Revascularization to Prevent Postoperative Bowel Infarction After Surgery for Acute Superior Mesenteric Artery Thromboembolism

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Despite advances in diagnostic techniques, this high mortality has been attributed to difficulties in diagnosis.3 Undue delay in treatment promotes ischemic damage, or may even complete the bowel infarction. Because intestinal ischemia causes local and systemic circulatory disorders,4,5 the surgical treatment of acute SMA thromboembolism usually consists of resection of the necrotic bowel with or without mesenteric arterial revascularization.

Although successful results of bypass surgery for chronic mesenteric ischemia have been reported based on clinical experience,6 controversy persists about the significance and indications of revascularization therapy for acute mesenteric infarction. Ideally, surgery should involve not only the removal of unsalvageable tissue, but also the correction of damaged circulation;7–9 however, the reperfusion of ischemic tissue may be followed by unstable hemodynamics, or by multiple organ distress syndrome.5,10 Nevertheless, the viability of tissue damaged by ischemia is extremely difficult to determine, especially in the acute phase of SMA thromboembolism. In fact, the postoperative course of patients who undergo revascularization is frequently complicated by bypass failure due to coexisting shock, thrombosis, or persistent gut ischemia.10–12

It has been reported that devascularized intestinal segments with a tissue oxygen pressure (t-PO2) of lower than 10 mmHg are at risk of ischemic perforation or necrosis.13 The capability of tissue to recover from the ischemia is thought to be closely related to the local t-PO2.13,14 Accordingly, the combination of revascularization and selective bowel resection under the guidance of a t-PO2 monitor may reduce the risk of postoperative bowel infarction.

This study was conducted to confirm the significance of this treatment in the acute phase of SMA thromboembolism. After 120 min of experimental intestinal ischemia with a t-PO2 of less than 15 mmHg were...
resected, and the postoperative courses were compared between dogs given SMA embolectomy and those that were not. Under the hypothesis that revascularization of the SMA reduces the risk of postoperative mesenteric infarction, we also investigated whether the order of treatments, depending on whether removal of intestine was followed or preceded by the revascularization, made any difference to the final outcome.

Materials and Methods

This study complied with the National Institute of Health Guide for the Care and Use of Laboratory Animals and the guidelines established in the laboratory (Kaken Pharmaceutical, Shizuoka, Japan). Surgery was performed using an aseptic technique.

Animal Preparation

A total of 19 beagle dogs weighing 8–11 kg were used for this study. About 20 ml of blood was collected from each dog about 3 h preoperatively, and 1 cm² of fibrin clot was made from the platelet-poor plasma. After the intramuscular injection of atropine sulfate (0.05 mg/kg) and xylazine hydrochloride (2 mg/kg), pentobarbital sodium (15 mg/kg) was administered intravenously for the induction of general anesthesia. Additional doses of pentobarbital sodium were given, if necessary. After tracheal intubation, respiration was controlled by a ventilator (Shimano, Tokyo, Japan). The intravenous infusion of normal saline was continued during the operations to maintain a normal blood pressure of 80–120 mmHg.

The abdomen was opened via a midline incision, and the SMA was carefully exposed about 3 cm from its aortic origin. The vessel was clamped atraumatically at the proximal and distal portions, and incised transversely to insert the fibrin clot. Preliminary experiments using a Doppler ultrasound flowmeter confirmed that 1 cm² of fibrin clot could acutely deplete the blood flow signal checked at the vasa recta of the jejenum and ileum. The opening in the artery was carefully closed with a polypropylene suture. Systemic arterial blood pressure was measured in the foreleg.

Doppler Ultrasound Flowmetry

A Doppler ultrasound flow meter (ES-111 SP II, Hayashi Denki, Kawasaki, Japan) was used to detect the arterial pressure in the vasa recta of the bowels.

Tissue Oxygen Pressure

Tissue oxygen pressure (t-PO₂) in the subserous layer was monitored using a needle probe connected to a tissue oxygen pressure monitor (PO₂-100 DW, Intermedical, Tokyo, Japan). Measurement of t-PO₂ was made in the middle of the small intestine, before resection. Otherwise, the sites of measurement were chosen as specified below.

Experimental Procedure

The dogs were randomly divided into a control group (group I, n = 7), and an SMA revascularization group (group II, n = 12), 120 min after implantation of the embolus. In group I, the arterial blood supply at the vasa recta along the entire length of the small intestine was examined by a Doppler ultrasound flowmeter. In a certain part of the small intestine, where no Doppler blood flow signal was detected, the t-PO₂ was measured with the tissue oxygen monitor. According to previous research using the tissue oxygen monitor, devascularized small intestine with a t-PO₂ of lower than 15 mmHg has an 85% probability of forming a necrotic lesion. Thus, the intestinal segment with a t-PO₂ of lower than 15 mmHg was resected, and intestinal continuity was reestablished in the conventional manner. In group II, the SMA was opened at the site of the initial incision, and the embolus was removed until the reappearance of maximal blood flow was confirmed.

To compare outcomes after different orders of the operative procedures, group II was further divided into two subgroups. In group IIa (n = 6), thrombectomy was performed after resection of ischemic intestine; and in group IIb (n = 6), 30 min of reperfusion following embolectomy preceded the resection (n = 6). The abdominal incision was closed; and the infusion of saline (100 ml/day) and penicillin G (10 units/day) was continued for 3 days after the operations. No anticoagulants were used in this study.

Histological Examination of the Small Intestine

The small intestine was removed 120 min after the insertion of the thrombus from groups I and IIa, and after 30 min of reperfusion following embolectomy from group IIb. The tissues were fixed in 10% buffered formalin for 5 days and embedded in paraffin. Sections 4 μm thick were made and stained with hematoxylin–eosin.

Extension of Thrombus

At the end of the experiments, a longitudinal incision was made along the SMA. Microscopic sections of emboli were fixed, embedded in paraffin, sectioned, and stained as explained above. Any newly formed red thrombus in the free margins of emboli was easily detected at the low magnification power, since the