

General

Comparative assessment of bone cement implantation syndrome in cemented bipolar hemiarthroplasty: impact in patients with and without preexisting heart disease

Varah Yuenyongviwat¹, Jiranuwat Janejaturanon¹, Theerawit Hongnaparak¹, Khanin Iamthanaporn^{1a}

¹ Department of Orthopedics, Faculty of Medicine, Prince of Songkla University

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Background

With the increasing incidence of hip fractures in older adults, hip replacement with a cemented femoral stem has become a viable treatment option. However, concerns regarding potential complications, particularly bone cement implantation syndrome (BCIS), especially in patients with preexisting medical conditions, have prompted orthopedic surgeons to explore alternative approaches.

Objective

The research question of this retrospective study is whether BCIS incidence in patients with preexisting heart disease undergoing cemented bipolar hemiarthroplasty is higher than that of patients without preexisting heart disease.

Methods

We retrospectively analyzed data from 311 patients undergoing cemented bipolar hemiarthroplasty, including 188 without preexisting heart disease and 123 with heart disease. Anesthetic records were reviewed to assess parameters related to BCIS. BCIS severity was graded systematically, emphasizing key metrics, such as hypotension, arterial desaturation, and the loss of consciousness.

Results

Among the patients, no perioperative deaths occurred. Grade 1 BCIS was observed in 13 patients (4.18 %), without instances of grade 2 or 3. Notably, grade 1 BCIS was observed in only 2 patients with preexisting heart disease (1.63%) and 11 patients (5.85%) without preexisting heart disease.

Conclusion

BCIS incidence after cemented bipolar hemiarthroplasty was minimal, with a predominantly low severity. Importantly, preexisting heart disease did not pose a significant increase in the risk of BCIS. This finding confirms the safety of cemented bipolar hemiarthroplasty in older adults.

Level of Evidence

III

^a Corresponding author:

Address: Department of Orthopedics, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand

Phone: (66)74451601 Fax: (66)74451603

Email: khanin.i@psu.ac.th

INTRODUCTION

Femoral neck fractures pose a contemporary challenge in orthopedics. Hemihip replacement is a popular treatment, with choices between cemented and cementless prostheses.^{1,2} Modern stems in hip hemiarthroplasty demonstrate advantages over cemented stems, depicting a reduction in implant-related complications and mortality comparable to those of their cementless counterparts.³ However, surgeons are concerned about bone cement implantation syndrome (BCIS), a rare yet substantial complication requiring meticulous attention in orthopedic practice.^{4,5}

BCIS is a multifaceted phenomenon characterized by a sudden and potentially life-threatening response to bone cement during arthroplasty.⁶ BCIS manifests as hypotension, arterial desaturation, and varying degrees of consciousness loss; however, its exact cause remains unknown.^{7,8} It is supposedly triggered by a robust allergic response, inflammation, heat, and complement activation; a study that utilized blood flow measurements and intraoperative ultrasound reported on the intricacies of BCIS.⁹ Previous investigations have highlighted the impact of cement on the circulatory system, potentially causing silent pulmonary embolism, evading detection using conventional methods.^{10,11}

Preexisting conditions and risk factors for BCIS, including older age, poor physical condition, impaired heart or lung function, pulmonary hypertension, osteoporosis, bone metastases, hip fractures, metastatic disease, and increased procoagulant levels, are of particular concern.^{8,12-14} Notably, preexisting heart problems, documented in cases of chronic heart failure and chronic ischemic heart disease, have raised specific concerns.¹⁰ However, limited studies have compared the specific incidence of BCIS in patients with cardiovascular system disorders to those without.

The question of this study is whether BCIS incidence in patients with preexisting heart disease undergoing cemented bipolar hemiarthroplasty is higher than that of patients without preexisting heart disease. We hypothesized that patients with preexisting heart conditions would exhibit a higher incidence of BCIS.

MATERIALS AND METHODS

This retrospective study was approved by our institutional review board. The study cohort comprised 311 patients who underwent cemented bipolar hemiarthroplasty at our institution between May 2013 and February 2023. Of them, 188 had no preexisting heart conditions, whereas 123 had documented underlying heart diseases, necessitating cemented bipolar hemiarthroplasty.

Individuals with a history of hip fractures attributed to cancer, infections, or metabolic diseases were excluded. In addition, we excluded patients with a history of hip fractures previously treated with alternative surgical methods, including proximal femoral nail antirotation or multiple cannulated screws. Furthermore, individuals who underwent surgery for hip replacement and fractures in other areas simultaneously were excluded.

In this study, all patients underwent bipolar hemihip arthroplasty using a posterolateral approach in the lateral decubitus position. Surgical procedures were performed using standard instruments, without computer navigation. Femoral preparation involved the use of standard broaches and washing with a bulb syringe. Subsequently, the surgeon informed the anesthesiologist about the upcoming stem implantation preparation, and the anesthesiologist prioritized patient hydration to ensure procedural readiness. The process was continued by inserting a distal femoral plug into the femoral canal, positioned 1.5–2 cm below the stem tip. The femoral canal was dried using a suction tube. To maintain dryness and vent pressure during cement insertion, a plastic venting tube connected to a wall negative-pressure suction system was introduced into the canal. After venting, the canal was packed with dry gauze. Cement preparation involved hand mixing in a cement cartridge and injection using a cement gun, starting distally. The venting tube was removed immediately before femoral stem insertion, and the procedure was concluded after a waiting period for cement curing. All cemented femoral stems were of the force-closed type, including the C-stem (DePuy International, Leeds, UK), CPT stem, and MS-30 stem (Zimmer Biomet, Warsaw, IN, USA).

Medical and anesthetic records from the electronic medical hospital data were reviewed. The parameters included demographic data, the American Society of Anesthesiologists (ASA) risk score, underlying diseases, systolic blood pressure (SBP), arterial oxygen saturation, and consciousness. Preexisting heart disease was categorized according to the International Classification of Diseases, Tenth Revision, encompassing myocardial infarction, arrhythmia, congestive heart failure, valve disease, and cardiomyopathy. Data on SBP, heart rate, and arterial oxygen saturation were collected at four intervals as follows: (i) pre-anesthesia induction, (ii) every 5th minute for 10–15 min before bone-cement implantation, (iii) every 5th minute for at least 15 min post-implantation, and (iv) upon arrival in the recovery room. BCIS severity was scored based on the lowest SBP and oxygen saturation recorded within 15 min after cementation, classifying patients into no BCIS (grade 0) or grade 1, 2, or 3 BCIS, following the classification of Donaldson et al.⁹ The BCIS grading was established as follows: grade 1, moderate hypoxia (arterial oxygen saturation <94%) or hypotension (>20% reduction in SBP); grade 2, severe hypoxia (arterial oxygen saturation <88%) or hypotension (>40% drop in SBP) or unexpected loss of consciousness; and grade 3, cardiovascular collapse requiring cardiopulmonary resuscitation.

Statistical analysis was conducted using R software (version 3.2.1; R Foundation for Statistical Computing, Vienna, Austria). Quantitative data are presented as mean $\pm$ standard deviation or median (IQR). We performed the independent samples t-test to compare two independent groups. Categorical data were analyzed using the chi-squared or Fisher's exact test. Multivariate logistic regression analysis was performed to identify factors associated with preexisting heart disease. P-values <0.05 were considered statistically significant.

Table 1. Demographic data of patients with and without preexisting heart disease

Characteristic	No preexisting heart disease (n=188)	Preexisting heart disease (n=123)	P-value
Age	83 (74,87) ^b	81 (76,86) ^b	0.871
Sex			0.182
Female	144 (76.6%)	85 (69.1%)	
Male	44 (23.4%)	38 (30.9%)	
Body height (cm)	155 (150,160) ^b	156 (153,160) ^b	0.118
Body weight (kg)	52 (46,60) ^b	55 (46.8,61.2) ^b	0.093
BMI (kg/m ²)	21.8 ± 3.8 ^a	22.3 ± 3.8 ^a	0.276
ASA classification			< 0.001
2	105 (55.9%)	36 (29.3%)	
3	83 (44.1%)	85 (69.1%)	
4	0 (0%)	2 (1.6%)	
Medical history			
Liver disease	7 (3.7%)	5 (4.1%)	1
Chronic kidney disease	55 (29.3%)	56 (45.5%)	0.005
DM	58 (31%)	32 (26%)	0.412
HT	130 (69.1%)	90 (73.2%)	0.526
DLP	69 (36.7%)	50 (40.7%)	0.561
Stroke	31 (16.5%)	12 (9.8%)	0.13
Lung disease	20 (10.6%)	11 (8.9%)	0.768
Dementia	7 (3.7%)	1 (0.8%)	0.153
Parkinson	9 (4.8%)	5 (4.1%)	0.983
Cancer	2 (1.1%)	1 (0.8%)	1
VTE	1 (0.5%)	0 (0%)	1
EBL (mL)	300 (200,400) ^b	250 (150,375) ^b	0.116
Preoperative hemoglobin level (g/dL)	11.6 ± 1.5 ^a	11.2 ± 1.7 ^a	0.026
Serum creatinine level (μmol/dL)	0.8 (0.7,1) ^b	0.9 (0.7,1.4) ^b	<0.001

BMI, body mass index; ASA, American Society of Anesthesiologists; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; VTE, venous thromboembolism; and EBL, estimated blood loss

^a Mean values with standard deviations, ^b Median (IQR)

RESULTS

The study comprised 123 and 188 patients with and without preexisting heart disease, respectively; all patients underwent cemented bipolar hemiarthroplasty. In the preexisting heart disease group, the specific conditions included 71 cases of arrhythmia, 5 cases of congestive heart failure, 23 cases of myocardial infarction, 11 cases of valvular heart disease, and 37 cases of cardiomyopathy.

[Table 1](#) summarizes the demographic data for both groups, suggesting no statistically significant differences in age, sex, body mass index, or estimated blood loss. However, patients with preexisting heart disease exhibited lower preoperative hemoglobin levels and higher ASA classifications, serum creatinine levels, and chronic kidney disease.

In BCIS assessment, 13 cases (4.18%) were identified among 311 patients, all categorized as grade 1 BCIS, without occurrence of grades 2 or 3 BCIS. Notably, within the subset experiencing grade 1 BCIS, only 2 cases were associated with preexisting heart disease (1.63% of the heart dis-

ease group), whereas the remaining 11 cases had no history of preexisting heart disease (5.85% of the non-heart disease group). We observed no statistically significant difference in the BCIS rates between the two groups ($P=0.101$).

Upon evaluating the baseline characteristics with statistically significant differences between the two groups, we considered factors including ASA classification, preoperative hemoglobin levels, and serum creatinine levels. This analysis involved patients in both the non-BCIS and BCIS groups and indicated no statistically significant variations ([Table 2](#)).

Patients with BCIS did not experience major cardiovascular or pulmonary complications postoperatively until discharge. The preexisting heart disease group experienced longer hospitalization than the non-preexisting heart disease group, both pre- (3 days vs. 2 days) and post-surgery (5 days vs. 4 days), resulting in an overall extended duration (9 days vs. 7 days), indicating a significant difference ($p<0.001$). The administration of packed red blood cells did not significantly differ between the groups before, during, or after surgery ($P=0.3$) ([Table 3](#)).

Table 2. Demographic data of the groups with and without BCIS

Characteristic	Without BCIS group (n=298)	BCIS grade I group (n=13)	p-value
ASA classification			0.796
II	136 (45.6%)	5 (38.5%)	
III	160 (53.7%)	8 (61.5%)	
IV	2 (0.7%)	0	
Preoperative hemoglobin level (g/dL)	11.5 ± 1.6 ^a	10.9 ± 2 ^a	0.262
Serum creatinine level (μmol/dL)	0.8 (0.7,1.1) ^b	0.7 (0.6,0.9) ^b	0.094

^aMean values with standard deviations, ^bMedian (IQR)

BCIS, bone cement implantation syndrome; ASA, American Society of Anesthesiologists

Table 3. Medical history

Characteristic	Non-preexisting heart disease (n=188)	Preexisting heart disease (n=123)	p-Value
Postoperative complication			
cardio-vascular system	2 (1.1%)	4 (3.3%)	0.218
hip related	3 (1.6%)	1 (0.8%)	1
others	15 (8%)	13 (10.6%)	0.563
Length of hospitalization (days)			
before surgery	2 (1,4) ^b	3 (1.5,6) ^b	0.006
after surgery	4 (4,6) ^b	5 (4,7) ^b	0.03
total	7 (5,10) ^b	9 (6,14) ^b	0.001
PRC transfusion			
preoperative	2 (1.1%)	1 (0.8%)	1.00
intraoperative	42 (22.3%)	34 (27.6%)	0.353
postoperative	11 (5.9%)	9 (7.3%)	0.78
Total	55 (28.7%)	44 (35%)	0.3

^b Median (IQR)

PRC, packed red cells

DISCUSSION

Understanding the incidence and impact of BCIS in patients undergoing cemented bipolar hemiarthroplasty is vital because of its potentially life-threatening nature.¹⁵ This infrequent complication raises concerns, particularly in patients with preexisting heart conditions. This is because BCIS directly affects cardiovascular function. Motivated by the gaps in existing research, we provide insights into the incidence and risk factors of BCIS in patients with cardiovascular disorders. Contrary to our expectations, the incidence of BCIS did not significantly increase in patients with preexisting heart disease.

We observed notable differences in the incidence of BCIS upon comparing our results with previous findings. We observed a minimal incidence of BCIS, with only 4.18% of patients experiencing grade 1 BCIS and no instances of grade 2 or 3 BCIS. This finding contrasts sharply with those of Jaffe et al., where BCIS was present in 35% of the patients, with severe BCIS (grades 2 and 3) occurring in 10% of the patients regardless of the grade.¹⁶ In addition, Bökeler et al. reported a higher overall BCIS incidence (46%); patients

undergoing the second generation cementing technique experienced BCIS more frequently (58%) than those undergoing the third generation technique (35%).⁴ Furthermore, Weingärtner et al. highlighted a persistent risk, reporting on BCIS symptoms in 37% of patients undergoing cemented hip hemiarthroplasty, with a significantly higher rate of cardiovascular complications and in-hospital mortality in patients with BCIS.⁶ In our study, the incidence of BCIS was lower in the heart disease group (1.63%) than that in the non-heart disease group (5.85%).

The lower incidence of BCIS, particularly the absence of high-grade cases, may be attributable to various factors in surgical and perioperative management. Our initial hypothesis focused on the shape of the femoral stem, supported by the findings of Chulsomlee et al. They emphasized the correlation between stem geometry and risk of BCIS, highlighting the incidence of BCIS in patients undergoing cemented hip arthroplasty, particularly upon using a shape-closed femoral stem design.¹⁷ In addition, Gozzard et al. investigated cement pressurization during femoral stem insertion; the findings support our choice of a force-closed stem. A force-closed stem, with its smaller proximal

geometry, likely contributes to reduced intramedullary pressure during stem insertion, thereby lowering the risk of BCIS.¹⁸ Notably, previous studies reporting on higher BCIS incidence used closed shape stems, such as Bicon-tact® (Aesculap, Tuttlingen, Germany) and IC long stem implantcast® (Buxtehude, Germany).^{4,6} This evidence confirms the association between stem design and diminished intramedullary pressure, reinforcing the rationale behind our preference for a force-closed femoral stem.

Another hypothesis explaining the lower incidence of BCIS in our study involves the implementation of venting techniques, which has not been explicitly mentioned in previous studies.^{4,6,16} Venting techniques were detailed by Spitzer,¹⁹ who emphasized their role in preventing cardiovascular collapse during cemented femoral stem procedures. This phenomenon aligns with the findings of Pitto et al. who demonstrated the benefits of venting by creating a vacuum in the femoral medullary cavity during stem insertion.²⁰ Pitto et al. observed a statistically significant decrease in severe transatrial embolic events during femoral component insertion and minimal changes in oxygen levels and pulmonary shunt values upon venting.²⁰ We utilized only proximal venting, in contrast to the complete venting described by Pitto et al. Nonetheless, we observed a lower incidence of BCIS. Thus, partial venting may reduce the risk of BCIS, highlighting the potential importance of venting techniques in enhancing the safety of cemented procedures.

This study had some limitations that warrant consideration. First, its retrospective design may have introduced bias, potentially limiting our ability to establish causal relationships. Second, the reliance on medical and anesthetic records may have introduced variations in data completeness and accuracy. Third, the single-center focus may have affected the generalizability of our findings to broader populations. Nonetheless, we conducted a thorough statistical analysis and adhered to rigorous methodology, which contributed to the reliability of our results. Our study offers valuable insights into BCIS in a specific population and serves as a foundation for further research in diverse settings.

CONCLUSION

Our study emphasizes the safety of cemented bipolar hemiarthroplasty and indicates a minimal incidence of low-severity BCIS. Importantly, preexisting heart disease did not significantly increase the risk of BCIS, confirming the safety of cemented bipolar hemiarthroplasty in older adults. Factors such as utilizing a force-closed femoral stem and exploring venting techniques, although only partially applied in our study, may contribute to reducing the risk of BCIS. Despite the retrospective study design, cemented bipolar hemiarthroplasty remains a safe option for older adults, offering valuable insights to orthopedic surgeons and anesthesiologists in optimizing patient outcomes.

ETHICS APPROVAL AND CONSENT

This study was approved by the Ethics Committee and Institutional Review Board of the Faculty of Medicine, Prince of Songkla University. This article does not contain any studies with human participants performed by any of the authors.

AUTHORS' CONTRIBUTIONS

Study conception and design: VY, JJ, KI; acquisition of data; VY, JJ, KI, TH: analysis and interpretation of data; VY, JJ, KI: writing of the manuscript; VY, JJ, KI, TH: critical revision.

CONFLICT OF INTEREST

The authors declare that they have no competing interest.

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