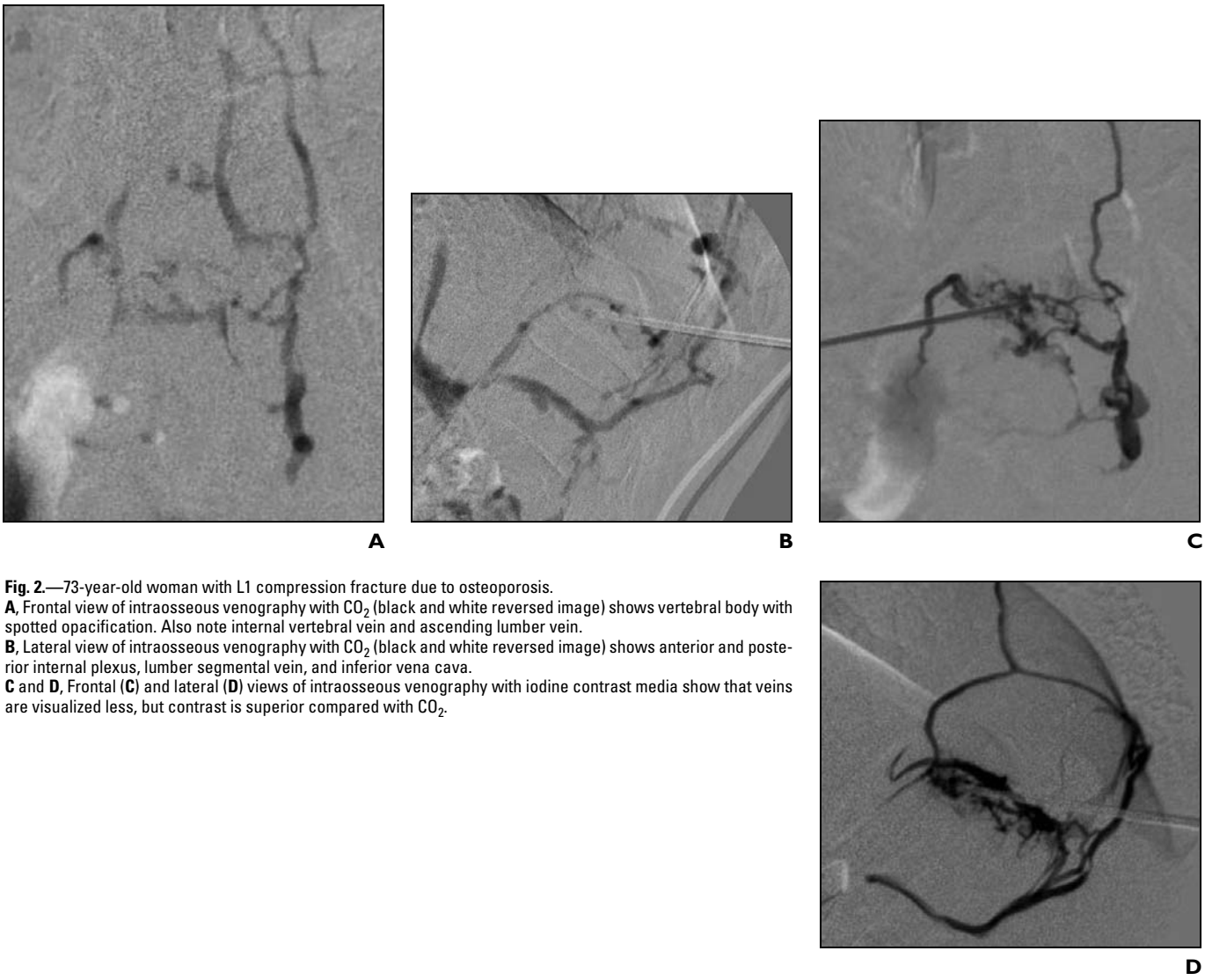

Fig. 2.—73-year-old woman with L1 compression fracture due to osteoporosis.
A, Frontal view of intraosseous venography with CO_2 (black and white reversed image) shows vertebral body with spotted opacification. Also note internal vertebral vein and ascending lumber vein.
B, Lateral view of intraosseous venography with CO_2 (black and white reversed image) shows anterior and posterior internal plexus, lumber segmental vein, and inferior vena cava.
C and **D**, Frontal (**C**) and lateral (**D**) views of intraosseous venography with iodine contrast media show that veins are visualized less, but contrast is superior compared with CO_2.

vertebral bodies. On CO_2 venography, images of five of these vertebrae also showed unilateral marrow blush, whereas the pattern was evaluated as bilateral marrow blush in the other two subjects.

In eight vertebrae, a fracture cleft was visualized on iodine venography and similarly evaluated as a fracture cleft on CO_2 venography. In these eight vertebrae, the contrast agent was aspirated after iodine venography and the vertebral bodies were flushed with physiologic saline. Nevertheless, this procedure failed to eliminate contrast agent from the cleft, and the interference with optimal visualization occurred during the injection of cement (Fig. 1).

In two venography examinations, the intervertebral disk was visualized on iodine venography and similarly evaluated as the intervertebral disk on CO_2 venography.

Perivertebral Veins

We compared CO_2 and iodine venography of perivertebral veins. The results are shown in Table 1. Of 47 vertebral bodies, the veins were not visualized on iodine venography for four vertebrae with only the cleft being seen in these cases. Among the 43 vertebrae for which the perivertebral veins were visualized on iodine venography, there were 33 (78%) for which the same veins were visualized with CO_2 (Fig. 2). For the remaining 12 vertebrae, the veins proximal to the vertebral body that were seen on iodine venography could not be visualized with CO_2.

Discussion

The utility of antecedent venography in determining improved clinical outcomes or decreased complication during vertebroplasty is controversial. Jansen et al. [10] advocated the use of antecedent venography to decrease potential complications associated with incorrect or suboptimal needle placement in the basivertebral venous plexus or in direct connection with a paravertebral vein. McGraw et al. [11] reviewed 135 intraosseous venograms and compared them in a blinded fashion with the subsequent final vertebroplasty result and concluded that intraosseous venography provides useful information in predicting polymethylmethacrylate (PMMA) flow characteristics within the vertebral body and in predicting potential undesirable sites of cement deposition,

TABLE 1 Findings of CO_2 and Iodine Venography: Perivertebral Veins

Veins Visualized				CO_2 Venography	Iodine Venography
BV+	IV+	PV+	SVC/IVC/CIV	3	2
BV+	IV+	PV		0	8
BV+	IV+			0	1
	IV+	PV+	SVC/IVC/CIV	8	4
	IV+	PV		18	16
		PV+	SVC/IVC/CIV	7	2
		PV		9	10
		None		1	4
Undetermined				1	0

Note.—BV = basivertebral vein, IV = internal vertebral veins, PV = paravertebral veins, SVC = superior vena cava, IVC = inferior vena cava, CIV = common iliac vein, None = only the fracture cleft was visualized and no veins were seen, Undetermined = could not be determined due to poor image.

such as through cortical defect and within venous structures. On the contrary, because of differences in the viscosity and flow characteristics of contrast material and cement, venographic findings are not predictive of the actual flow of PMMA cement and the path of extravasation [7, 8, 12]. Moreover, Gaughen et al. [13, 14] mentioned that antecedent venography did not significantly augment the effectiveness or safety of percutaneous vertebroplasty procedures performed by this group of experienced interventional neuroradiologists.

To delineate a potentially dangerous route by which PMMA cement might escape the confines of the vertebral body, we have performed venography in all cases. However, sometimes the persistence of intravertebral opacification obscured visualization of cement, especially during an injection into a fractured cleft or through the endplates to the intravertebral disks. Therefore, we investigated whether CO_2 could be used as a contrast agent in place of iodine.

CO_2 has been advocated as an angiographic contrast agent with the aim of reducing the incidence of contrast-induced nephropathy in patients with renal insufficiency. Its benefits have been described previously [15, 16]. Because CO_2 is a gas and rapidly flows out of the target vessels, it may be necessary to inject a large amount of it in a short time, as compared with an iodine contrast agent. Therefore, contrast enhancement with CO_2 may extend to more distal veins than those visualized with an iodine contrast agent. In light of these factors, we adopted the following criteria when evaluating the visualization of perivertebral veins: Rather than evaluating which blood vessel was being visualized with a CO_2 contrast agent, we defined the findings of iodine venography as the gold standard and evaluated the extent to which the veins close to the vertebra seen under iodine venography were also visualized with CO_2. The outcome of this procedure was that veins proximal to the vertebral body that were visualized on iodine venography were also visualized with CO_2 in 33 (78%) of 43 cases. However in 20% of cases, either the veins visualized with iodine were not seen with CO_2 or the evaluation was not possible. Possible causes for this outcome include reflexive patient movement in response to pain associated with the increase in intravertebral pressure immediately after injection and motion artifacts caused by inadequate breath-holding. Such patient movement occurred similarly in patients imaged with CO_2 and in those imaged with an iodine contrast agent. However, degradation of the image due to motion artifacts appears to be more severe in CO_2 venography than in iodine venography.

With respect to visualization of vertebral bodies, the rate of agreement between venography with CO_2 and that with iodine was 75.5%. The difference in visualization between the two techniques appears to be due to the effect of motion artifacts, as might be expected. All clefts and intervertebral disks that were visualized with iodine venography were also seen with CO_2 venography.

Bone cement and CO_2 differ appreciably in their viscosity, and it may be difficult to predict the distribution characteristics of cement from the results of CO_2 venography. However, the anatomy of the perivertebral veins can be evaluated and serves as a reference for the injection of cement. Furthermore, in patients with a fracture cleft, there is absolutely no impediment to cement injection due to stasis of contrast agent when using CO_2, thus indicating its usefulness.

In conclusion, CO_2 venography can be safely performed. However, it is slightly inferior to iodine venography with respect to contrast enhancement of the vertebral body of interest and its perivertebral veins. Therefore, we do not believe that CO_2 venography can completely replace venography performed with an iodine contrast agent. In situations in which preoperative diagnostic imaging reveals the presence of a fracture cleft, CO_2 can be used as a successful alternative choice for venography.

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