RESEARCH ARTICLE

Hemodynamic and Arterial Blood Gas Parameters during Cemented Hip Hemiarthroplasty in Elderly Patients

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Abstract

Background: Patients undergoing cemented hip hemiarthroplasty may develop bone cement implantation syndrome (BCIS) which is a leading cause of intraoperative complications. The purpose of this study was to evaluate cardiovascular changes during cemented hip hemiarthroplasty in elderly patients.

Methods: Cemented hip hemiarthroplasty was performed on 72 patients with femoral neck fracture. All patients were catheterized with a radial artery catheter to assess mean arterial pressure (MAP) and arterial blood gas (ABG) in these time points: just before cementation, just after cementation (0^{th}), 5 min (5^{th}) and 10 min (10^{th}) after cementation, and at the end of surgery (END). Also, systolic and diastolic blood pressure (SBP & DBP), heart rate and any arrhythmia or cardiac arrest was evaluated.

Results: Seventy-two patients (33 females, 39 males; mean age: 66.8±7 years) were evaluated. All parameters changed during cementation with a significant drop in MAP, SBP, and DBP immediately after cementation and pH and base excess decreased significantly (P<0.001) with no changes in O2 saturation. Mean heart rate rose until the 5^{th} and then decreased dramatically with no bradycardia presentation. During cementation, 12 patients showed arrhythmia, but no cardiac-arrest was observed.

Conclusions: Under strict observation of a anesthesiology care team, hemiarthroplasty can be a safe method for femoral neck fracture in elderly osteoporotic patients without severe cardiopulmonary compromise.

Key words: ABG, Bone cement, Hemiarthroplasty, Hemodynamics, Mean arterial pressure

Introduction

The incidence of femoral neck fractures increases with age and the treatment of choice is cemented hip hemiarthroplasty (1). Bone cement functions as a supportive material that forms a mechanical bond between the cement, bone, and prosthesis (2). When hardened, bone cement forms a buffer between the bone and the prosthesis, which evenly distributes weight and other stresses that impinge on the prosthesis and bone (3).

Patients undergoing this method may develop bone cement implantation syndrome (BCIS), a leading cause of intraoperative morbidity and mortality (4). This syndrome is characterized by hypotension, pulmonary hypertension, increased central venous pressure, pulmonary edema, broncho-constriction, hypoxemia, low partial end tidal carbon-dioxide, cardiac dysrhythmia or arrhythmia, cardiogenic shock, transient decrease in arterial oxygen tension, thrombocytopenia, hypothermia, cardiac arrest, and sudden death (5-9). A classification system for BCIS has been proposed according to its severity as follows: grade 1: moderate hypoxemia (Spo2<94%) or a decrease in systolic arterial pressure (SAP) >20%; grade 2: severe hypoxemia (Spo2<88%) or hypotension (decrease in SAP>40%) or unexpected loss of consciousness; and grade 3: cardiovascular collapse requiring cardiopulmonary resuscitation (10). There are several theories about the cause of BCIS, but the direct etiology is still unclear. Because of the high frequency of femoral neck fractures in the elderly and possible life threatening complications following BCIS we evaluated cardiovascular parameter changes during hip hemiarthroplasty. The aim of this

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Table 1. Patients' demographic data and intraoperative characteristics

Age (year)	66.8 ± 7
Female (%)	33 (45.8 %)
BMI (body mass index (Kg/m^2))	25.92 ± 3.22
ASA* grade I (%)	14 (19.44 %)
ASA* grade II (%)	58 (80.56 %)
Diabetes (%)	37 (51.38 %)
Hypertension (%)	43 (52.79 %)
Previous myocardial infarction (%)	5 (6.95 %)
Previous cardiac arrhythmia (%)	2 (2.77 %)
Incidence of arrhythmia during surgery (%)	12 (16.7 %)
Incidence of cardiac arrest during surgery (%)	0 (0 %)
Operative time (min)	71.3 ± 17.2
Intraoperative fracture (%)	3 (4.16 %)
Intraoperative blood loss (ml)	289 ± 130.8

* American Society of Anesthesiologists

study was to assess the cardiovascular index changes during cemented hip hemiarthroplasty for femoral neck fractures.

Materials and Methods

This was a before and after cross-sectional study conducted on 72 patients with osteoporotic displaced femoral neck fracture (Garden III and IV), who referred to our department between January 2010 and December 2011. All of the patients were treated in our department with a cemented hip hemiarthroplasty.

The study was approved by the ethics committee of the Guilan University of Medical Sciences and informed consent was obtained from all patients at their preoperative visits.

Exclusion criteria were as follows: femoral neck fracture Garden I and II (undisplaced fracture), cognitive impairment, alcoholism, major medical co-morbidity, pulmonary coexisting disorders, and recipients of institutional care.

Management of anesthesia and surgery

The induction of anesthesia was performed using propofol 0.5 mg/kg (Fresenius Kabi Co.) and maintenance of anesthesia was performed by intravenous infusion of propofol 50-70 µg/kg, ramifentanil (0.15 µg/kg/min) (GSK- UK pharmaceutical company), and repetitive dosages of ANECUR® 25mg/2.5, (Abureihan Co.). All of the patients were mechanically ventilated with tidal volume 10 ml/kg, FIO2 50% and respiratory rate 12/min, I/E ratio 1/2 and peak flow 20/l/min and then the patient was placed in the lateral decubitus position and a longitudinal skin incision centered over the greater trochanter in the lateral position was done. The tractus iliotibialis and the gluteal aponeurotic fascia were divided on the line of the skin incision. The anterior part of the gluteus medius and minimus insertion was incised down to the bone; prolonged distally through the vastus lateralis in a curved line to spare some tendinous tissue at the greater trochanter for reattachment. Then the anterior hip capsule was excised.

After removing the femoral head, the hip was gently flexed, adducted and internally rotated. The femoral canal was reamed with increasing sizes of the reamers. After cortical reaming was felt, broaches were placed precisely and the fit of the broach within the canal was assessed. Adequate axial and rotational stability was tested with no motion of the broach in the canal. Then the femoral stem trial was inserted. The precise size of the femoral stem was also tested to rotational and extraction forces.

A cement restrictor was inserted 2 cm below the estimated position of the stem tip. Poly-Methyl-Metha-Acrylate cement was introduced in a retrograde manner with a cement gun at low pressure and the Lubinus SP II+ Mega Kopf prosthesis (Waldemar Link GmbH & Co.KG, Hamburg, Germany) was inserted. After inserting the predetermined and measured femoral bipolar head, the hip was reduced and the stability of the hip joint was again tested.

Study Protocol

During surgery, all of the patients were catheterized with a radial artery catheter to assess MAP and ABG in these five time points: just before cementation, just after cementation (0^{th}), 5 min (5^{th}) and 10 min (10^{th}) after cementation, and at the end of surgery (END). Also, SBP, DBP, heart rate, and any arrhythmia or cardiac arrest was noted. Intraoperative blood loss was calculated by the blood volume of suction devices, and the volume of blood was estimated in previously weighed sponges and drapes. After surgery we followed all patients for one year to identify late onset morbidity or mortality.

Statistics

All data were statistically analyzed using SPSS software package for windows ver. 19.0 (SPSS Inc., Chicago, IL, USA). Repeated measure analysis of variance (ANOVA), Fisher exact test, and chi-square test was used to evaluate the effects of bone cementation plus prosthesis insertion on systemic hemodynamics and blood gas parameters and $P<0.001$ was considered statistically significant.

Results

Seventy-two patients (33 females, 39 males; mean age: 66.8±7 years) were evaluated. Table 1 shows all of the patients' demographic features and intraoperative characteristics. Three fractures occurred during stem insertion, 12 cases showed arrhythmia during cementation, and there was no case of cardiac arrest.

All parameters changed during cementation with a significant depression in MAP, SBP, and DBP immediately after cementation. Mean heart rate rose until the 5^{th} and then decreased dramatically with no bradycardia presentation and pH and base excess decreased significantly ($P<0.001$) with no changes in O2 saturation ($P<0.001$). Index changes during surgery are shown in

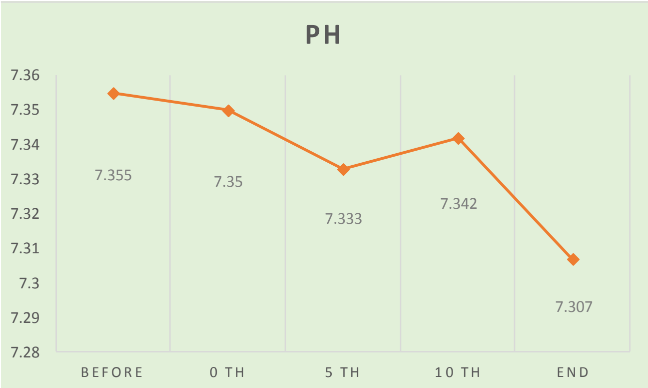

Figure 1. Changes in pH during cementation.

Figure 2. Changes in base Excess during cementation.

Table 2 and Figure 1-4.

During cementation, 12 cases showed arrhythmia with higher frequency in cases that had a previous history of myocardial infarction. One year after surgery, there was no reported cases of mortality and no late onset cardiovascular compromise.

Discussion

In arthroplasty procedures, bone cement is used to fill all small openings in the spongy skeleton and to fill all of the hollows on uneven surfaces (11). Hence, the cement strongly adheres to the surface of the prosthesis. Accurate bone cement mixing and precise application techniques are the foundation of successful outcomes, as they both increase the stability and the longevity of the prosthesis (12).

Bone cement has two different components: a white powder component (polymer) and a liquid component (monomer). The polymer component consists of bead-shaped particles with a diameter typically of 40 microns made of Poly-Methyl-Metha-Acrylate-copolymer (PMMA). The liquid component mainly contains the monomer Methyl-Metha-Acrylate (13). Table 3 shows the different components of the bone cement.

When the two components are mixed, the liquid monomer polymerizes around the powder particles to form hardened PMMA in an exothermic reaction. The end result is a soft, pliable, doughy material which then hardens into a cement-like PMMA complex (13).

Bone cement implantation syndrome (BCIS) is a well-recognized complex of sudden physiologic changes that occur within minutes of the implantation of PMMA bone cement to secure a prosthetic component into the femur (14).

The incidence of intraoperative mortality during cemented hip hemiarthroplasty is 0.11% with all death incidences occurring around the time of PMMA cementation (15).

There are several theories about the cause of BCIS which says that different components of PMMA are the main cause of BCIS manifestations. Some of these theories are: 1) The direct effect of the exothermic cement reaction; 2) Air or gas embolism caused by polymerization process; 3) Increase in intramedullary pressure resulting from the introduction of hot acrylic cement (this increase could force marrow and fat into the circulation, producing pulmonary emboli); and 4) Fat and debris from the femoral shaft emboli of the femoral canal during cement and implant insertion (16-18).

Cemented femoral technique has also been associated with a greater risk of fat embolization and hypotension. Christie et al. have shown that femoral hemiarthroplasty

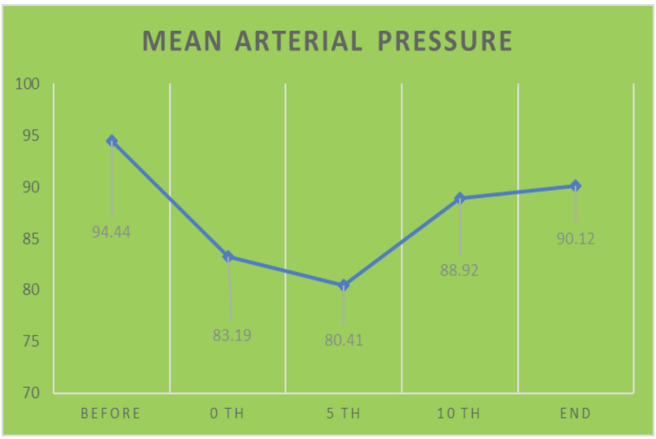

Figure 3. Changes in mean arterial pressure during cementation.

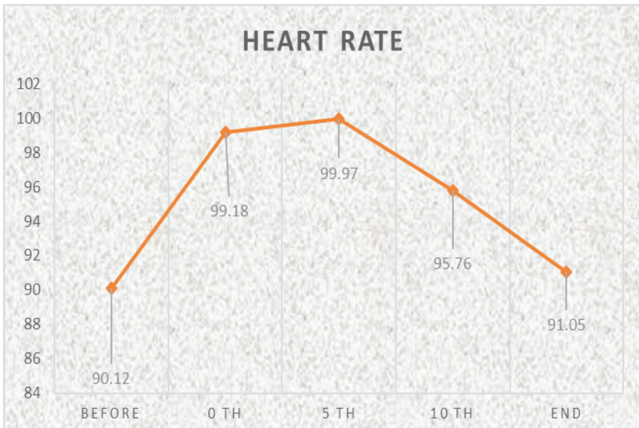

Figure 4. Changes in heart rate during cementation.

Table 2. Changes in cardiovascular indexes during cementation

Parameters	Before	0_{min}	5_{min}	10_{min}	END	*P* value
O2 Saturation (O2 Sat)	98.17 ± 1.03	98.18 ± 0.92	98.27 ± 0.87	98.28 ± 0.81	98.46 ± 0.74	*P*> 0.001 (Non-significant)
Partial Pressure of Carbon Dioxide (mmHg)	34.58 ± 3.29	36.01 ± 3.15	36.05 ± 3.19	34.18 ± 3.39	33.71 ± 3.30	*P*< 0.001 (Significant)
Mean Arterial Pressure (mmHg)	94.44 ± 13.35	83.19 ± 14.19	80.41 ± 19.20	88.92 ± 12.28	90.12 ± 7.64	*P*< 0.001 (Significant)
Systolic Blood Pressure (mmHg)	128.76 ± 18.03	118.60 ± 21.53	114.31 ± 25.76	119.29 ± 19.91	129.43 ± 12.10	*P*< 0.001 (Significant)
Diastolic Blood Pressure (DBP)	82.18 ± 14.24	76.33 ± 15.25	70.05 ± 14.59	76.53 ± 14.90	77.68 ± 12.33	*P*< 0.001 (Significant)
Heart Rate (min)	90.12 ± 10.47	99.18 ± 17.05	99.97 ± 16.96	95.76 ± 15.18	91.05 ± 13.67	*P*< 0.001 (Significant)

Table 3. Components of bone cement

Powder Component	Liquid Component
Polymer Poly-Methyl-Metha-Acrylate/ copolymer (PMMA)	*Monomer* Methyl-Metha-Acrylate (MMA)
Initiator Benzoyl Peroxide (BPO)	*Accelerator* N,N-Dimethyl-Para-Toluidine (DMPT) dimethyl-Para-Toluidine (DMpt)
Radio-Opacifier Barium Sulphate (BaSO4) Zirconia (ZrO2)	*Stabilizer* Hydroquinone
Antibiotics e.g., Gentamycin	

with cement fixation is associated with more frequent and more extensive thromboembolic cascades if cement is not used. Previous studies have shown that the cement may play an important role in mortality increase due to its possible risk of inducing cerebrovascular complications and cardiovascular events (19-21). For example, Clark et al. have also shown significant falls in cardiac output and stroke volume during cementation (22). Nevertheless, our study showed no cardiac arrest during surgery and no death at postoperative follow up times of 1 month, 3 months, and 1 year, indicating that the use of cement does not increase the aforementioned risks. In addition, our results showed no significant depression in O2 saturation. In 2010, Kotyra et al. studied hemodynamic changes during bone cementation for femoral neck fractures (23). They concluded that O2 saturation, pCo2 and PO2 levels did not show statistically significant changes during surgery, which was similar to our results. On the other hand, in our survey, cardiac arrhythmia occurred only in patients with a history of cardiovascular disease. All cardiovascular changes, including increase in heart rate and blood pressure, returned to normal level when surgery finished. Just the acidosis remained until the end of surgery in a level of pH, which was not a life threatening complication.

In 2012, Taylor et al. presented a randomized control trial on hemiarthroplasty outcomes with and without cement (24). They concluded that in elderly patients who were treated with hemiarthroplasty for displaced femoral neck fracture, implant-related complication rates were significantly lower in the group treated with a cemented implant, and so better results were presented in this group. In 2013, Li et al. presented a meta-analysis study and concluded that compared with non-cemented hemiarthroplasty, cemented hemiarthroplasty can attain less implant-related complications with no increased risk of mortality, cardiovascular and cerebrovascular complications, general complications, local complications, and reoperation rate in treating elderly patients with femoral neck fractures(25). Based on these studies and our results, displaced femoral neck fractures in elderly osteoporotic cases (70 years or older) without severe cardiopulmonary compromise and under strict observation of an anesthesia care team, cemented hemiarthroplasty can be a safe treatment method.

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