Cardiac output during hemiarthroplasty of the hip

A PROSPECTIVE, CONTROLLED TRIAL OF CEMENTED AND UNCEMENTED PROSTHESES

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In a prospective, controlled study, we measured the effect on cardiac output of the introduction of methylmethacrylate during hemiarthroplasty for displaced fractures of the femoral neck. We treated 20 elderly patients who were similar in age, height, weight and preoperative left ventricular function with either cemented or uncemented hemiarthroplasty. Using a transoesophageal Doppler probe, we measured cardiac output before incision and at six stages of the procedure: during the surgical approach, reaming and lavage of the femoral canal, the introduction of cement, the insertion of the prosthesis, and in reduction and closure.

We found that before the cement was introduced, there was no difference in stroke volume or cardiac output ($p > 0.25$). Cementation produced a transient but significant reduction in cardiac output of 33% ($p < 0.01$) and a reduction in stroke volume of 44% ($p < 0.02$). The introduction of cement did not affect the heart rate or mean arterial pressure. There was no significant difference in cardiac function on insertion of the prosthesis. Standard non-invasive haemodynamic monitoring did not detect the cardiovascular changes which may account for the sudden deaths that sometimes occur during cemented hemiarthroplasty.

The fall in stroke volume and cardiac output may be caused by embolism occurring during cementation, but there was no similar fall during reaming or insertion of the prosthesis.

J Bone Joint Surg [Br] 2001;83-B:414-8.

Received 22 June 2000; Accepted after revision 9 October 2000

There are well-recognised changes in vascular physiology during the operation of cemented hemiarthroplasty of the hip; occasionally fatal cardiovascular collapse occurs around the time of cementation.¹⁻³ The aetiology of these cardiovascular changes is unknown. Fat and marrow embolism,⁴⁻⁶ the peripheral vasodilatation effect of the cement monomer,^{7,8} and activation of the clotting cascade in the lungs⁹ may all play a role.

Until recently, intraoperative measurement of cardiac output required insertion of a catheter into the pulmonary artery, a procedure which is associated with significant risk.¹⁰ Transoesophageal echocardiography allows qualitative evaluation of pulmonary embolisation, but the probe is relatively large and oesophageal rupture has been described.¹¹ The transoesophageal Doppler probe is a new instrument which uses an oesophageal probe, 6 mm in diameter, to measure cardiac output.¹²

We have measured the effect on the cardiac output of the introduction of methylmethacrylate during hemiarthroplasty of the hip for displaced fracture of the femoral neck.

Patients and Methods

Patients were recruited into the trial from the practice of two orthopaedic surgeons, one of whom favoured uncemented hemiarthroplasty for most patients and the other cemented hemiarthroplasty. All patients had a displaced fracture of the femoral neck. We excluded patients with severe cardiorespiratory disease, cardiac conduction defects, gastro-oesophageal pathology, diabetes or senile dementia. Our 20 patients, aged between 59 and 83 years, all had a preoperative ECG to exclude asymptomatic septal defects and valvular lesions. Patients in the two groups were of comparable age, height and weight and had similar left ventricular function (Table I). The local Ethics Research Committee approved the study.

Anaesthetic technique. A standard anaesthetic technique was used, and the anaesthetist was allowed to deviate from the protocol only if required by the patient's condition. No premedication was used. Before inducing anaesthesia with etomidate, we set up five-lead ECG, non-invasive monitoring of blood pressure and pulse oxymetry. Patients were intubated after receiving vecuronium (0.1 mg/kg) and

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0301-620X/01/311477 \$2.00

Table I. Details of the patients (median and range) for the two groups

	Cemented (n = 9)	Uncemented (n = 10)	Mann-Whitney U test
Age (yrs)	69 (60 to 69)	72 (67 to 79)	0.2
Weight (kg)	56 (51 to 70)	63 (50 to 78)	0.5
Height (cm)	147 (142 to 154)	151 (146 to 156)	0.3
Median echo/5	3	3	

Table II. The stages during surgery at which transoesophageal Doppler readings were taken for the two groups

Stage	Cemented	Uncemented
0 (baseline)	Preincision	Preincision
1	Surgical approach	Surgical approach
2	Reaming	Reaming
3	Lavage	Lavage
4	Cementation	Preinsertion
5	Prosthesis	Prosthesis
6	Reduction and closure	Reduction and closure

alfentanil (1 µg/kg). The lungs were ventilated to achieve normocapnia, and the end-tidal capnographic recordings were noted. We maintained anaesthesia with oxygen (33%), in nitrous oxide and soflurane (1% to 2%), aiming to maintain blood pressure within 10% of the baseline reading. For analgesia, we administered morphine (0.05 to 0.1 mg/kg) intravenously. At the end of surgery, any residual muscle relaxation was reversed with neostigmine and glycopyrrolate. Patients received maintenance fluids intravenously, and gelatin solution or blood to compensate for intraoperative loss. Physiological signs, including the temperature of the tympanic membrane, were recorded throughout the procedure.

Assessment of cardiac output. The cardiac output recorded before the incision was made provided the baseline measurement. Using a transoesophageal Doppler probe, a separate research anaesthetist recorded cardiac output during the surgical approach, reaming and lavage of the femoral canal, cementation, insertion of the prosthesis, and reduction and closure (Table II). A 12F-oesophageal probe, inserted after induction of anaesthesia, was connected to a TECO II monitor (Medicina Developments, Cookham, Berkshire, UK) which continuously displayed blood flow in the descending thoracic aorta. The recordings were downloaded onto a database. Blood pressure, ECG readings, end-tidal CO₂ and oxygen pulse saturation were recorded, as were any anaesthetic interventions. The anaesthetist remained blind to the transoesophageal Doppler readings.

Operative technique. For both cemented and uncemented hemiarthroplasty we used a standard anterolateral approach with the patient in the lateral position.¹³ In all cases the femoral canal was prepared with standard Charnley reamers, and syringed with 100 ml of saline. In uncemented hemiarthroplasty, an Austin Moore prosthesis (Howmedica International, Limerick, Ireland) was inserted and the hip reduced. In cemented hemiarthroplasty, a cement restrictor was inserted before lavage of the femoral canal. The

cement was introduced in a retrograde fashion with a cement gun and pressurised, and a Thompson prosthesis was inserted. We reduced the hip once the cement had polymerised.

Statistical analysis. We tested the null hypothesis that there is no difference in cardiac output between the different stages of cemented and uncemented hemiarthroplasty. All results were analysed independently on SPSS V8.0 software (SPSS Inc, Chicago, Illinois). We used non-parametric tests throughout, and the Mann-Whitney U test to assess differences between the groups and changes in variables from baseline. We calculated that it was necessary to have a minimum of ten patients in each group to obtain a 95% chance of detecting a 30% difference in cardiac output between the two groups.

Results

The transoesophageal Doppler computer software failed in one patient who was undergoing cemented hemiarthroplasty leaving 19 in the study.

Fig. 1

Graph of cardiac output (l/min; median and range) for each stage of the procedure.

Fig. 2

Graph of stroke volume (ml; median and range) for each stage of the procedure.

Fig. 3

Graph of mean arterial pressure (mmHg; median and range) for each stage of the procedure.

Cardiac output (Fig. 1). Before cementation there was no difference ($p > 0.45$) in cardiac output between the cemented and uncemented groups (median value 5.1 l/min; 4.1 to 5.3). The introduction of cement produced a transient but significant reduction of 33% (21 to 45) in cardiac output ($p < 0.01$). There was no significant difference in cardiac output when the prosthesis was inserted or when the wound was closed ($p > 0.77$). As Table III shows, cementation produced no significant difference in

mean arterial pressure (MAP) or heart rate ($p > 0.05$).

Stroke volume (Fig. 2). There was no difference ($p > 0.25$) in stroke volume between the cemented and uncemented groups before cement was introduced (58 ml; 47.8 to 69.8), but cementation produced a significant reduction of 44% (36 to 52, $p < 0.02$). There was no significant difference in stroke volume when the prosthesis was inserted, or during closure ($p > 0.48$).

Mean arterial pressure (MAP) (Fig. 3). The baseline MAP was different for the two groups ($p = 0.05$). There was no difference during reaming ($p = 0.68$) or lavage of the femoral canal ($p = 0.57$). When cement was introduced, the MAP fell, but the difference between the cemented and the uncemented groups at a similar point did not quite reach significance ($p = 0.06$). There was no difference during insertion of the prosthesis ($p = 0.33$), or during reduction of the hip and closure ($p = 0.39$).

Heart rate. Table III shows that there was no significant difference in heart rate between the groups during preparation of the femoral canal, introduction of cement, insertion of the prosthesis, or closure ($p > 0.12$).

Discussion

Our study is the first to quantify the reduction in cardiac function which is associated with cementation. Using the minimally invasive transoesophageal Doppler device, we observed a decline in cardiac output of 33% and a reduction in stroke volume of 44% during cementation. The heart rate and MAP were not affected. Earlier studies which measured blood pressure during cemented arthroplasty of the hip identified cementation as the point at which transient hypotension occurs.^{8,13-18} In an uncontrolled study of patients undergoing total hip replacement Ling and James¹⁶ noted a fall in blood pressure of 11% when cement was introduced into the femur. The 20% fall which we observed, with a p value of 0.06, fell short of being significant.

Lennox and McLauchlan¹⁹ reported a significant increase in perioperative mortality in patients undergoing cemented hemiarthroplasty. They did not discuss the incidence and severity of non-fatal intraoperative cardiovascular disturbances which may result in postoperative stroke or myocardial infarction. In dogs, the increase in intramedullary pressure during cementation produces microemboli, which may be a cause of cardiorespiratory changes.^{4,20,21} In both uncemented and cemented hip hemiarthroplasty, transoesophageal echocardiography has revealed notable showers of emboli during instrumentation of the femoral canal. The largest showers have usually been seen during cementation and insertion of the prosthesis, but their appearance has not been confined to these stages.^{11,22} It is not known how these emboli affect cardiac function. Emboli are released both before and after cementation, raising the possibility that the decrease in cardiac output and stroke volume may be the result of both marrow emboli and the vasodilatation effect of the monomer.⁷

Table III. Mean (range) cardiac output (CO), stroke volume (SV), mean arterial pressure (MAP) and heart rate (HR) at each stage for the two groups

Stage	Cemented (n = 9)	Uncemented (n = 10)	p value
CO 0 Baseline	5 (4.1 to 5.3)	4.9 (4.2 to 5.1)	0.51
CO 1 Surgical approach	4.7 (3.4 to 4.8)	4.5 (4.0 to 5.0)	0.90
CO 2 Reaming	4.3 (3.4 to 4.8)	4.5 (4.0 to 4.8)	0.84
CO 3 Lavage	4.3 (3.3 to 4.8)	4.4 (4.0 to 4.9)	0.41
CO 4 Cementation	3.5 (2.2 to 4.1)	4.4 (4.0 to 4.9)	0.01
CO 5 Prosthesis	4.3 (2.6 to 4.7)	4.2 (3.7 to 4.6)	0.93
CO 6 Closure	4.2 (3.6 to 5.0)	4.2 (3.5 to 4.9)	0.77
SV 0 Baseline	58.2 (47.8 to 70)	54.3 (52.3 to 62.9)	0.39
SV 1 Surgical approach	46.4 (40.4 to 55.7)	48.7 (44.7 to 60.2)	0.62
SV 2 Reaming	43.3 (37.7 to 48.8)	50.0 (42.0 to 59.2)	0.51
SV 3 Lavage	41.9 (35.6 to 54.7)	45.6 (40.8 to 53.7)	0.74
SV 4 Cementation	32.3 (24.9 to 38.8)	45.6 (40.8 to 53.7)	0.02
SV 5 Prosthesis	41.7 (28.4 to 47.9)	42.1 (40.0 to 50.0)	0.81
SV 6 Closure	40.1 (35.9 to 42.5)	40.3 (38.0 to 48.0)	0.90
MAP 0 Baseline	84 (77 to 108)	116 (106 to 120)	0.05
MAP 1 Surgical approach	102 (94 to 109)	90 (78 to 105)	0.18
MAP 2 Reaming	95 (89 to 109)	89 (78 to 112)	0.68
MAP 3 Lavage	92 (84 to 99)	87 (78 to 99)	0.57
MAP 4 Cementation	76 (72 to 78)	87 (78 to 99)	0.06
MAP 5 Prosthesis	83 (74 to 89)	94 (74 to 107)	0.33
MAP 6 Closure	87 (68 to 108)	93 (77 to 100)	0.39
HR 0 Baseline	72 (57 to 85)	89 (79 to 98)	0.02
HR 1 Surgical approach	82 (67 to 95)	98 (87 to 112)	0.03
HR 2 Reaming	87 (70 to 93)	98 (88 to 105)	0.12
HR 3 Lavage	91 (76 to 98)	100 (89 to 111)	0.17
HR 4 Cementation	94 (59 to 102)	100 (89 to 111)	0.24
HR 5 Prosthesis	87 (62 to 112)	99 (81 to 107)	0.76
HR 6 Closure	92 (65 to 100)	98 (89 to 101)	0.42

In animal studies of cardiac output during simulated cemented arthroplasty, a catheter inserted into the pulmonary artery via a thoracotomy measured a reduction in cardiac output during cementation of 21%.²¹ The complications which accompany the use of pulmonary artery catheters preclude their use in man, but the transoesophageal Doppler device gave satisfactory measurements in our patients. Conventional intraoperative monitoring did not reveal this reduction. The use of a transoesophageal Doppler probe carries the risk of oesophageal perforation, but at 6 mm it is only the size of a nasogastric tube, and no perforation has been reported. Its use to improve fluid balance management and reduce postoperative cardiopulmonary complications in surgery on the femoral neck has been demonstrated.^{12,24}

We are aware of the limitations of our study. The small number of patients increases the possibility of a type-II error. Smaller significant differences in cardiac output may have occurred at other times but remained undetected. When considering differences in the baseline MAP and heart rate between the cemented and uncemented groups, it

is possible that there was an unidentified factor in the cemented group. During recruitment of patients, we did not investigate their intake of antihypertensive medication, such as beta-blocking agents, which could slow the heart rate and lower the MAP.

Our study confirms significant falls in cardiac output and stroke volume during cementation, and demonstrates the superiority of the transoesophageal Doppler technique over conventional non-invasive monitoring in detecting such changes.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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