ORIGINAL PAPER

Changes in blood pressure during cemented hemiarthroplasty for hip fracture in elderly patients under spinal anaesthesia

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ABSTRACT

Blood pressure changes around cement insertion during total hip arthroplasty have been investigated; however, there is little agreement regarding whether a similar phenomenon occurs during hemiarthroplasty in the elderly under spinal anaesthesia. Therefore, our objective was to examine blood pressure around cement insertion during hemiarthroplasty in the elderly. For this retrospective, single-centre, case series study, we identified 430 hips of patients aged >65 years who underwent cemented hemiarthroplasty under spinal anaesthesia from January 2010 to August 2018. The maximum regulation ratio (MRR) was used to express changes in blood pressure immediately after cement insertion and was calculated as follows: the greatest difference (positive or negative) during 5 min after cement insertion into the bone canal divided by systolic blood pressure just before cement insertion. The timings of vasopressor administration and blood transfusion were recorded. The median MRR was compared for each American Society of Anesthesiologists (ASA) classification. The mean MRR was 4.0% (SD:10.4; range −26 to 83). MRR of patients with a >10% increase in blood pressure was significantly less than that of patients with a <10% change in blood pressure. Vasopressor was used in three patients 10 min after cement insertion into the bone canal. There was no significant difference between MRR groups and ASA classification (p = 0.182, respectively). MRR was not significantly different for each ASA classification. However, few cases showed a reduction in blood pressure immediately after cement insertion, regardless of ASA classification.

Keywords: cemented bipolar hemiarthroplasty, spinal anaesthesia, blood pressure, American Society of Anaesthesiologists classification, elderly

Abbreviations:
THA: total hip arthroplasty :
BCIS: bone cement implantation syndrome
SV: stroke volume
CI: cardiac index
CO: cardiac output
ASA: American Society of Anesthesiologists
PMMA: polymethyl methacrylate
MRR: maximum regulation ratio

INTRODUCTION

By 2060, the global population aged >65 years is expected to rise to 17.8%, with a rapid increase expected particularly in the latter half of the century.[1] Correspondingly, the mean age of patients with femoral neck fracture will increase, thus, increasing the complication risk of during the operation for femoral neck fractures. Routine treatments for displaced femoral neck fracture include hemiarthroplasty and total hip arthroplasty (THA). However, whether these procedures should involve cemented or cementless fixation remains controversial. Although surgical time and total blood loss in cementless hemiarthroplasty is less than that in cemented hemiarthroplasty,[2] the mean reduction in mobility score,[3] residual pain,[3] maximal gait function,[4] intra- and postoperative fracture[5] and subsidence[5] favours cemented hemiarthroplasty. Recent guidelines established in Western countries recommend cement fixation for hemiarthroplasty in femoral neck fracture in elderly patients. However, Parvizi et al[6] have reported that cemented THA and hemiarthroplasty cause irreversible cardiorespiratory disturbances and even death. Hypoxia, hypotension, pulmonary hypertension, arrhythmias and cardiac arrest occurring immediately after cement insertion are collectively called bone cement implantation syndrome (BCIS).[7,8]

Fujita et al monitored patients' blood pressure during THA under general anaesthesia and showed that there were no episodes of major hypotension in patients with a mean age of 64.5 years.[9] As patients with displaced femoral neck fracture who undergo hemiarthroplasty are generally the elderly who suffer from comorbidities, reduction in stroke volume (SV) and cardiac index (CI) due to pulmonary embolic events after cement insertion[10] are noted. Compared with patients who undergo THA for degenerative hip disease, a reduction in blood pressure may be observed in those who undergo hemiarthroplasty for femoral neck fracture in patients with a mean age of over 80 years.

The objective of the present study was to examine blood pressure changes around cement insertion during hemiarthroplasty for hip fracture in elderly patients independent of age and physical status compared with the THA patients.

PATIENTS AND METHODS

Patients who underwent surgery between January 2010 and August 2018 for femoral neck fracture were included in this retrospective, single-centre, case series study. The surgical database used for this study comprised 699 hips as shown in the flow diagram (Figure 1). We excluded patients aged <65 years (n = 14), those who underwent internal fixation (n = 172), blood transfusion (n = 12) and total hip arthroplasty (n = 9), those who underwent surgery general anaesthesia (n = 40) and those with bone metastasis (n = 1) and missing data (n = 21). The remaining 430 hips were analysed in this study. Study approval was obtained from the institutional review board of the Hamamatsu Medical Center. The baseline characteristics of patients are summarized in Table 1. Surgery-related data such as preoperative waiting period, operative time, intraoperative infusion volume, intraoperative blood loss, spinal anaesthesia level and 0.5% plain bupivacaine volume were extracted from medical records. Garden classification and ASA physical status were categorized by the first author.

Anaesthesia management and surgical procedure

All patients underwent the same surgical procedure. Briefly, lumbar spinal anaesthesia was performed in the lateral position, with fracture side face up. All patients received spinal anaesthesia with 2.0–3.0 ml isobaric bupivacaine (0.5%) administrated at the lumbar level (L2-3
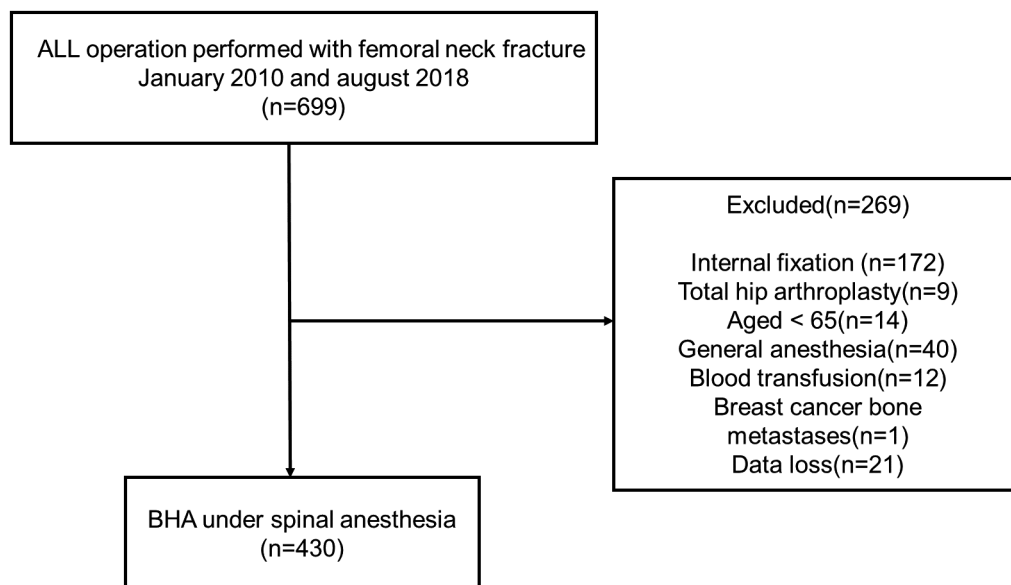
Fig. 1 Flow diagram for the study

Table 1 Baseline characteristics

	Mean (SD)	Range (min-max)	Distribution no. (%)
Age (year)	83.1 (7.5)	65–103	
Sex (male)			110 (25.6)
Fracture side (Right)			225 (52.3)
Garden classification			
I			0
II			14 (3.3)
III			59 (13.7)
IV			357 (83.0)
Height (cm)	151.5 (9.1)	130–182	
Body weight (kg)	46.0 (9.5)	23.7–78.8	
Body mass index (kg/m^2)	20.0 (3.50)	11.1–35.8	
Antihypertensive drug			167 (37.8)
ASA physical status			
Class1			27 (6.3)
Class2			271 (63.0)
Class3			132 (30.7)

or L3-4); the volume of bupivacaine was adjusted according to patients' age, body weight and height. After performing the spinal block, patients were maintained in the lateral position for heart rate and blood pressure stabilization. Oxygen was continuously given through the nasal

cannula or mask over SpO$_2$ 95%. Lactated Ringer's solution was loaded to fill the volume after spinal anaesthesia and an artificial colloidal solution was added after femoral neck resection to prepare for bleeding from the medullary canal. All surgeries were performed through a posterior approach using Exter V40® (Stryker Orthopedics, Mahwah, NJ, USA) and modern cementing technique with Simplex P bone cement (Stryker, Kalamazoo, MI, USA), followed by irrigation and drying of the femoral canal, plugging of the distal medullary canal (through vacuum mixing of the cement), filling with polymethyl methacrylate (PMMA) bone cement using a proximally pressurized retrograde cement gun (which had an appropriate sized bipolar head) and completing the procedure using a suture capsule.

Assessments

The number of patients who required blood transfusion was determined. The timing of vasopressor (ephedrine or phenylephrine) administration was recorded and classified as follows: 15 min prior to and 10 min after cement insertion, with frequent injection during the surgery. Systolic and diastolic blood pressures and heart rate were analysed from patients' anaesthesia records. Non-invasive blood pressure measurements were assessed at the upper arm every 2.5 min, starting from entry into the operation theatre until exit. The maximum regulation ratio (MRR) described by Fujita et al[9] was used to express changes in blood pressure immediately after cement insertion and was calculated as follows: the greatest difference (positive or negative) during 5 min after cement insertion into the bone canal divided by systolic blood pressure just before cement insertion. Similarly, heart rate was calculated to express regulation ratio [maximum regulation ratio heart rate (MRRHR)]. Patients were classified into three groups on the basis of MRR: group A (increased by >10%), group B (changed by <10%) and group C (decreased by >10%). Patients were divided into four age groups: 65–74 years, 75–84 years, 85–94 years and 95–103 years; the MRR of each age group and ASA classification was analysed and their distributions assessed.

We investigated the correlation coefficient among MRR and age, BMI, blood loss, infusion volume and operative time. The relationships between MRR and antihypertensive drug and anticoagulant and antiplatelet drug were assessed.

Statistical analysis

The distribution of each group (A, B and C) was analysed using the chi square goodness-of-fit test. Between-group differences in MRR for the different age groups and ASA classification were analysed using the non-parametric Kruskal–Wallis test. The relationships among MRR and age, blood loss, BMI, infusion volume and operative time were analysed using the Pearson correlation coefficient. The relationships between MRR and antihypertensive drug and anticoagulant and antiplatelet drug were assessed using the Mann–Whitney U test. The threshold for significance was $p < 0.05$. All statistical analyses were performed using EZR version 1.38 (64-bit).

RESULTS

Surgical data are shown in Table 2. Vasopressor was used in 15 patients at 15 min before and in 3 patients at 10 min after cement insertion into the bone canal, whereas 32 patients received frequent injections during surgery. The mean MRR was 4.0% (SD: 10.4; range −26 to 83). The distribution of each group (A, B and C) is shown in Figure 2.

The results showed that MRR of patients with a >10% increase in blood pressure was significantly less than that of patients with a <10% change in blood pressure ($p < 0.05$; χ^2

Table 2 Operative data

	Mean (SD)	Range (min-max)	Distribution no.(%)
Surgery waiting days	6.1 (5.1)	0–36	
Duration of operation	90.6 (15.6)	55–144	
Intraoperative infusion volume	898.3 (339.9)	110–2005	
Intraoperative blood loss (ml)	334.5 (150.6)	58–1108	
Level of spinal anesthesia			
L1/2			1 (0.2)
L2/3			77 (17.9)
L3/4			325 (75.6)
L4/5			26 (6.0)
L5/S1			1 (0.2)
0.5% plain bupivacaine volume	2.58 (0.25)	1.8–3.6	
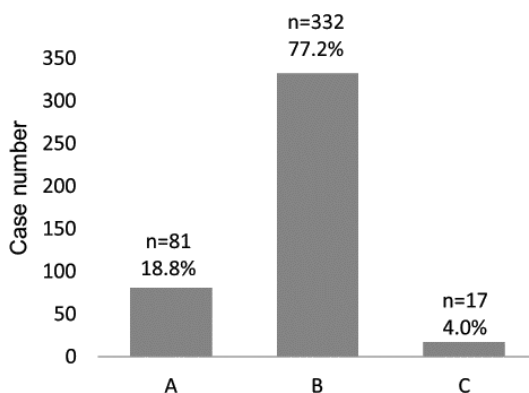
Fig. 2 The distribution of the MRR (maximum regulation ratio)

= 382.33). The distribution of each MRR group for each ASA classification and for each age group showed Figure3 and Figure4. No significant difference between the MRR groups and ASA classification showed (p = 0.182; Kruskal–Wallis test). On the other hand, significant difference between the MRR groups and each age groups showed (p = 0.033; Kruskal–Wallis test). The p-values for all the groups were as follows: 1:2, p=0.269; 1:3, p=0.997; 1:4, p=0.530; 2:3, p=0.044 and 2:4, p=0.928. No significant differences correlations coefficients were detected between MRR and MRRHR (r=−0.0248, p=0.608), age (r=−0.0185, p=0.702), BMI (r=0.0159, p=0.743), blood loss (r=−0.002, p=0.966), infusion volume (r=−0.0444, p=0.358) and operative time (r=0.0065, p=0.893). No significant differences were observed for the relationship between MRR and antihypertensive drug and anticoagulant and antiplatelet drug.
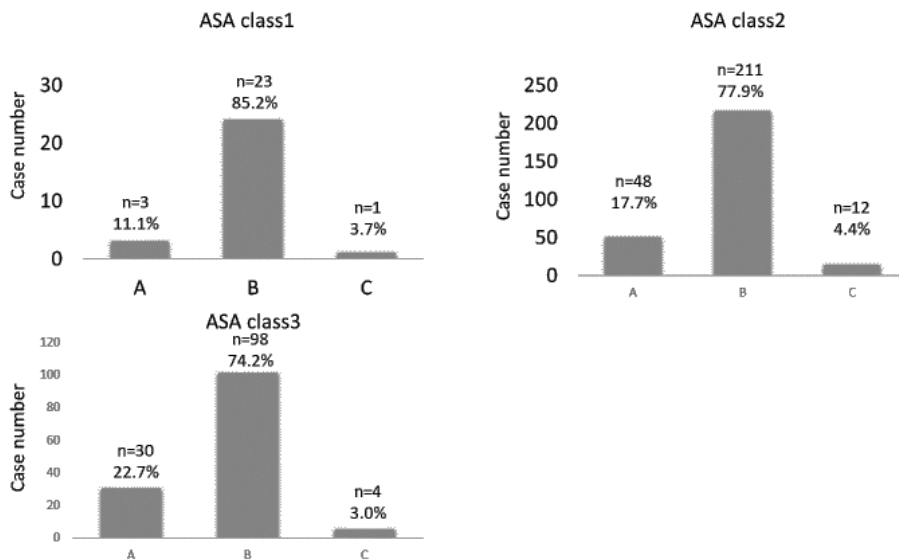
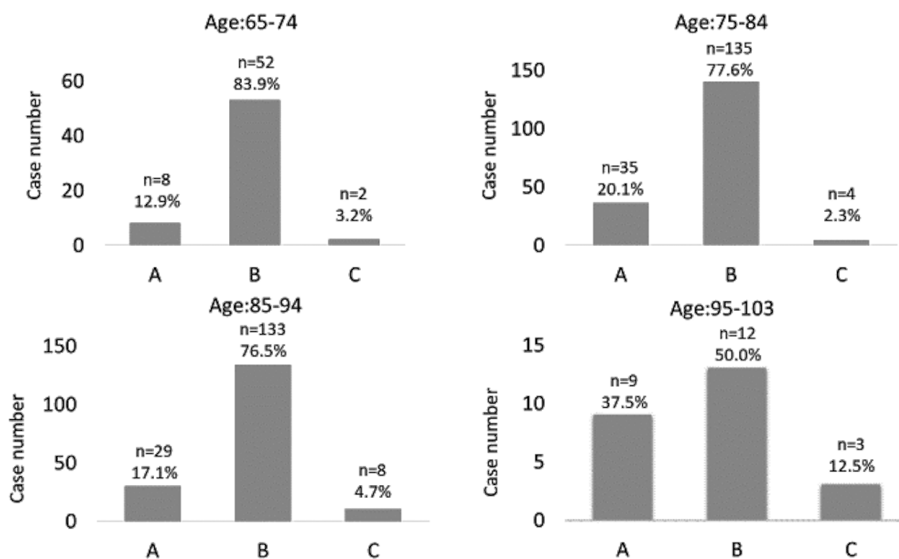**Fig. 3** The distribution of the each MRR group for each ASA classification

Fig. 4 The distribution of the each MRR group for each age groups

DISCUSSION

This study investigated changes in blood pressure around cement insertion during hemiarthroplasty for hip fracture under spinal anaesthesia in elderly patients. Vasopressor use was limited, and it was used immediately after cement insertion. Our results showed that MRR of patients with a >10% increase in blood pressure was significantly less than that of patients with a <10% change in blood pressure. Age group2 had a significantly higher MRR than age group3,

but no significant differences in their correlation coefficients were detected between MRR and MRRHR. Other age and ASA classification did not affect the change in blood pressure around cement insertion.

BCIS may be attributed to the circulation of PMMA cement monomer in blood during cementation, histamine release, complement activation, endogenous cannabinoid-mediated vasodilatation and pulmonary embolization. Among these, pulmonary embolism is considered to be the main cause, as demonstrated previously in individuals with embolic showers in the right atrium using transoesophageal echocardiography.[11-14] While some studies have reported that cardiac output (CO), SV and CI decrease after cement insertion,[8,15,17] others have not been able to show a significant decrease in blood pressure after cement insertion.[16,17]

This study examined changes in blood pressure during cemented hemiarthroplasty under spinal anaesthesia for different age groups and ASA classification. A recent prospective study comparing cemented and cementless groups showed no difference in haemodynamics for each ASA classification.[18] Because hemiarthroplasty under spinal anaesthesia is widely performed, it is imperative to verify whether cementing under spinal anaesthesia can be safely performed. This study showed age group2 had a significantly higher MRR than age group3, but no significant differences between their correlation coefficients were detected between MRR and MRRHR. Its variability was small and clinical significance was unclear.

Fujita et al[9] monitored blood pressure during THA using the interface bioactive bone cement technique and showed that in most cases, blood pressure remained unchanged on the femoral side. In their study, surgery was performed under general anaesthesia in patients with a mean age of 64.5 years.[9] We observed we and Fujita et al similar blood pressure changes; MRR of patients with a >10% increase in blood pressure was significantly less than that of patients with a <10% increase in blood pressure after cement insertion. However, in our study, surgery was performed under spinal anaesthesia in patients with a mean age of 83.0 years and was of a semi-emergency nature. From this reason, age and general status may have little effect on blood pressure changes after cement insertion.

The Cochrane Collaboration of anaesthesia for hip fracture surgery in adults found no clear evidence on whether spinal anaesthesia is superior to general anaesthesia, although there were fewer early deaths (within 1 month) after spinal anaesthesia.[19] There is a lack of studies examining haemodynamics around cement insertion during hemiarthroplasty under spinal anaesthesia in the elderly and in those with a poor condition; our study aims to fill the gap.

In our study, while 4.0% elderly patients showed a prominent decrease in blood pressure during hemiarthroplasty immediately after cement insertion under spinal anaesthesia, others showed a significant decrease in blood pressure prior to cement insertion and, therefore, required ephedrine. We attributed the latter to bleeding from the bone canal might decrease blood pressure before cement insertion. A previous study has shown that pulmonary vascular resistance and pulmonary artery pressure increase immediately after cement insertion.[15] Given this, we consider that if the right ventricle fails to compensate for any increase, significant hypotension may be caused pulmonary vascular resistance associated with prosthesis insertion.

There are some limitations of this study. First, as this was a retrospective study, the results may be influenced by outcome reporting bias and selection bias. Patients in a poor condition might undergo the procedure under general anaesthesia. Second, ASA physical status was categorized by one orthopaedic surgeon; ASA classification identified specific cases, but without clear diagnostic criteria. Finally, as we measured blood pressure using an electric sphygmomanometer, acute cardiovascular effects around cement insertion might have been masked.

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CONCLUSION

We showed that MRR of patients with a >10% increase in blood pressure was significantly less than that of patients a <10% change in blood pressure. Hemiarthroplasty for femoral neck fracture in the elderly under spinal anaesthesia was did not significantly induce major hypotension independent of age and physical status by measuring blood pressure, preparing vasopressor and maintaining circulating blood volume for drip.

ACKNOWLEDGEMENTS

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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