Experimental Study on Acute Ischemic Small Bowel Changes Induced by Superselective Embolization of Superior Mesenteric Artery Branches with *N*-Butyl Cyanoacrylate

Hwan Jun Jae, MD, Jin Wook Chung, MD, Hyo-Cheol Kim, MD, Young Ho So, MD, Hyung Guhn Lim, MD, Whal Lee, MD, Byoung-Kwon Kim, MD, and Jae Hyung Park, MD

PURPOSE: To evaluate the degree of ischemic changes of the small bowel after superselective embolization of superior mesenteric artery (SMA) branches at the vasa recta level with *N*-butyl cyanoacrylate (NBCA) in dogs.

MATERIALS AND METHODS: In six dogs, superselective embolization was performed with NBCA in five isolated branches of the SMA at the vasa recta level. All dogs were sacrificed 24 hours after embolization. According to the extent of the NBCA mixtures on radiographs of the specimen, embolized segments were divided into group A (embolization of three or fewer vasa recta) or group B (embolization of four or more vasa recta). Histologic evaluation of the mucosal, submucosal, and muscle layers of the embolized segments was performed by a pathologist.

RESULTS: In group A (n = 15), histologic findings were normal in seven segments (47%). Mild ischemic changes were noted in the mucosal layer in eight segments, the submucosal layer in four segments, and the muscle layer in one segment. In group B (n = 15), ischemic changes were noted in the mucosal layer in all 15 segments, the submucosal layer in 14 segments, and the muscle layer in 10 segments. The difference in ischemic damage between groups A and B was statistically significant.

CONCLUSIONS: Superselective embolization involving three or fewer vasa recta of the SMA was relatively tolerable, and embolization involving four or more vasa recta carried an increased risk of substantial ischemic bowel damage. Further studies are necessary to determine the clinical implications of our findings in human subjects.

J Vasc Interv Radiol 2008; 19:755–763

Abbreviations: NBCA = N-butyl cyanoacrylate, SMA = superior mesenteric artery, TAE = transcatheter arterial embolization

IN 1972, Rosch et al (1) introduced the technique of transcatheter arterial embolization (TAE) as an alternative to surgery in the control of upper gastrointestinal bleeding. Bookstein et al (2) also performed TAE with an autologous clot to stop lower gastrointestinal bleeding in 1974. Although TAE has been a widely accepted treatment modality for the management of upper gastrointestinal bleeding (3–5), it has not achieved the same recognition for lower gastrointestinal bleeding. The stomach and duodenum have a rich collateral blood supply that is generally sufficient to prevent ischemic complications of embolization. In contrast, the lower gastrointestinal tract does not have a rich collateral supply (6). The potential risk of bowel infarction after TAE of lower gastrointestinal bleeding is, therefore, expected to be greater. In early lower gastrointestinal tract embolization series, bowel infarction occurred at an unacceptably high frequency—as high as 20%–33% (2,7). The high rates of infarction in these early series were probably related to the relatively large-caliber catheters (usually 5–6.5 F) used and more limited embolic agents (autologous clot and gelatin sponges) available to the early investigators (8). Superselective embolization could not be performed with these limitations, and, thus, much larger vascular territories than necessary were often occluded.

Therefore, from the mid 1970s through the early 1990s, TAE for lower gastrointestinal bleeding was largely abandoned in favor of vasopressin in-

From the Departments of Radiology (H.J.J., J.W.C., H.C.K., Y.H.S., W.L., J.H.P.), Emergency Medicine (H.J.J.), and Pathology (B.K.K.), Seoul National University Hospital, 28 Yongon-dong, Chongno-gu, Seoul, 110-744, Korea; and the Department of Radiology, Chosun University College of Medicine, Gwangju, Korea (H.G.L.). Received July 20, 2007; final revision received and accepted January 22, 2008. From the SIR 2007 annual meeting. **Address correspondence to** J.W.C.; E-mail: chungjw@radcom.snu.ac.kr

None of the authors have identified a conflict of interest.

DOI: 10.1016/j.jvir.2008.01.024

fusion (8). Although vasopressin infusion was associated with a high initial control rate, it was not an ideal treatment option for lower gastrointestinal bleeding because of a high rebleeding rate (20%–50%) and cardiovascular complications including coronary vasoconstriction and arrhythmia (9–11).

However, there have been remarkable advances in low-profile coaxial catheter systems, embolic agents, and digital angiographic equipment. With these, we can select small target vessels more easily without spasms, and can embolize them more accurately.

Recently, several articles reporting successful embolization at the vasa recta level have been published, and superselective embolization has emerged as a practical treatment option for lower gastrointestinal bleeding (9,12–14). However, this improvement with superselective embolization has decreased, but does not eliminate, the risk of bowel ischemia (12). To our knowledge, there has not been much discussion focused on ischemic bowel changes after superselective embolization with recent techniques and equipment. Thus, the purpose of our study was to evaluate the degree of ischemic changes of the bowel after superselective embolization of superior mesenteric artery (SMA) branches at the vasa recta level with *N*-butyl cyanoacrylate (NBCA) in dogs.

MATERIALS AND METHODS

Study Design

Six adult dogs (weight, 20–32 kg) were used for this experiment, and superselective embolization of five isolated target branches of the SMA was performed in each dog. According to the extent of the NBCA embolization on the radiographs of the specimen, embolized segments were divided into two groups, as follows: Group A included segments with embolization of three or fewer vasa recta, and group B included segments with embolization of four or more vasa recta. Mesenteric branches feeding only the small bowel were embolized, and the classification of segments into groups A or B was performed retrospectively after necropsy. This experiment was approved by the animal care committee of our institution.

Figure 1. Baseline angiogram of the SMA obtained with a 5-F cobra catheter after insertion of a femoral sheath.

Preparation of Experimental Animal

Anesthesia was induced by means of intramuscular injection of 20 mg of ketamine hydrochloride (Ketalar; Yuhan Yanghang, Seoul, Korea) and 40 mg of xylazine hydrochloride (Rompun; Bayer Korea, Seoul, Korea) and maintained with intravenously administered tiletamine-zolazepam (Zoletil; Virbac, Carros, France). The dogs were positioned supine, and their legs were tethered. The right inguinal area was sterilized, and all procedures were performed aseptically.

Superselective Embolization

A 5-F introducer sheath was inserted into the femoral artery by means of a Seldinger technique under ultrasonographic guidance. A baseline angiogram of the SMA (**Fig 1**) was obtained with a 5-F cobra catheter (Cook, Bloomington, Indiana). A 3-F microcatheter (Microferret; Cook) was coaxially placed through the 5-F catheter and positioned distally into isolated mesenteric branch vessels at the vasa recta level. We performed superselective embolization in the five isolated target branches of the SMA in each dog. To overcome the possible interruption of collateral supply to the adjacent embolized bowel segment, we tried to separate the target arteries as far as possible. We planned not to enroll the neighboring embolized bowel segments if the distance between embolized segments was less than 30 cm at inspection after sacrifice.

Superselective embolization was performed by experienced interventional radiologists (H.J.J., J.W.C.) with use of an NBCA mixture. Embolization techniques were as follows: NBCA was mixed with iodized oil (Lipiodol; Andre Guerbet, Aulnay-Sous-Bois, France) in a ratio of 1:3. The iodized oil supplied the radiopacity of the mixture and delayed the polymerization time (15). Before injection of the NBCA mixture, the microcatheter was flushed with 5% dextrose solution to prevent premature polymerization of the mixture in contact with residual blood or saline. The NBCA mixture was injected under careful fluoroscopic monitoring. Only a small amount of the NBCA mixture (0.1–0.3 mL) was injected through a 1-mL syringe.

The end point of embolization was decided by the operator according to the extent of glue shown at fluoroscopy. However, the ischemic damage might have been affected by the result of how distal the embolic agent went. Therefore, we tried to vary the extent