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The Relationship Between Sigmoidal Intramucosal pH and Intestinal Arterial Occlusion During Aortic Reconstructive Surgery*

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Objectives: *To investigate the effects of perioperative occlusion of intestinal arteries on clinical outcome and changes in sigmoidal intramuscular pH (pHi). To determine the value of sigmoidal pHi measurement in predicting ischaemic colitis after aortic reconstructive surgery.*
Design: *Prospective, non-selective, open study.*
Materials: *Forty patients undergoing elective aortic infrarenal surgery were monitored with pHi. Pre- and postoperative digital venous subtraction angiography was combined with operative data to evaluate perioperative occlusion of intestinal arteries.*
Results: *All patients had a significant ($p < 0.05$) drop in pHi after aortic clamping which returned to baseline 2–4 h after declamping. None of the patients had clinical signs of ischaemic colitis postoperatively. All patients had angiographically proven, patent superior mesenteric arteries pre- and postoperatively. Patients were divided into three groups: patients with no changes in intestinal arteries ($n = 13$), patients with perioperative occlusion of the inferior mesenteric artery ($n = 22$) and patients with perioperative occlusion of the inferior mesenteric and one or both iliac arteries ($n = 5$); there were no significant differences in pHi values between the groups.*
Conclusions: *Return of the sigmoidal pHi to baseline values within 6–12 h after declamping probably predicts a postoperative course without ischaemic colitis. Perioperative occlusion of the inferior mesenteric artery alone, or in combination with occlusion of one or both internal iliac arteries, does not cause ischaemic colitis in patients whose sigmoidal pHi rises after declamping.*

Key Words: Aortic surgery; Ischaemic colitis; Intramucosal pH; Angiography.

Introduction

Ischaemic colitis after reconstructive surgery of the abdominal aorta is a well known complication with a reported incidence varying from 0.2–10%, depending on the indication for surgery and the diagnostic criteria used.[1–7] Clinically recognised ischaemic colitis has a high mortality rate, whereas clinically less obvious forms of colon ischaemia may cause shock and multiple organ failure.[8] Identified risk factors for the occurrence of ischaemic colitis are: the type of surgery (supra- *vs.* infrarenal; acute *vs.* elective; primary *vs.* redo surgery), history of prior colon surgery, the occurrence of perioperative hypotension and perioperative occlusion of the intestinal arteries.[5,6,9–11]

Non-invasive measurement of intramucosal pH (pHi) of the colon is a promising predictor of intestinal ischaemia and other complications after abdominal aortic surgery with a reported sensitivity of 100% and specificity of 92% for major morbidity.[12–14] The aims of this study were: (1) to investigate the effects of perioperative occlusion of intestinal arteries on clinical outcome and changes in sigmoidal pHi and (2) to determine the value of sigmoidal pHi measurement in predicting clinically important ischaemic colitis.

Materials and Methods

The study was approved by the Medical Ethical Committee of our hospital. After giving informed consent, 40 patients undergoing elective infrarenal aortic surgery were studied prospectively from Sep-

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Table 1. Patients and operations

	n
Sex ratio (M : F)	33 : 7
Mean (range) age (years)	68 (45–86)
Type of disease	
aneurysm	26
occlusive disease	14
Type of surgery performed	
tube graft	12
aortic bifurcation graft	27
aortic endarterectomy	1
IMA reimplantation	4

tember 1991 to May 1993. Demographic and surgical data are given in the Table 1.

Sigmoid pHi was measured using a tonometer (Tonometrics, Bethesda Maryland, U.S.A.), arterial blood gas samples and a conventional blood gas analyser (Ciba Corning 288, Medfield, U.S.A.). The tonometer consists of a silicon balloon which is filled with saline, the carbon dioxide produced by the intestinal mucosa diffuses into the balloon. The partial carbon dioxide pressure of the sample in the balloon can be measured and its value, corrected for equilibration period ($PtCO_2$), can be entered into a modified Henderson-Hasselbalch formula together with the arterial bicarbonate ($[HCO^{3-}]a$) to estimate pHi: $pHi = 6.1 + ([HCO^{3-}]a / PtCO_2)$[15]. The sigmoidal tonometer was placed in the sigmoid colon transanally after induction of anaesthesia and its position checked by the surgeon during laparotomy and corrected when necessary. Baseline measurement of pHi was made before aortic clamping. Subsequent measurements were made with at least 30 min equilibration periods and the last measurement was made 24 h after aortic clamping. Measured pHi values were not communicated to the operating surgeon and did not influence the type of surgery performed.

Pre- and postoperative digital venous subtraction angiography (super 80 CP, Philips Medical Systems, The Netherlands) were performed and occlusion of the superior mesenteric artery (SMA), the inferior mesenteric artery (IMA) and the internal iliac arteries (IIAs) scored by two of the investigators. During surgery, back bleeding of the IMA and ligation of the IMA and/or IIAs were noted. Angiographic and intraoperative data were combined to establish perioperative occlusion of any of the above mentioned intestinal arteries.

The occurrence of clinically important ischaemic colitis was defined as a combination of the following signs: bloody stools, peritonitis, metabolic acidosis, or when coloscopy and/or relaparotomy showed ischaemic colitis.

Statistical analysis was performed using linear regression (least squares method) and Student's *t*-test, a $p < 0.05$ was considered statistically significant.

Results

None of the patients had abdominal angina before operation. Preoperative angiography showed occlusion of the IMA in 12 patients, occlusion of one IIA in five and none had occlusion of both IIAs before operation. The SMA was patent in all patients pre- and postoperatively.

According to pre- and postoperative angiography and intraoperative data, patients were divided into three groups: Group 1: IMA and IIAs unchanged ($n = 13$; Group 2: occlusion of the IMA and IIAs unchanged perioperatively ($n = 22$) and Group 3: occlusion of the IMA and occlusion of one (one patient) or both IIAs (four patients) perioperatively ($n = 5$). Mean aortic clamp times were for Group 1: 63 min (95% CI 45–81), Group 2: 75 min (95% CI 62–88), Group 3: 124 min (95% CI 88–160; significantly different from Groups 1 and 2, $p < 0.05$). None of the patients were hypotensive (systolic blood pressure < 80 mmHg) for more than 5 min perioperatively.

Figure 1 shows the measured mean pHis for the three groups. The only point at which there was a statistically significant difference between groups was at 30 min after aortic clamping between groups 1 and 2 ($p < 0.05$). In all groups the pHi dropped significantly after aortic clamping compared to baseline ($p < 0.05$) and in all groups mean pHi values returned to their baseline values within 2–4 h after declamping. No patients had clinical evidence of ischaemic colitis. Nine patients had coloscopy on the first postoperative day and none had endoscopic signs of colonic ischaemia. None of the patients died, morbidity consisted of two patients with wound dehiscence, one patient with an intraabdominal bleeding 8 days postoperatively, one patient with an inguinal wound infection and three patients with postoperative pneumonia.

Discussion

One of the major complications after aortic reconstructive surgery is the occurrence of ischaemic colitis. Several investigators have identified perioperative

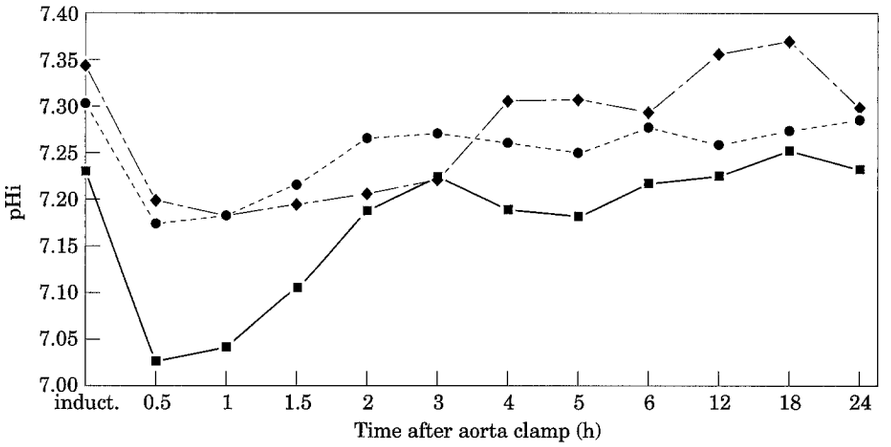

Fig. 1. Mean sigmoid pHi for patients with inferior mesenteric artery and internal iliac arteries unchanged (n = 13; ■), for patients with inferior mesenteric artery occluded and internal iliac arteries unchanged (n = 22; ●) and for patients with inferior mesenteric and one or both internal iliac arteries occluded perioperatively (n = 5; ◆)

occlusion of the inferior mesenteric artery and/or internal iliac arteries as risk factors for the development of ischaemic colitis.[1,16,17] Other investigators have not found a relationship between perioperative occlusion of a previous patent IMA and ischaemic colitis.[9]

Some methods used to reduce the risks of postoperative ischaemic colitis are: maintaining patency of the intestinal arteries when possible, reimplantation of these arteries and reducing aortic clamp times.[11] Despite the efforts to maintain intestinal blood flow, intestinal arteries are sometimes occluded perioperatively (by ligation, atherosclerotic emboli or thrombosis) which can be shown by comparing pre- and postoperative angiographies.

In our study, perioperative occlusion of a preoperative patent IMA alone or in combination with occlusion of one or both IIAs did not cause longer, or more severe, sigmoidal intramucosal acidosis, nor did it cause the development of clinically recognised ischaemic colitis. The SMA (pre- and postoperatively patent in all our patients) is probably the most important source for collateral intestinal blood flow provided the marginal artery is patent. Patients in Group 3 (IMA and one or both IIAs occluded) had a significantly longer mean aortic clamp time because the operation was more complicated. This did not result in more severe, or longer, sigmoidal intramucosal acidosis.

Fiddian-Green *et al.* showed that duration of sigmoidal intramucosal acidosis (defined as a pHi below 6.86) correlated with the occurrence of ischaemic colitis.[13] Björck and Hedberg showed that if sigmoidal intramucosal acidosis (defined as a pHi below 7.10) was reversed within 2 h, no major complications (including ischaemic colitis) developed, but when prolonged acidosis occurred, 80% of the patients developed major complications.[12] All patients in our study had a significant drop in sigmoidal pHi after aortic clamping but all returned to their individual baselines within 6–12 h after declamping and none developed ischaemic colitis.

We found considerable variation in (postinduction and preclamping) baseline pHis (in all patients range: 7.51–6.99; mean 7.23). These variations are possibly caused by reductions in intestinal blood flow due to redistribution of blood flow and/or relative hypotension after induction of anaesthesia. Thus, even though some patients had pHi values <7.10 this did not predict occurrence of ischaemic colitis. The only statistical difference we found in pHi values between the groups was a lower pHi in the group without changes in intestinal arteries after 30 min of aortic clamping. We cannot explain this difference, but do not believe it to be clinically important.

In conclusion, the absolute value of sigmoidal pHi in the individual patient has to be interpreted with caution. However, a return to baseline pHi within 6–12 h of declamping probably predicts a postoperative course without the occurrence of ischaemic colitis. Perioperative occlusion of the IMA alone, or in combination with one or both IIAs (providing the SMA is patent), does not influence the length and depth of sigmoidal intramucosal acidosis.

Sigmoidal intramucosal (trend) monitoring is a promising method for the prediction of postoperative ischaemic colitis, especially in patients at high risk for this complication.

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