Intraoperative intravascular volume optimisation and length of hospital stay after repair of proximal femoral fracture: randomised controlled trial

Susan Sinclair, Sally James, Mervyn Singer

Abstract

Objectives: To assess whether intraoperative intravascular volume optimisation improves outcome and shortens hospital stay after repair of proximal femoral fracture.
Design: Prospective, randomised controlled trial comparing conventional intraoperative fluid management with repeated colloid fluid challenges monitored by oesophageal Doppler ultrasonography to maintain maximal stroke volume throughout the operative period.
Setting: Teaching hospital, London.
Subjects: 40 patients undergoing repair of proximal femoral fracture under general anaesthesia.
Interventions: Patients were randomly assigned to receive either conventional intraoperative fluid management (control patients) or additional repeated colloid fluid challenges with oesophageal Doppler ultrasonography used to maintain maximal stroke volume throughout the operative period (protocol patients).
Main outcome measures: Time declared medically fit for hospital discharge, duration of hospital stay (in acute bed; in acute plus long stay bed), mortality, perioperative haemodynamic changes.
Results: Intraoperative intravascular fluid loading produced significantly greater changes in stroke volume (median 15 ml (95% confidence interval 10 to 21 ml)) and cardiac output (1.2 l/min (0.1 to 2.3 l/min)) than in the conventionally managed group (−5 ml (−10 to 1 ml) and −0.4 l/min (−1.0 to 0.2 l/min)) ($P<0.001$ and $P<0.05$, respectively). One protocol patient and two control patients died in hospital. In the survivors, postoperative recovery was significantly faster in the protocol patients, with shorter times to being declared medically fit for discharge (median 10 (9 to 15) days *v* 15 (11 to 40) days, $P<0.05$) and a 39% reduction in hospital stay (12 (8 to 13) days *v* 20 (10 to 61) days, $P<0.05$).
Conclusions: Proximal femoral fracture repair constitutes surgery in a high risk population. Intraoperative intravascular volume loading to optimal stroke volume resulted in a more rapid postoperative recovery and a significantly reduced hospital stay.

Introduction

The Audit Commission estimated that each year 57 000 patients undergo surgical correction of fractures of the femoral neck in England and Wales.[1] The East Anglian hip fracture audit revealed a median hospital stay of 20 days and hospital mortality of 5-24%.[2] These data indicate a high risk population and major resource implications. Patients who present with femoral fracture are often in poor general health, and surgery represents a huge physiological challenge; this is reflected in the complications experienced and poor recovery. Using fluid or inotrope therapy, or both, to optimise cardiac output and tissue oxygen delivery has been shown to influence outcome and reduce hospital stay in high risk patients having major surgery.[3-5] The technique used in these studies, pulmonary artery catheterisation, is not practicable in femoral fracture repair. Oesophageal Doppler ultrasonography permits rapid, minimally invasive, and continuous estimation of cardiac output.[6 7] We examined the possible benefits of intraoperative circulatory optimisation using this minimally invasive technique in patients with fractured neck of femur.

Methods

All patients presenting with fractures of the femoral neck were considered. Exclusion criteria were age less than 55 years, fracture secondary to neoplasm, fractures occurring during hospitalisation for an acute illness, fracture through the site of a previous surgical correction or associated with instability of a previous prosthesis, planned regional anaesthesia (which would preclude placement of the oesophageal Doppler probe), and refusal of consent or inability to contact next of kin in the case of patients unable to give consent themselves. The approval of the University College London Hospitals Ethics Committee was gained before starting the study.

All patients received any medical intervention deemed appropriate by the admitting orthopaedic team, including fluid resuscitation on admission and restoration of an adequate haemoglobin concentration. Maintenance intravenous fluid therapy (1000 ml dextrose-saline 12 hourly) was given from the time of oral fluid restriction until the time of operation and after operation until the patient's oral fluid intake was adequate. Preoperative analgesia was dictated by the patient's need and continued if needed until the time of surgery. The American Society of Anaesthesiologists' grading of health status[8] was estimated, and the Goldman cardiac risk index[9] was calculated.

All patients received a standardised anaesthetic. Premedication with temazepam 10-20 mg orally was given if the patient had not received intramuscular analgesia within the previous two hours. The patient was induced with etomidate, intubation was facilitated by vecuronium, and anaesthesia maintained by oxygen, nitrous oxide, and enflurane. Perioperative analgesia was provided with a combination of lateral femoral cutaneous nerve block with 0.5% bupivicaine, nitrous oxide, and intravenous fentanyl. Because of the age and frailty of some of the patients, the anaesthetist remained free to titrate these drugs according to the needs of the individual patient. In addition to routine monitoring, a 6 mm diameter oesophageal Doppler ultrasound probe (ODM2, Abbott, Maidenhead) was

See editorial by Gan and Arrowsmith

Bloomsbury Institute of Intensive Care Medicine, Division of Medicine, University College London Medical School, London WC1E 6JJ
Susan Sinclair, *clinical research fellow*
Mervyn Singer, *senior lecturer in intensive care medicine*

Department of Orthopaedics, University College London Hospitals, London [postcode please]
Sally James, *sister, orthopaedic ward*

Correspondence to: Dr M Singer (m.singer@ucl.ac.uk).

BMJ 1997;315:909–12

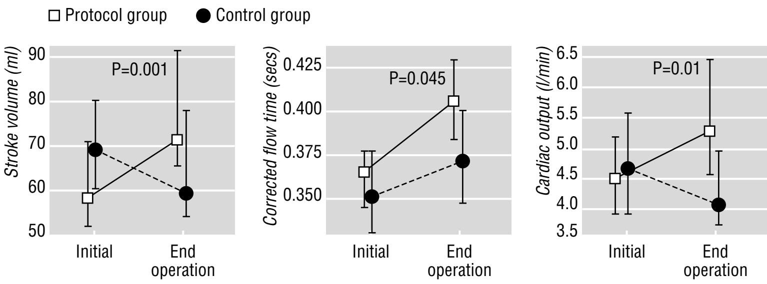

Fig 1 Median (95% confidence interval) change in stroke volume, aortic systolic corrected flow time, and cardiac output from 15 minutes after induction of anaesthesia (initial) to the end of the operation (end operation)

passed through the mouth immediately after induction of anaesthesia. By use of a monitor displaying blood flow velocity waveforms, the probe was oriented to measure the velocity of the descending thoracic aortic blood flow continuously at a distance of 30-35 cm from the teeth.[6 7] The area of each velocity-time waveform relates to total left ventricular stroke volume, which can be approximated by a calibration factor utilising a nomogram incorporating the patient's age, height, and weight. The systolic flow time can be corrected for heart rate with Bazett's equation; this corrected flow time value is a good index of systemic vascular resistance.[10] Heart rate was monitored continuously and blood pressure was measured by an automatic sphygmomanometer at 3-5 minute intervals. Estimated cardiac output and stroke volume, corrected aortic systolic flow time, and volume of fluid infused were noted every 15 minutes.

After consent had been obtained, the patients were individually randomised before induction of anaesthesia by a sealed envelope technique to either protocol or control groups. All patients received crystalloid, hydroxyethyl starch colloid, or blood to replace estimated fluid losses and to maintain heart rate and blood pressure. In addition, protocol patients received hydroxyethyl starch fluid challenges guided by Doppler measures of stroke volume and corrected flow time. A corrected flow time value <0.35 second was taken to indicate possible hypovolaemia. Patients in the protocol group were given an initial fluid challenge of 3 ml/kg hydroxyethyl starch over 5-10 minutes. If the stroke volume was either maintained or increased after the fluid challenge but the corrected flow time remained below 0.35 second the fluid challenge was repeated. If stroke volume rose by more than 10% but the corrected flow time exceeded 0.35 second the fluid challenge was repeated until no rise in stroke volume occurred. If the corrected flow time rose above 0.40 second with no increase in stroke volume, no further fluid was given until the corrected flow time or stroke volume fell by 10%.

Table 1 Characteristics of patients and their operations. Values are medians (interquartile ranges) or numbers of patients

	Protocol group	Control group
Age (years)	74 (70.5-82)	75.5 (69-80)
American Society of Anesthesiologists' grading	2 (2-3)	2 (2-3)
Goldman cardiac risk index	9 (9-13)	9 (8-12)
Hospital stay before operation (days)	1 (1-1.5)	1 (1-1.5)
Haemoglobin concentration before operation (g/l)	125 (111-137)	127 (107-140)
Duration of operation (min)	67.5 (60-92.5)	77 (60.5-90)
Type of operation:		
Dynamic hip screw or screw plus plate	8	10
AO cannulated screw	4	3
Arthroplasty	8	7

The anaesthetist was blinded to the Doppler measurements but was aware of the fluid volumes given as fluid challenges to the protocol group. The operating time was recorded as the skin was being closed. The Doppler values obtained 10 minutes after induction of anaesthesia and at skin closure were recorded for analysis as "initial" and "end operation" respectively.

Postoperative management was carried out on the orthopaedic ward with both medical and nursing staff blinded to the randomisation of the patient into protocol or control groups. The dates and location of death, discharge, or transfer were recorded, enabling the time spent in an acute hospital bed and total length of stay in hospital to be determined. As many such patients will have hospital discharge delayed for social reasons, the number of days before the orthopaedic staff deemed they were medically fit to return to their previous circumstances were also recorded.

Statistical analysis

Sample size (20 per group) was projected by seeking a one third reduction in hospital stay for survivors in the group with optimised fluids during operation. This figure was based on results obtained from preoperative optimisation studies.[3-5] The control group's stay was assumed to be 18.6 (SD 5) days on the basis of data taken from an internal hospital audit performed in 1990-1, with a 10% hospital mortality,[11] an α value of 0.05, and a β value of 0.9. Primary outcome measures were hospital stay and time to declaration of medical fitness for discharge. Secondary measures were intraoperative haemodynamic differences between the groups. The Mann-Whitney U test was used to compare demographic, haemodynamic, and outcome data in protocol and control groups. Hospital stay and time to declaration of medical fitness were analysed only for survivors.

Results

The protocol and control groups were similar in terms of age, Goldman cardiac risk index, American Society of Anaesthesiologists grading, preoperative haemoglobin concentration, and type and duration of operation performed (table 1). The duration of preoperative stay in hospital was also similar.

Patients in the protocol group received significantly more fluid per minute of operating time than those in the control group (table 2). Stroke volume, corrected flow time, and cardiac output rose significantly in the protocol group but fell in the control group (table 1, fig 2). Heart rate and blood pressure did not change significantly in either group.

Three patients died during the course of the study. One patient in the protocol group died 36 days after operation from bronchopneumonia with pre-existing amyloid cardiac failure. Two patients in the control group died, one on the second day from a cerebrovascular accident and one on the 65th day from pneumonia and congestive cardiac failure, 30 days after transfer to a long stay ward for care of the elderly.

Patients in the protocol group had a significantly shorter hospital stay whether this was assessed as time spent in an acute hospital bed, the number of days after operation until being declared medically fit, or the total number of days spent as a hospital inpatient (fig 3). Seven survivors in the control group had a hospital stay exceeding 25 days but none of the survivors in the protocol group stayed longer than 24 days.

Discussion

Fractured neck of femur carries a high cost in terms of mortality, morbidity, and use of hospital and community resources.[11 12] An impressive impact on outcome was shown in the Peterborough Hip Fracture Project[13] which utilises a "surgical hip fracture team," a multidisciplinary approach to management with emphasis on the rehabilitative aspects of patient care. Early mobilisation is crucial, and this in turn depends on prompt postoperative recovery. The outcome of high risk patients undergoing major surgery was significantly improved by haemodynamic optimisation in the perioperative period;[3-5] patients with fractures of the neck of femur should be similarly managed as a high risk population. However, since Schultz et al showed that using a pulmonary artery catheter to detect and correct haemodynamic dysfunction in the preoperative and postoperative periods reduced mortality from 29% to 2.9%,[14] there has been little attempt to influence the outcome of these patients by manipulating their cardiovascular performance.

In view of the age, frailty, and perceived high cardiovascular risk in this patient population, it is likely that many remain under-resuscitated before, during, and after the operation as clinicians fear that giving excessive fluid will precipitate left ventricular failure.[14] This is reflected in our study by the significantly lower volumes of fluid given to the control patients.

Reducing patients' stay in hospital

Unless it is profound, hypovolaemia is difficult to diagnose on clinical grounds. It will contribute to perioperative hypoperfusion of tissues and lead to organ dysfunction after operation.[15] This may manifest itself in a clinical spectrum ranging from generalised malaise to multiple organ failure. This will adversely affect the patient's inclination or ability to mobilise during the postoperative phase, thereby prolonging hospital stay and worsening outcome. Our study showed this clearly. All patients were given preoperative resuscitation before they were randomised into control and protocol groups, which differed only by the additional volumes of colloid given to optimise circulatory status during the period of surgical stress. An advantage of colloid over crystalloid therapy is the lesser quantity needed to maintain intravascular volumes.[16] The success of this simple protocol in increasing haemodynamic performance confirms the suspicion of occult hypovolaemia. Maximal intravascular volume loading alone seemed sufficient to improve postoperative mobilisation, leading to a significant reduction in hospital stay.

Monitoring

The recently published 1993-4 report of the National Confidential Enquiry into Perioperative Deaths pinpointed mortality after hip fracture surgery as an area of particular concern.[17] In the 422 patients evaluated, the report highlighted the minimal use of invasive intraoperative monitoring (central venous pressure was monitored in eight patients, arterial pressure in five, pulmonary artery catheterisation in none) and of high dependency or intensive care after operation (with only 24 admissions). The wide variation in intravascular volume required during the intraoperative period reflects the importance of precise monitoring to enable adequate but not excessive fluid loading.

The fluid challenge principle is familiar to all anaesthetists, yet it is difficult to gauge benefit accurately in the absence of sufficient haemodynamic monitoring. The Doppler ultrasound haemodynamic monitoring used in this study enables precise fluid optimisation in the intraoperative period. It is simple to use and prolongs the time required to prepare the patient for surgery only minimally. As the technology is minimally invasive, the patient could be managed subsequently on a general orthopaedic ward. We found no complications attributable either to the technique or the fluid resuscitation regimen.

Postoperative recovery

Preventing perioperative tissue oxygen debt by adequate fluid resuscitation may thus contribute to a better postoperative recovery.[18] An equivalent effect using the same monitoring equipment and a similar fluid administration protocol has been shown in patients having elective cardiac surgery.[15] The timing of this volume loading and removal of any such tissue oxygen debt may be crucial. Delaying fluid replacement until the

Table 2 Haemodynamic data and volumes of infusions given during operation. Values are medians (95% confidence intervals)

	Protocol group	Control group	P value
Perioperative change in:			
Stroke volume (ml)	13 (8 to 21.5)	−6 (−10 to 4)	<0.001
Cardiac output (l/min)	1.0 (−0.5 to 1.6)	−0.25 (−0.9 to 0.3)	<0.05
Corrected flow time (ms)	38.5 (22.5 to 64.5)	24 (−9 to 46)	<0.05
Fluid infused intraoperatively (ml):			
Crystalloid	725 (500 to 1000)	1000 (700 to 1250)	NS
Colloid	750 (550 to 950)	0 (0 to 450)	<0.001
Total per minute of operating time	22 (19.8 to 24.9)	15.5 (13.4 to 19.2)	<0.01

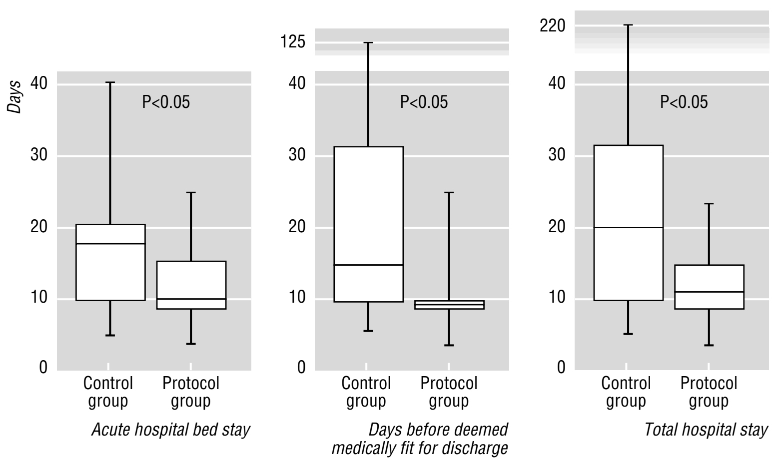

Fig 2 Acute bed stay, days before deemed medically fit for discharge, and total duration of hospital stay for survivors. Median, quartiles, and extremes are shown for 18 control patients and 19 protocol patients

Key messages

- Patients undergoing hip fracture repair constitute a high risk group with considerable mortality and morbidity and an often protracted postoperative hospital stay
- These patients often have depleted intravascular volume in the perioperative period and rarely receive either invasive haemodynamic monitoring or high dependency care
- Haemodynamic optimisation guided by pulmonary artery catheter in the perioperative period has been shown to improve outcome in high risk patients undergoing major surgery, but this is not considered routinely practicable for hip fracture repair
- Intravascular volume optimisation directed by minimally invasive oesophageal Doppler monitoring in the intraoperative period significantly reduces hospital stay

postoperative period may be partly responsible for patients not benefitting from aggressive haemodynamic management after they have been admitted to an intensive care unit.[19 20] Use of this simple procedure could produce considerable cost benefit in terms of shorter hospital stays and improved patient outcome.

We thank the orthopaedic department of University College London Hospitals (in particular Mr Chris Lavy, consultant orthopaedic surgeon) and the casualty theatre staff (in particular Sister Kate Saunders) for their support and invaluable help with this study.

Funding: Project Grant from the Special Trustees of the Middlesex Hospital.

Conflict of interest: None.

1 Audit Commission. *United they stand. Co-ordinating care for elderly patients with hip fracture.* London: HMSO, 1995.
2 Todd CJ, Freeman CJ, Camilleri-Ferante C, Palmer CR, Hyder A, Laxton CE, et al. Differences in mortality after fracture of hip: the East Anglian audit. *BMJ* 1995;310:904-8.
3 Shoemaker WC, Appel PL, Kram HB, Waxman K, Lee T. Prospective trial of supranormal values of survivors as therapeutic goals in high risk surgical patients. *Chest* 1988;94:1176-86.
4 Berlauk JF, Abrams JH, Gilmour IJ, O'Connor R, Knighton DR, Cerra F. Preoperative optimisation of cardiovascular hemodynamics improves outcome in peripheral vascular surgery. *Ann Surg* 1991;214:289-99.
5 Boyd O, Grounds RM, Bennett D. A randomised clinical trial of the effect of deliberate perioperative increase of oxygen delivery on mortality in high risk surgical patients. *JAMA* 1993;270:2699-707.
6 Singer M. Continuous non-invasive aortic blood flow monitoring. In: Gullo A, ed. *Anaesthesia, pain, intensive care and emergency care No 10.* Berlin: Springer-Verlag. 1995:819-28.
7 Singer M, Bennett ED. Non-invasive optimization of left ventricular filling by esophageal Doppler. *Crit Care Med* 1991;9:1132-7.
8 American Society of Anesthesiologists. New classification of physical status. *Anesthesiology* 1963;24:111.
9 Goldman L, Caldera DL, Nussbaum SR, Southwick FS, Krogstad D, Murray B, et al. Multifactorial index of cardiac risk in non cardiac patients. *N Engl J Med* 1977;297:845-50.
10 Singer M, Allen MJ, Webb AR, Bennett ED. Effects of alterations in left ventricular filling, contractility and systemic vascular resistance on the ascending aortic blood velocity waveform of normal subjects. *Crit Care Med* 1991;19:1138-44.
11 Parker MJ, Palmer CR. Prediction of rehabilitation after hip fracture. *Age Ageing* 1995;24:96-8.
12 Keene GS, Parker MJ, Pryor GA. Mortality and morbidity after hip fractures. *BMJ* 1993;307:1248-50.
13 Parker MJ, Pryor GA, Myles JW. The value of a special surgical team in preventing complications in the treatment of hip fractures. *Int Orthop* 1994;18:184-8.
14 Schultz RJ, Whitfield GF, LaMura JJ, Raciti A, Krishnamuthy S. The role of physiologic monitoring in patients with fractures of the hip. *J Trauma* 1985;25:309-316.
15 Mythen MG, Webb AR. Peroperative plasma volume expansion reduces the incidence of gut mucosal hypoperfusion in cardiac surgery. *Arch Surg* 1995;130:423-429.
16 Nees JE, Hauser CJ, Shippy C, State D, Shoemaker WC. Comparison of cardiorespiratory effects of crystalline hemoglobin, whole blood, albumin, and Ringer's lactate in the resuscitation of hemorrhagic shock in dogs. *Surgery* 1978;83:639-47.
17 *Report of the National Confidential Enquiry into Perioperative Deaths (NCEPOD) 1993/1994.* London:NCEPOD, 1996.
18 Shoemaker WC, Appel PL, Kram HB. Tissue oxygen debt as a determinant of lethal and nonlethal postoperative organ failure. *Crit Care Med* 1988;16:1117-20
19 Hayes MA, Timmins AC, Yau EH, Palazzo M, Hinds CJ, Watson D. Elevation of systemic oxygen delivery in the treatment of critically ill patients. *N Engl J Med* 1993;330:1717-22.
20 Gattinoni L, Brazzi L, Pelosi P, Latini R, Tognoni G, Pesenti A, et al. A trial of goal-oriented hemodynamic therapy in critically ill patients. SvO_2 Collaborative Group. *N Engl J Med* 1995;333:1025-32.

(Accepted 28 May 1997)

Effects of obesity and weight loss on left ventricular mass and relative wall thickness: survey and intervention study

Kristjan Karason, Ingemar Wallentin, Bo Larsson, Lars Sjöström

Department of Cardiology, Sahlgrenska University Hospital, Gothenburg, S-413 45 Sweden
Kristjan Karason, *consultant cardiologist*

Department of Clinical Physiology, Sahlgrenska University Hospital
Ingemar Wallentin, *associate professor*

continued over

BMJ 1997;315:912–6

Abstract

Objectives: To investigate the consequences of longstanding obesity on left ventricular mass and structure and to examine the effects of weight loss on these variables.

Design: Cross sectional survey and controlled intervention study.

Setting: City of Gothenburg and surrounding areas, Sweden.

Subjects: 41 obese patients treated with weight reducing gastric surgery, 31 obese patients treated conventionally, and 43 non-obese subjects.

Main outcome measures: Changes in left ventricular mass and relative wall thickness.

Results: Obese patients had higher blood pressure, greater left ventricular mass, and increased relative wall thickness than did matched non-obese control subjects. Obese subjects treated with gastric surgery had a substantial weight loss and a significant reduction in all variables when compared with conventionally treated obese subjects. Univariate and multivariate analysis of pooled data from the two groups of obese subjects showed that changes in relative wall thickness and left ventricular mass were more closely related to the change in weight than to the concomitant change in blood pressure.

Conclusions: Structural heart abnormalities occurring in conjunction with obesity diminish after weight loss. The regression in these structural aberrations is better predicted by the weight loss than by the accompanying reduction in blood pressure. To prevent or improve abnormalities of heart structure in obese people, weight control should be the primary goal; it should be regarded as at least as important as regulating blood pressure.