PREDICTION OF THE VIABILITY OF REVASCULARIZED INTESTINE WITH RADIOACTIVE MICROSPHERES

CHRISTOPHER K. ZARINS, M.D., Ann Arbor, Michigan, DAVID B. SKINNER, M.D., F.A.C.S., Chicago, Illinois, BUCK A. RHODES, Ph.D., and A. EVERETTE JAMES, JR., M.D., Baltimore, Maryland

Mesenteric vascular occlusion with intestinal ischemia remains an unsolved clinical problem with the mortality rate in excess of 80 per cent. At operation, one frequently is faced with the problem of determining intestinal viability. The decision may be critical for all nonviable intestine must be resected, but enough length must be preserved to maintain sufficient absorptive surface area. The poor reliability of commonly used gross visual criteria, such as intestinal color and vascular pulsation, are well recognized, and a second operation to reassess intestinal viability after 24 hours often is practiced. In search of an objective measure of tissue viability, the presence or absence of reactive hyperemia after revascularization of intestinal segments was investigated. Radionuclide-labeled microspheres were used to assess microcirculatory blood flow.

METHOD

Sixteen fasting adult beagle dogs, weighing between 8 to 14 kilograms, were anesthetized with intravenously administered pentobarbital sodium, 30 milligrams per kilogram. Vascular supply to a 15 centimeter segment of the terminal part of the ileum was occluded by clamping the mesenteric pedicle with a bulldog clamp and compressing the intramural vessels with rubber bands wrapped around the intestinal wall. The abdomen was closed temporarily, and 1,000,000 units of penicillin and 0.25 gram of streptomycin were administered intramuscularly. Hydration was maintained with 250 to 750 milliliters of normal saline solution administered intravenously during the course of the study.

After an ischemic period of four to ten hours, the segment was revascularized by releasing the occluding clamp and bands. Viability was estimated on the basis of color and vascular pulsations ten minutes after restoration of blood flow. Simultaneously, 2 to 4 millicuries of 99mTc-labeled albumin microspheres were injected into the proximal part of the aorta through a previously placed transfemoral 17 gauge catheter. The microspheres, 15 to 30 microns in size, were too large to pass through the capillary bed and lodged in precapillary channels, where they were distributed in relation to blood flow (3). Rectilinear scintiscans were obtained with the intestine spread on a 2 millimeter lead plate to exclude other abdominal radioactivity. In ten dogs, resection of one-half of the injured segment was performed with anastomosis between normal and ischemic intestine using a one layer continuous No. 5-0 wire suture. A scintiscan and a microscopic examination of the resected specimen were performed. The intestine was returned to the peritoneal cavity, and the dogs were allowed to recover without further supportive measures. Four days later, eight dogs underwent repeat laparotomy, microsphere injection, and intestinal scintiscan.

One month later, microspheres were injected into all survivors, adhesions were lysed, and the injured segment was scintiscanned. Barium studies were obtained in several dogs. In two dogs, four ischemic segments of differing duration were prepared. Segments were occluded such that, at the end of ten hours, ischemic segments of four, six, eight, and ten hours existed in each dog. Differences were noted in scintiscanning characteristics after revascularization.

We believe the scintiscans reflected the relative microvascular blood distribution. Radiodensity of the injured segment was compared with that of normal adjacent intestine and judged to be hyperemic if there was definite increased density (Fig. 1); normal if no apparent differences were demonstrable (Fig. 2); or ischemic if the revascularized segment had decreased density compared with that of normal tissue (Fig. 3).

Autopsies were performed on dogs that died


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after operation and all survivors that were sacrificed at one month. Pathologic findings, except those associated with intestinal ischemia, were not present.

RESULTS

Reactive hyperemia and viability. Of 14 scintiscans performed ten minutes after revascularization, five were judged to be hyperemic, four normal, and five ischemic. All five dogs with hyperemic scintiscans had a viable-appearing intestine with normal color and vascular pulsations after revascularization. All segments subsequently proved to be viable. Four dogs survived uneventfully, and in three, mucosal regeneration was complete at one month. The fifth dog died four days postoperatively of necrosis and perforation at a site of excessive mechanical compression by a rubber band used to occlude the intramural blood supply. The injured segment was fully viable with peristaltic activity when scintiscans were done again on the morning of the fourth postoperative day. All four dogs with normal scintiscans had grossly viable intestine at operation. Two were well one month later, one dog died of intestinal infarction after four days, and one dog was moribund and had cachexia after one month due to stricture of the ischemic segment. Among the five dogs with ischemic scintiscans, three intestinal segments appeared grossly viable and two appeared necrotic after revascularization. None proved to be viable, and all five dogs died within six days of sepsis and intestinal necrosis, some having intestinal perforation.

Duration of ischemia and hyperemic response. As the duration of ischemia progressed, the hyperemic response diminished. Hyperemia was maximal in the four hour group but also was seen in the six and eight hour groups. Ischemic scintiscans were seen after as little as four hours’ occlusion and in all of the ten hour segments. Ischemia time alone was a poor predictor of viability, and in the four hour ischemic group, both hyperemic and ischemic scintiscans were seen along with both viable and nonviable intestine. Peristalsis was not noted in the intestine with ischemia time of more than four hours and, when present, was a good indicator of viability.

In two dogs in which simultaneous revascularization of four, six, eight, and ten hour segments was performed, the four segments could not be distinguished on the basis of color or vascular pulsation. Scintiscanning characteristics differed greatly,
however, and marked hyperemia was noted in the four hour segment (Fig. 4).

FOLLOW-UP OBSERVATION SCINTISCS

Four days after the ischemic insult, two dogs from each group were reanesthetized and underwent exploration. Intestinal segments were thickened and edematous and appeared viable in seven of the eight dogs and nonviable in one dog. An area of incipient perforation was present in one segment. Microspheres again were injected intra-aortically, and a scintiscan was obtained. Three dogs had hyperemic scintiscans and all had viable intestine. Five had normal or ischemic scintiscans with two viable segments. Segments that were initially hyperemic were not necessarily hyperemic at four days. Similarly, intestine that initially had a normal scintiscan in some instances became hyperemic after four days—these ultimately were viable. Hyperemia remained a good predictor of viability at four days, but normal or ischemic scintiscans were of little value.

One month after ischemia, seven surviving dogs underwent re-exploration, rescintiscanning, and were sacrificed. A varying degree of fibrosis and mucosal regeneration was present. Mild stricture formation at the point of mechanical compression was common but was not associated with dilatation of the proximal part of the intestine or with evidence of intestinal obstruction. Three segments continued to manifest hyperemia, and in these, fibrosis was more prominent and mucosal regeneration incomplete (Fig. 5). Three segments were healed with full mucosal regeneration and normal scintiscans. In one dog with a normal scintiscan, stricture of the ischemic segment was prominent and symptomatic.

Resection and Anastomosis. Resection of one-half of the injured segment was performed in ten dogs. A scintiscan of the resected specimen confirmed that the increased radioactivity was present within the intestinal wall and not in the intraluminal space. Anastomosis was performed with normal intestine on one side and with injured intestine on the other. The suture line remained intact in eight of the ten dogs.

All six dogs with hyperemic or normal scintiscans had intact anastomoses while two of four dogs with ischemic scintiscans had leaks develop at the suture line. The other two died of infarction and sepsis, but no suture line leak could be demonstrated at postmortem examination. The omentum
was prominent in its attachment to the anastomosis and may have been important in preventing suture line leaks in some dogs.

**DISCUSSION**

The inaccuracy of the gross appearance in assessing intestinal viability has been well documented and was confirmed in this study. Of the 14 dogs, 12 were believed to have viable intestine on the basis of prompt return of color and vascular pulsations. Four proved to have nonviable intestine, and in a fifth a severe stricture developed which would have required intestinal resection for survival. If this dog were included, then the error in predicting viability would be 42 per cent.

Reactive hyperemia has been a consistent finding after revascularization of ischemic muscle and has been shown to be a good predictor of myocardial viability after coronary occlusion. It has been demonstrated to occur in the small intestine by surface temperature measurements and shown to be a good predictor of viability. Reactive hyperemia was demonstrated in this study by the distribution of 15 to 30 micron spheres, and its presence correlated well with intestinal viability. All five dogs with hyperemic scintiscans had viable intestine, although one dog died of a technical error related to excessive mechanical compression of the intestine. Furthermore, the absence of good microvascular flow was found to be a reliable index of nonviability. No dog with a ischemic scintiscan had viable intestine despite its gross appearance. Thus, hyperemia or ischemia as seen by scintiscanning immediately after revascularization was certainly a useful prognostic indicator of viability, while normal scintiscans were of indeterminate predictive value.

Follow-up observation scintiscans at four days and one month were of interest in that they demonstrated the persistence of hyperemia in previously ischemic intestine. Hyperemia detected at those times correlated with injured tissue. Normal scinti-

scans were found in three dogs with fully healed intestine one month later.

Absolute radioactivity was meaningless in this study, since the injected dosage varied from dog to dog. Relative intestinal perfusion was determined by comparison to known, normal, viable intestine. This might be a limitation in clinical use, if no definite viable intestine was present for reference. Quantitative documentation of relative radioactivity is possible using a columnated probe and small portable radiation detector. The description of such a detector, adaptable to operating room use, is being prepared (2). Recently, Moossa and his associates (1), using the same technique described in this article, have studied revascularized colon in rhesus monkeys using quantitative scintiscanning techniques. They confirmed that monkeys exhibiting reactive hyperemia in the ischemic segment had a viable colon, while those with blood flow below normal either died or had a marked pathologic condition evolve during the seven weeks' observation period.

Whether or not nutritional capillary blood flow is represented by microsphere distribution may be questioned. Arteriovenous anastomoses in the intestine may play a role in the apparent perfusion, as seen by microsphere distribution. This, however, seems unlikely, since only 3 per cent of splanchic blood flow passes through arteriovenous anastomoses larger than 20 microns in size.

Both arterial and venous occlusions were produced experimentally. This was analogous to strangulation obstruction but not to intestinal infarction due to arterial occlusion or low flow states. Whether or not this will affect the possible usefulness of this particular technique certainly remains to be seen.

Clinical evaluation of this technique seems warranted. In the future, effective prediction of intestinal viability may improve survival rates and reduce the need for second look procedures after revascularization of intestinal ischemia.
SUMMARY

Viability of ischemic intestine was predicted by documenting the presence of reactive hyperemia after revascularization. Intestinal ischemia of four to ten hours’ duration was surgically induced in 14 dogs.

Ten minutes after intestinal revascularization 99mTc-albumin microspheres were introduced into the aortic blood stream. Scintillation scans documented relative intestinal perfusion. Viable intestine was hyperemic, while nonviable tissue appeared hypoperfused. This method more accurately predicted viability of ischemic intestine than did observation of color or return of pulsations and is adaptable for intraoperative use.

REFERENCES