Original Report

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Using CO_2-Enhanced Arteriography to Investigate Acute Gastrointestinal Hemorrhage

OBJECTIVE. The objective of the study was to compare the efficacy of CO_2-enhanced arteriography with that of arteriography enhanced with standard iodinated contrast material in the detection of gastrointestinal hemorrhage.

CONCLUSION. For acute gastrointestinal hemorrhage, we did not find an advantage to using CO_2 to show active bleeding. In fact, CO_2 was inferior to iodinated contrast material in revealing nonbleeding vascular anomalies.

Acute gastrointestinal hemorrhage is a common cause of morbidity and mortality. In most cases the source of bleeding is identified at endoscopy, but in 10–20% of patients no bleeding point is shown [1]. Diagnosis in this group often relies on radiologic investigation.

Selective mesenteric arteriography has an established role in the investigation of gastrointestinal hemorrhage, having been reported to show relevant abnormalities (i.e., abnormal vessels or a bleeding point) in approximately 60% of patients for whom no cause was seen at endoscopy [2]. However, in up to one third of patients angiography fails to show abnormalities [2], some of which are subsequently diagnosed at surgery. Attempts to improve the positive yield from arteriography include the use of pharmacologic agents to stimulate local hemorrhage [3, 4]. Reported results have varied, and severe, uncontrolled hemorrhage is a risk.

More recently, attention has focused on the potential advantages of CO_2-enhanced arteriography [5]. CO_2 has been shown to be a safe intraarterial contrast agent with a negligible associated risk of contrast reaction or nephrotoxicity [5]. Also, CO_2 possesses a number of favorable physical characteristics. After intravascular injection, CO_2 displaces but does not mix with blood and, therefore, is not diluted. Its buoyancy theoretically enhances opacification of nondependent vessels, such as the celiac axis and superior mesenteric artery. Its low viscosity enables it to pass through vascular defects, and once in the extravascular space the gas expands, thus maximizing the amount of contrast agent at sites of abnormality.

This study was designed to evaluate prospectively the role of CO_2-enhanced arteriography in the investigation of acute gastrointestinal hemorrhage. We had the approval of the local ethics committee.

Subjects and Methods

Fifteen consecutive patients referred for arteriographic investigation of acute gastrointestinal hemorrhage were enrolled in the study. Three patients had previously undergone iodinated contrast–enhanced arteriography and were included in the study because of continued gastrointestinal blood loss.

We used a standard transfemoral approach and 5-French selective femorovisceral catheters (Simmons or Cobra; Terumo, Tokyo, Japan; or Sos-Omni; Angiodynamics, Queensbury, NY) to consecutively catheterize the celiac axis, superior mesenteric artery, and inferior mesenteric artery. In three patients superselective catheterization was also performed. All patients underwent iodinated contrast–enhanced angiography using iopamidol (Niopam; Bracco, Milan, Italy) followed by CO_2-enhanced angiography. In two patients the entire procedure was repeated a few days later because bleeding began again.

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The volume of iodinated contrast material injected varied between 36 and 42 ml at flow rates of 6–7 ml/sec. For the inferior mesenteric artery 8–10 ml was injected by hand. The CO_2 was delivered using an automated injection system (CO_2JECT; Angiodynamics). The volume of CO_2 injected per vessel ranged from 30 to 50 ml (median, 50 ml) at flow rates of 10–30 ml/sec. For superselective studies the same volume of CO_2 was used and the flow rate was reduced to 5–15 ml/sec. Postembolization images were acquired using both CO_2 and iodinated contrast material.

Digitally subtracted images were acquired on an Advantx LCA angiography system (General Electric Medical Systems, Milwaukee, WI) after administration of intraarterial hyoscine-*N*-butyl bromide (Buscopan; Boehringer Ingelheim, Bracknell, England) during suspended respiration. Images were acquired at a rate of three per second for the first 6 sec and then every second to a maximum of 30 sec. A 1024 × 1024 imaging matrix was used, and images were postprocessed and remasked.

TABLE 1 Correlation Between Contrast Agents and Vessels

Contrast Agent	Vessel Imaged		
	Celiac Axis	SMA	IMA
Iopamidol	17	16	8
CO_2	16	14	4

Note.—Seventeen studies were performed in 15 patients. SMA = superior mesenteric artery, IMA = inferior mesenteric artery.

TABLE 2 Number of Abnormalities Found with Each Agent

Clinical History		Contrast Agent	
Episode Type	*n*	Iopamidol	CO_2
Single	11	3	2
Multiple	4	2	0
Total	15	5	2

Results

Ten men and five women who ranged from 29 to 81 years old (median, 64 years) were examined. All patients presented with acute gastrointestinal blood loss. Eleven patients had no previous history of gastrointestinal hemorrhage, and four patients had a history of multiple previous episodes for which no cause had been found. Thirteen patients presented with melena and two with hematochezia.

Seventeen studies were performed on 15 patients. Forty-one vessels were imaged using iodinated contrast material, and 34 were also imaged using CO_2 (Table 1). In one study the superior mesenteric artery was not imaged using iodinated contrast material because the bleeding point had been identified in the celiac circulation. The inferior mesenteric artery was not imaged using iodinated contrast material in nine studies. In four instances, an abnormality had already been identified; in two, the patient had undergone previous aortic surgery; in one, atheroma prevented catheterization of the inferior mesenteric artery; in one, upper gastrointestinal blood loss was evident at endoscopy; and in one, the procedure was abandoned at the patient's request.

The use of CO_2 enhancement was abandoned in two patients because of intolerable abdominal discomfort. In two other patients the inferior mesenteric artery was not imaged using CO_2 because, in one, stabilization of coexistent respiratory problems became a priority and, in the other, urgent transfer to the operating theater was necessary.

Potential sources of hemorrhage were identified in five patients using iodinated contrast–enhanced arteriography (Table 2). In three, each of whom presented with a single episode of acute gastrointestinal blood loss, active bleeding was seen. CO_2-enhanced angiography showed active bleeding at the same site in two of these patients (Fig. 1). The bleeding points were successfully embolized in two patients, and the third patient was treated surgically.

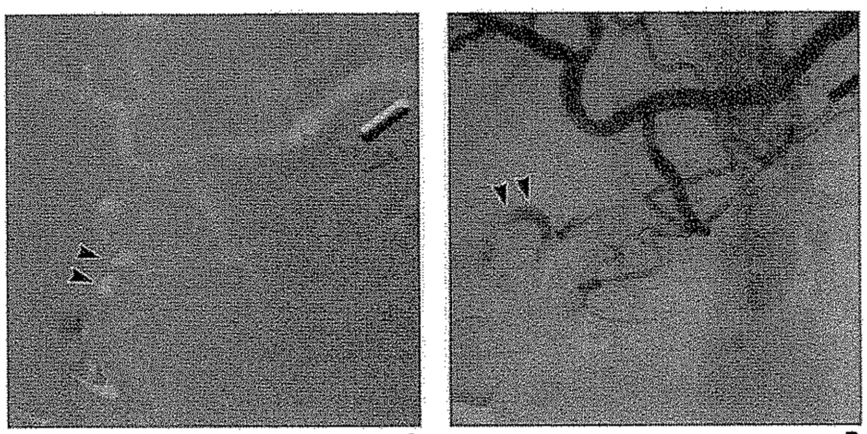
In the other two patients, the iodinated contrast–enhanced arteriogram showed an abnormality that was not actively bleeding but was thought to be a likely source of the gastrointestinal hemorrhage (Fig. 2). CO_2-enhanced angiography showed neither active bleeding nor any other abnormality in these patients. Both these patients proceeded to surgical resectioning. The results of histologic examination of the specimens were inconclusive, and the lesions were considered to be small areas of telangiectasia. Neither of the patients has presented again with gastrointestinal bleeding.

Of the 10 patients with no abnormality shown by angiography, seven have remained well; two proceeded to surgery, at which a diagnosis was made; and the other died from an unrelated cause.

Discussion

CO_2 was first used as an intraarterial contrast agent in the early 1970s. Contrast resolution on the standard radiographic images was poor, and not until the advent of digital subtraction imaging in the 1980s did CO_2-enhanced arteriography become a feasible alternative to iodinated contrast–enhanced angiography [6]. The current indications for use of CO_2 are a reflection of both its safety and its unique physical properties [5]. These indications include imaging of patients with renal impairment or iodine sensitivity, demonstration of arteriovenous shunting within tumors and arteriovenous malformations, and accurate assessment of tumor vascularity.

More recently, the detection of arterial bleeding has been proposed as another indi-



A B

Fig. 1.—79-year-old man with life-threatening gastrointestinal hemorrhage.
A, Selective celiac axis digital subtraction arteriogram obtained with CO_2 administration shows extravascular CO_2 (*arrowheads*) arising from branch of gastroduodenal artery. Later arteriogram (not shown) revealed CO_2 within duodenal loop.
B, Selective celiac axis digital subtraction arteriogram obtained with iodinated contrast administration reveals active bleeding (*arrowheads*). Note delineation of feeding vessels.

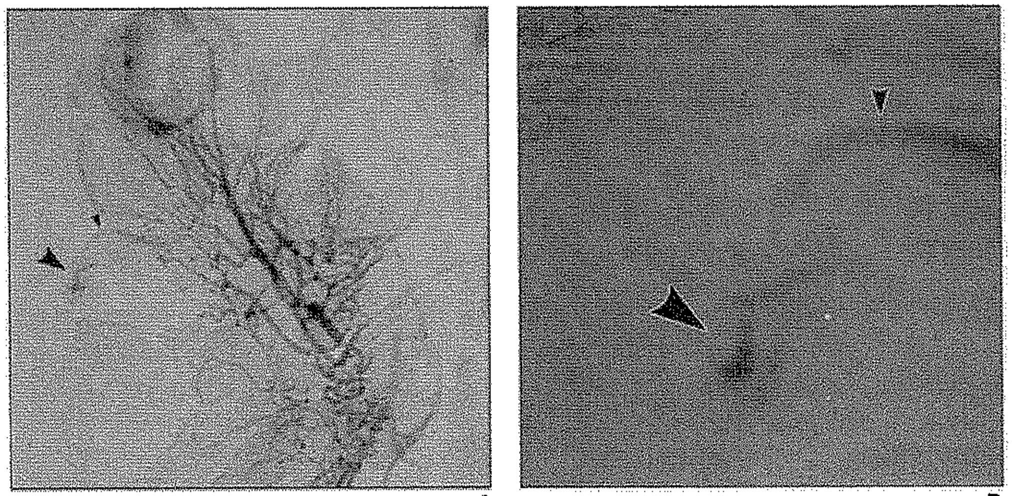


Fig. 2.—34-year-old man with 2-year history of recurrent gastrointestinal hemorrhage. Images show nonbleeding vascular lesion in right hemicolon (*large arrowhead*) as well as early filling of draining vein (*small arrowhead*). This finding was considered to be small telangiectatic lesion.
A, Selective superior mesenteric artery digital subtraction arteriogram obtained with iodinated contrast administration.
B, Coned-down view of **A**. We regret that we are unable to illustrate the corresponding CO_2-enhanced image. No hard copy was made.

cation for CO_2-enhanced arteriography [5]. In a study of 15 patients, CO_2 showed arterial bleeding sites in 11 patients whereas iodinated contrast material revealed these sites in only seven patients (Textor HJ et al., presented at the Society of Cardiovascular and Interventional Radiology meeting, September 1998). In our study, we failed to show any advantage to using CO_2 to identify bleeding sites within the gastrointestinal tract.

A possible explanation for our findings is that the study was small and the data may therefore have been unrepresentative. Furthermore, although the positive yield from iodinated contrast–enhanced arteriography has been reported to vary between 43% and 87% [7, 8], in this study presumed sites of bleeding were identified in 33% of patients, with only three patients (20%) showing active hemorrhage. Second, accurate catheter placement and controlled CO_2 delivery are essential to obtaining CO_2-enhanced arteriograms of diagnostic quality [5]. We performed selective and, in some cases, superselective mesenteric catheterization, and the CO_2 was delivered using an automated system that should abolish the problems of explosive delivery [5]. The technical factors were therefore considered optimal, and that they were so is supported by CO_2-enhanced arteriography's correctly showing two of the three sites of active hemorrhage. However, spatial resolution on CO_2-enhanced arteriograms was relatively poor, with fragmentation of the CO_2 bolus, and although this problem may not be important for showing active bleeding, identification of small vascular lesions was impossible.

The quality of digitally subtracted images can be reduced by patient movement. Intraarterial administration of iodinated contrast material rarely results in patient movement. However, in our experience, administration of CO_2 frequently results in abdominal discomfort and consequent patient movement. In two patients the procedure had to be abandoned because of abdominal pain after CO_2 injection, and in another patient the images were so severely degraded that active hemorrhage seen on the iodinated contrast–enhanced study could not be seen on the CO_2-enhanced study. Abdominal discomfort, nausea, and vomiting are recognized side effects of CO_2 and are experienced after injection into the abdominal aorta [9]. The exact mechanism of the response is unknown, but causes include patient apprehension and IV glucagon [9]. The response can be reduced by administering small-volume test injections before image acquisition. This procedure was relatively ineffective in our study, suggesting that other factors, such as local concentration of CO_2 within the mesenteric vessels, may have a role. Movement of gas within the bowel despite intraarterial spasmolytic agents also contributed to motion artifacts. In addition, some patients, particularly elderly patients, had difficulty holding their breath. The best CO_2-enhanced studies were in patients who were paralyzed and ventilated.

In conclusion, in patients presenting with acute gastrointestinal hemorrhage, CO_2-enhanced arteriography is both difficult to perform and difficult to interpret. We could find no diagnostic advantage to using CO_2 to show active bleeding in the gastrointestinal tract. In addition, CO_2 was inferior to iodinated contrast material in showing small, nonbleeding vascular abnormalities. These are often the cause of acute gastrointestinal blood loss and, in one study, accounted for 65% of all true-positive abnormalities shown by angiography [2].

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References

1. Rollins ES, Picus D, Hicks ME, Darcy MD, Bower EL, Kleinhoffer MA. Angiography is useful in detecting the source of chronic gastrointestinal bleeding of obscure origin. *AJR* **1991**;156: 385–388
2. Whitaker SC, Gregson RHS. The role of angiography in the investigation of acute or chronic gastrointestinal hemorrhage. *Clin Radiol* **1993**;47: 382–388
3. Malden ES, Hicks ME, Royal HD, Aliperti G, Allen BT, Picus D. Recurrent gastrointestinal bleeding: use of thrombolysis with anticoagulation in diagnosis. *Radiology* **1998**;207:147–151
4. Rosch J, Keller FS, Wawrukiewicz AS, Krippaehne WW, Dotter CT. Pharmacoangiography in the diagnosis of recurrent massive lower gastrointestinal bleeding. *Radiology* **1982**;145:615–619
5. Hawkins IF, Caridi JG. Carbon dioxide (CO_2) digital subtraction angiography: 26-year experience at the University of Florida. *Eur Radiol* **1998**;8:391–402
6. Hawkins IF. Carbon dioxide arteriography. *AJR* **1982**;139:19–24
7. Fiorito JJ, Brandt LJ, Kozicky O, Grosman IM, Sprayragen S. The diagnostic yield of superior mesenteric angiography. *Am J Gastroenterol* **1989**;84:878–881
8. Bar AH, DeLaurentis DA, Parry CE, Keohane RB. Angiography in the management of massive lower gastrointestinal tract hemorrhage. *Surg Gynecol Obstet* **1980**;150:226–228
9. Kerns SR, Hawkins IF Jr. Carbon dioxide digital subtraction angiography: expanding applications and technical evolution. *AJR* **1995**;164: 735–741