British Journal of Surgery 1996, 83, 1386–1389

A 4-year prospective audit of the cause of death after infrarenal aortic aneurysm surgery

A. J. P. SANDISON, Y. PANAYIOTOPOULOS, R. C. EDMONDSON, M. R. TYRRELL and P. R. TAYLOR

Departments of Surgery, Guy's and Lewisham Hospitals, London, UK
Correspondence to: Mr P. R. Taylor, Department of Surgery, 2nd Floor New Guy's House, Guy's Hospital, St Thomas Street, London SE1 9RT, UK

This study was a 4-year prospective audit of abdominal aortic aneurysm surgery including 222 aneurysm repairs: 106 elective, 76 urgent and 40 emergency. Twenty-five patients died: four who underwent elective surgery, seven urgent and 14 emergency. The two major causes of death, multiple organ failure and colonic ischaemia, were responsible for 11 of the 25 deaths. The three deaths from myocardial infarction all occurred in patients with a leaking aneurysm. Blood loss was significantly higher in patients with multiple organ failure and in those with colonic ischaemia. Methods to identify patients at high risk of massive blood loss and colonic ischaemia may be a way to reduce mortality.

Over the past 30 years the mortality rate from elective repair of abdominal aortic aneurysms (AAAs) has declined from over 15 per cent[1] to less than 5 per cent[2]. Some authors have suggested that elective mortality rates greater than 5 per cent are 'unacceptable and any surgical unit which consistently fails to achieve this figure should not continue to perform this kind of surgery'[3]. In contrast, reported mortality rates for repair of ruptured AAAs have not declined significantly and a recent audit[4] suggests that there is a wide variation in the mortality rate, from 47 to 70 per cent. The mortality rate from rupture, including deaths in the community, was found to be as high as 94 per cent[5].

This study describes the results of a prospective computerized audit of 222 AAA repairs undertaken over a 4-year period. The main causes of death were analysed to look for ways in which the outcome may be improved.

Patients and methods

All patients who had AAA repair between September 1991 and July 1995 under a single vascular consultant (P.R.T.) were entered into a prospective computerized audit. The details recorded are shown in *Table 1*. These were entered on to a custom-designed vascular database developed from Superbase IV (Software Publishing, Bracknell, UK), a Windows-based PC database program. Demographic details were entered on the patient's admission to hospital, and details of the medical history were taken from the patient's notes at the time of surgery. Operation details were recorded immediately after surgery and subsequent progress was entered at the time of discharge from hospital and at a routine 6-week outpatient review. During this interval the consultant provided an *ad hoc* one in one vascular emergency cover to two hospitals as well as performing all elective vascular surgery at both hospitals. Thus almost all the patients admitted to either of the two hospitals for aneurysm surgery are included.

All patients who presented electively with asymptomatic AAAs with a diameter of 5·5 cm or greater were considered for repair unless they had widespread malignancy or were receiving oxygen therapy at home. Aneurysms measuring between 4·0 and 5·5 cm were entered into the small aneurysm study. No upper age limit was applied for elective surgery; instead an attempt was made to assess physiological rather than chronological age. Patients with symptomatic aneurysms (tenderness, back pain or embolic complications) were offered urgent surgery. Those who reached hospital with a ruptured aneurysm had emergency surgery unless they were over 80 years of age with a blood pressure of less than 80 mmHg, despite initial fluid resuscitation.

Some 190 patients were men and 32 women. The median age was 71 (range 49–89) years. None of the elective, 11 of the urgent and six of the emergency cases were tertiary referrals. In the study interval three patients were refused elective surgery on the basis of advanced cardiac, respiratory or renal disease not amenable to improvement by intervention.

The principal operator was the consultant in 35 per cent of cases, the senior registrar in 54 per cent and the registrar in 11 per cent, the latter two under supervision.

Table 1 Details recorded in the computer database

Patient demographic details
Risk factors for atherosclerosis: smoking, hypertension, diabetes, hyperlipidaemia, gout, renal failure
No. of drugs taken
Symptoms and signs of arterial occlusive disease
Cardiac symptoms
Cerebrovascular symptoms
Intervention details: urgency
Operation
Name of surgeon
Grade of surgeon
Heparin dose
Operating time
Blood loss
Graft details
Inflow vessel
Outflow vessel
Complications
Comments
Outcome

Results

A total of 222 aneurysm repairs were performed; 106 (48 per cent) were elective, 76 (34 per cent) were urgent and 40 (18 per cent) were emergency repairs for ruptured aneurysms. The commonest risk factor was smoking (68 per cent), followed by hypertension (35 per cent), renal failure (7 per cent) and diabetes (6 per cent). All patients received prophylactic antibiotics. A tube graft was used in

Paper accepted 7 July 1996

67 per cent of repairs, a bifurcated graft to the iliacs in 29 per cent and a bifurcated graft to the femoral arteries in 4 per cent. The external iliac artery was used in preference to the femoral arteries as an outflow site wherever possible to minimize the incidence of graft infection. The inferior mesenteric artery was not reimplanted. The median length of stay in hospital was 12 (range 7–32) days for elective cases, 12 (range 4–80) days for urgent cases and 12 (range 0–182) days for emergency cases.

Overall 25 patients (11 per cent) died within 30 days of surgery. Four had undergone elective repair, seven urgent repair and 14 emergency repair. The causes of death in the elective, urgent and emergency cases are shown in *Tables 2, 3* and *4* respectively. *Table 5* lists the complications according to category of surgery.

Recorded blood loss was compared between patients with the Mann–Whitney *U* test. There was no significant difference in blood loss between elective and urgent cases, but a highly significant difference between elective and emergency cases ($P < 0{\cdot}0001$) and between urgent and emergency cases ($P = 0{\cdot}0001$) (*Fig. 1*). There was no significant difference in median blood loss between patients who had a postoperative myocardial infarction (1200 (range 100–7000) ml) and those who did not (1200 (range 100–15 000) ml). Patients who had a bifurcated graft lost more blood than those with a tube graft (1700 *versus* 1200 ml, $P = 0{\cdot}04$). Patients who developed colonic

Table 2 Causes of death in four patients undergoing elective repair of abdominal aortic aneurysm

Cause of death	No. of patients	Comment
Multiple organ failure, ischaemic right colon	1	Heavy bleeding from lumbar vessels during operation causing large blood loss. Laparotomy on day 7 for sepsis; necrotic right colon resected. Died 2 days later
Pneumonia	1	*Staphylococcus aureus* and *Escherichia coli* cultured from sputum
Cerebrovascular accident	1	Nephrectomy 6 weeks before AAA repair for hypernephroma. Adrenalectomy performed at AAA repair for metastasis. On day 6 following AAA repair had massive stroke which computed tomography showed to be a bleed into cerebral metastasis
Aspiration	1	Uneventful AAA repair. Readmitted on day 27 with small bowel obstruction. Aspirated under anaesthesia during laparotomy. Died the next day

AAA, abdominal aortic aneurysm

Table 3 Causes of death in seven patients undergoing urgent aneurysm repair

Cause of death	No. of patients	Comment
Multiple organ failure	3	Very friable aorta. Resuture of proximal anastomosis. Developed renal, cardiac and respiratory failure. Treatment withdrawn on day 19
		Returned to theatre for bleeding from top anastomosis. Massive blood loss. Became inotrope dependent. Died on day 19
		Died on day 19 after initially developing renal failure
Ischaemic colitis	1	Died after prolonged ventilation
Pulmonary embolus	1	Received prophylactic subcutaneous heparin throughout stay
Paraplegia	1	Also developed renal failure. Treatment withdrawn after discussion with family
Respiratory failure	1	Impossible to wean from the ventilator. Subsequent investigation showed carcinoma of the bronchus

Table 4 Causes of death in 14 patients undergoing emergency aneurysm repair

Cause of death	No. of patients	Comment
Multiple organ failure	4	Hypotensive for 10 min before clamping. Died on day 5
		On warfarin. Died on day 4
		Torrential bleeding. Abdomen packed to control. Colon ischaemic on day 3. Died on the same day
		Good initial result then developed renal failure. Re-explored as became septic but nothing found. Died on day 19
Myocardial infarction	3	Myocardial infarct on day 4
		Myocardial infarct on day 8
		Myocardial infarct on closing abdomen. Unresponsive to inotropes
Bleeding	3	Died on table. Retroaortic renal vein
		Aorta would not hold sutures. Massive blood loss
		No blood clotting products available
Ischaemic colitis	2	Both left-sided colon
Reperfusion	1	White legs in intensive care unit. Returned to theatre and aortobifemoral graft performed. Developed reperfusion syndrome with renal failure. Autopsy showed large bronchial carcinoma
Cerebrovascular accident	1	Died 8 days after operation

ischaemia lost significantly more blood than those who did not (8000 *versus* 1200 ml, $P = 0{\cdot}002$). Those who developed multiple organ failure lost significantly more blood than those who did not (5000 *versus* 1200 ml, $P < 0{\cdot}001$). Patients who died lost significantly more blood than those who survived (5000 *versus* 1100 ml, $P < 0{\cdot}0001$).

There was no significant difference in duration of operation between elective, urgent and emergency cases, between survivors and non-survivors, and between those who developed multiple organ failure or colonic ischaemia and those who did not.

There were three late complications. One aortoenteric fistula presented 6 months after the initial surgery and was treated by removal of the graft and insertion of bilateral axillofemoral grafts. However, this patient became septic while in hospital and refused further treatment; post-mortem examination showed acute diverticular disease. Two patients developed incisional hernias that did not require surgical repair.

Table 5 Complications in patients undergoing elective, urgent and emergency aneurysm repair

Complication	Elective	Urgent	Emergency
Pneumonia	6	7	6
Re-exploration for bleeding	3	3	0
Myocardial infarction	1	2	2
Distal embolus	1	1	0
Gastrointestinal bleed	1	0	0
Pneumothorax (from central venous line)	1	0	0
Renal failure			
Haemofiltration	0	1	5
Haemodialysis	0	0	1
Spinal cord ischaemia	0	1	0
Deep vein thrombosis	0	0	2
Pulmonary embolus	0	1	0
Bleed from chest (combined CABG and AAA repair)	0	1	0
Small bowel obstruction	0	0	1
Diathermy burn	0	0	1

CABG, coronary artery bypass grafting; AAA, abdominal aortic aneurysm

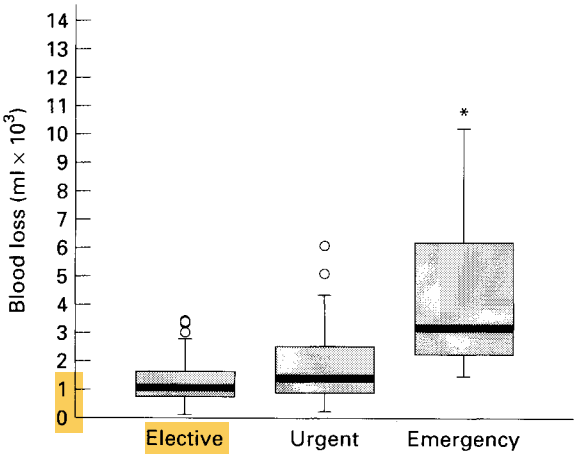

Fig. 1 Boxplot comparing blood loss in elective, urgent and emergency aortic aneurysm repair. Values are: median (dark line), interquartile range (box), full range (whiskers), outliers (○) and extremes (*). *$P = 0{\cdot}0001$ (emergency *versus* elective and urgent operations, Mann–Whitney U test)

Discussion

The mortality rates for elective, urgent and emergency surgery in this series were similar to those in other recent reports[6,7]. Although cardiac complications are considered to be the major cause of morbidity and mortality after aortic aneurysm repair, this was not confirmed in the present series. Myocardial infarction accounted for only three of the 25 deaths and these occurred only in patients undergoing emergency operation. Myocardial infarction comprised 10 per cent of the morbidity in all groups. The diagnosis of myocardial infarction in this series was based on a combination of clinical symptoms or electrocardiographic change associated with a significant rise in the creatinine kinase MB isoenzyme. Because of the high incidence of severe coronary artery disease in patients with aneurysms[8], many recommendations have been made regarding the preoperative cardiac investigations that should be performed in patients undergoing elective aneurysm repair. A recent report[9] showed that there is still a wide variation between hospitals in preoperative cardiac investigation. Patients having elective aneurysm repair routinely had resting electrocardiography and transthoracic echocardiography in this hospital; however, echocardiography detected only four at-risk patients, all of whom could have been recognized by the history and physical examination. Three patients were assessed by coronary angiography, and two were found to have untreatable ischaemic heart disease and were treated conservatively. One patient underwent coronary artery bypass grafting before aortic surgery, and a fourth had unrecognized hypertension that was treated for 3 months, after which he had uneventful aortic surgery. In view of the low rate at which echocardiography actually alters management, the authors have now changed their policy and rely on a detailed history and clinical examination combined with resting electrocardiography only. Patients identified as high risk are referred to a cardiologist for further assessment.

The two major causes of death in this series were multiple organ failure and ischaemic colitis (11 of 25 deaths). This confirms a recently reported series[6] which also found multiple organ failure to be the most important cause of death. The incidence of multiple organ failure was higher in urgent and emergency cases than in elective cases. Multiple organ failure in patients with ruptured AAAs was first described by Tilney *et al.*[10] in 1973 in a series of 18 patients. In the report by Huber *et al.*[6] it was noted that the operating time was significantly longer in non-survivors (7·7 *versus* 5·7 h in survivors) but that there was no significant difference in estimated blood loss between these two groups. However, there was no separate analysis to compare those with and without multiple organ failure. In discussing the results of Huber and co-workers[6], Hollier commented that in his experience 'multiple organ failure after aortic surgery is generally limited to those patients requiring large amounts of blood and crystalloid fluids or those who undergo suprarenal clamping'. The present results confirm the significant association between blood loss and the development of multiple organ failure. It is unclear exactly how these are related. It could be the blood loss itself, the hypotension consequent to the blood loss, or the massive transfusion of homologous blood. Colonic ischaemia, if progressive, may cause multiple organ failure by producing septic shock. It is interesting to note that in this series the development of colonic ischaemia was

associated with large blood loss. An explanation for this may be the postoperative use of high concentrations of inotropic drugs, which cause splanchnic vasoconstriction and exacerbate any tendency to colonic ischaemia.

Intestinal ischaemia followed by reperfusion causes acute lung injury in animal models[11], but the mechanism for this is unclear. There is no direct evidence of bacterial translocation[12] but high endotoxin levels have been demonstrated in systemic blood during aortic cross-clamping[13], suggesting that this could, in association with hypotension resulting from massive blood loss, be a trigger for a systemic inflammatory response that may lead to multiple organ failure.

Clearly, massive blood loss is unavoidable in most cases, particularly where an aneurysm has ruptured. The use of autotransfusion may be a more realistic way of reducing the need for transfusion of large quantities of homologous blood in these patients.

Respiratory complications were the commonest cause of morbidity in all categories of patient. Calligaro *et al.*[14] showed in a retrospective review that seven factors were independently associated with the development of major pulmonary complications after aortic surgery. Of these, only poor lung function on respiratory testing may be amenable to improvement before operation. Of note is the fact that infusing large volumes (more than 6 litres) of crystalloid was associated with pulmonary complications.

This prospective audit has shown that the major causes of death after aneurysm repair are multiple organ failure and colonic ischaemia. The previously reported high incidence of cardiac complications has not been confirmed. Both multiple organ failure and colonic ischaemia have been shown to be associated with large perioperative blood loss. Avoidance of large blood loss, whilst clearly desirable, is not always possible. The use of autologous blood transfusion in these circumstances may be beneficial.

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