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Original Research Article

Incidence of Bone Cement Implantation Syndrome in Patients Undergoing Cemented Knee Replacement and Hip Arthroplasty Procedures

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Abstract: *Bone Cement Implantation Syndrome (BCIS) is a potentially fatal perioperative complication characterized by hypoxia, hypotension, cardiac arrhythmias, and cardiac arrest. Reported incidences range from 28% to 37% globally. BCIS is classified by severity into Grade 1 (moderate hypoxia or hypotension), Grade 2 (severe hypoxia, severe hypotension, or unexpected loss of consciousness), and Grade 3 (cardiovascular collapse requiring cardiopulmonary resuscitation).* ***Objective:*** *To determine the incidence of Bone Cement Implantation Syndrome (BCIS), identify its severity grades, evaluate associated risk factors, and propose strategies to reduce morbidity and mortality in patients undergoing cemented hip and knee arthroplasty.* ***Methods:*** *This prospective cross-sectional study was conducted in the Orthopaedics Operation Theatres and the Department of Anaesthesia at Doctors Hospital and Medical Centre, Lahore, over six months, from September 2024 to February 2025, following approval from the College of Physicians and Surgeons, Pakistan. A total of 100 patients aged 20–80 years, classified as ASA I–IV, undergoing cemented total hip or knee arthroplasty under general, spinal, or combined spinal-epidural (CSE) anaesthesia were included through non-probability consecutive sampling. Patients with ASA >IV, chronic liver or kidney disease, acute kidney injury, carcinogenic states, or those refusing consent were excluded. The incidence and severity of BCIS were recorded intraoperatively based on established criteria. Data were analyzed using SPSS version 26, with descriptive statistics applied to determine incidence, distribution by anaesthesia type, and mortality rates.* ***Results:*** *Among 100 patients, 19 (19%) developed BCIS. Of these, 14 (73.6%) had Grade 1, 3 (15.6%) had Grade 2, and 2 (10%) had Grade 3 BCIS. The highest incidence occurred within 5–8 minutes after cementation. Regarding anaesthetic type, BCIS was observed in 5 (26.3%) patients under general anaesthesia, 8 (42.1%) under spinal anaesthesia, and 6 (31.5%) under combined spinal-epidural anaesthesia. Both Grade 3 cases occurred during hip arthroplasty in ASA-III patients, with a mortality rate of 100% in this group.* ***Conclusion:*** *Bone Cement Implantation Syndrome remains a critical cause of intraoperative morbidity and mortality in cemented arthroplasty procedures. Early recognition, vigilant perioperative monitoring, optimized pre-hydration, prophylactic use of low-dose epinephrine, and effective multidisciplinary coordination between surgical and anaesthetic teams can significantly reduce adverse outcomes.*

Keywords: Anesthesia, Arthroplasty, Bone Cement, Bone Cement Implantation Syndrome, Hypotension, Hypoxia, Mortality, Risk Factors

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Introduction

Polymethyl methacrylate (PMMA) bone cement was introduced by Sir John Charnley in 1953. (1) It is currently being used in orthopaedic joint replacement surgeries. Cement decreases the rate of implant-related complications and postoperative pain, but at the same time, it is associated with complications like bone cement implantation syndrome (BCIS). (2) BCIS is a confluence of clinical features that includes hypoxia, hypotension, cardiac arrhythmias, and cardiac arrest, increasing the risks of intraoperative mortality and morbidity (3). The clinical features of BCIS typically occur during femoral reaming, acetabular or femoral cementation, prosthesis insertion, or joint reduction. BCIS has been classified according to its severity as follows: (1) Grade 1: moderate hypoxia (SpO2 <94%) or Hypotension (SBP >20%), Grade 2: severe hypoxia (SpO2 <88%) or hypotension (SBP fall >40%) or unexpected loss of consciousness, and Grade 3: cardiovascular collapse requiring CPR.

Different models have been proposed to describe the pathophysiology of BCIS, including the vasodilatory effect of cement, the release of polymerization gases during the exothermic hardening reaction of cement, which can cause microembolism, and a histamine-mediated reaction to monomers. High intramedullary pressures, up to 1100 mmHg, are generated during the impaction of the cemented femoral stem. (2) Pulmonary artery flotation catheter and transoesophageal echocardiography should also be considered in high-risk patients. (1) Whenever BCIS happens, the cornerstone of therapy lies in providing prompt and effective supportive care and monitoring in the intensive care unit with the administration of 100% oxygen, central venous catheter placement for rapid delivery of inotropes, and invasive hemodynamic monitoring. (1) Hypotension should be treated on the lines of acute right ventricular (RV) failure. Fluid resuscitation to maintain the RV preload and inotropes to support ventricular contractility are recommended. Care should be taken to avoid overzealous fluid infusions, as it may cause an increased leftward shift of the interventricular septum, which would lead to a further drop in left ventricular output. Vasopressors, such as phenylephrine and noradrenaline, cause peripheral vasoconstriction, thereby increasing aortic blood pressure, which, in turn, supports coronary artery blood flow and improves myocardial perfusion and contractility (4). A protocol named 'Cement Curfew' was developed and implemented at various institutions to increase vigilance and reduce the incidence of BCIS (8).

The incidence of BCIS is unknown, not only because of the wide range but also because of the ambiguity of symptoms (10). Different incidences reported in previous studies were: 28% in 1016 patients (2), 37% in 208 patients (11), and 31% in 3294 patients (12). The rationale for this study is to determine the incidence of BCIS, better characterize BCIS, identify

risk factors for potentially fatal complications, and develop guidelines to further reduce mortality.

Thus, the primary objective of the study was to determine the incidence of Bone cement implantation syndrome (BCIS) in patients undergoing Cemented Knee Replacement and Hip Arthroplasty procedures.

Methodology

This prospective cross-sectional study was conducted in the operating theatres of the Orthopaedics and the Department of Anaesthesia at Doctors Hospital and Medical Centre, Lahore, over 6 months, following approval of the synopsis by the College of Physicians and Surgeons of Pakistan from September 2024 to February 2025. The anticipated percentage frequency is set at 37% (11), and a sample size of 100 is calculated with a 95% confidence interval and a 10% margin of error. Non-probability consecutive sampling was used. The electrocardiogram monitor was used to detect the blood pressure, heart rate (HR), electrocardiogram (ECG), and pulse oxygen saturation (SPO2) in all patients. The monitored indicators included the systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), HR, ECG, and SPO2. Patient were labelled as being suffered from BCIS, if any of the following changes had occurred around the time of bone cementation, prosthesis insertion, or reduction of joint: 1) systolic blood pressure (SBP) reduces more than 20%, 2) spO2 <94% on room air, 3) changes in mental status (GCS less than 15) and 4) arrhythmias on ECG.

Inclusion Criteria include Age 20-80 years, ASA Classification I to IV, and Cemented Knee Replacement and hip arthroplasty surgeries under both general and spinal anaesthesia.

Exclusion Criteria include ASA Classification >IV, Patients with Chronic Kidney Disease, Chronic Liver disease, Acute Kidney Injury, Patient refusal, and patients with carcinogenic states.

The data collected at the end of a procedure will be analysed using SPSS 29.0 software. Age and changes in hemodynamic monitoring indicators (SBP, DBP, MAP, SPO2, and HR) were analysed for mean and standard deviation. Gender and BCIS will be presented as frequency (%). The confidence interval (CI) will be set at 95%, and $p \leq 0.05$ will be considered significant. Data will be stratified by age, gender, ASA status, and type of anaesthesia. Post-stratification chi-square test will be applied.

Results

A total of 100 patients were included over 6 months. Out of 100, 56 (56%) were females and 44 (44%) were males. The mean age of patients was 58 years. Spinal Anaesthesia was used in 51 (51%) patients; combined spinal & epidural anaesthesia in 23 (23%); general anaesthesia alone in 19 (19%); and General Anaesthesia with epidural in 7 (7%) patients. The ASA status of these 100 patients was: ASA-II in 18 (18%), ASA-III in 54 (54%), and ASA-IV in 28 (28%). Total knee arthroplasty was done in 59 (59%) patients, and Hip arthroplasty in 41 (41%) patients. (Table 1)

Out of 100 patients, 19 developed bone cement implantation syndrome. Of these 19, 14 (73.6%) had Grade 1, 3 (15.6%) had Grade 2, and 2 (10%) had Grade 3 BCIS. The highest incidence of BCIS occurred between 5 and 8 minutes after cementation. In patients who do not meet the criteria for BCIS, the most common finding is premature ventricular contractions (PVCs) without hemodynamic instability, which resolve spontaneously. Among 19 patients with BCIS, 5 (26.3%) received general anaesthesia alone, 8 (42.1%) received spinal anaesthesia, and 6 (31.5%) received CSE. Both of the Grade-3 BCIS patients had intraoperative cardiac arrest. Both achieved ROSC in theatre, but expired the very next day while being in the I.C.U. on mechanical ventilation with right heart failure on echocardiography, and cardiac failure was the cause. Both grade 3 BCIS cases occurred in hip arthroplasty, and both are ASA-III, making the mortality rate for grade 3 100%. All the results are summarized in Table 2:

Table 1: Demographics and incidence of Bone cement implantation syndrome (BCIS)

Variable	Category / Statistic	Total (n = 100)	BCIS Present n (%)
Age (years)	Mean ± SD	62 ± 4	—
Gender	Male	44 (44.0)	5 (26.3)
	Female	56 (56.0)	14 (73.7)
ASA Classification	ASA I	—	—
	ASA II	54 (54.0)	5 (9.2)
	ASA III	28 (28.0)	9 (32.1)
	ASA IV	18 (18.0)	5 (27.7)
Comorbidities	Hypertension	48 (48.0)	—
	Diabetes mellitus	53 (53.0)	—
	Previous myocardial infarction	38 (38.0)	—
	COPD	19 (19.0)	—
	Asthma	11 (11.0)	—
Type of Surgical Procedure	Total Knee Replacement (TKR)	59 (59.0)	—
	Total Hip Replacement (THR)	41 (41.0)	—
Medication History	β-blockers	51 (51.0)	—
	ACE inhibitors / ARBs	39 (39.0)	—
	Diuretics	7 (7.0)	—
	Nitrates	21 (21.0)	—
	Calcium antagonists	25 (25.0)	—
	Antiplatelet drugs	42 (42.0)	—
	Warfarin	1 (1.0)	—
	Statins	68 (68.0)	—
	Insulin / Oral hypoglycemics	53 (53.0)	—

Table 2: Frequency of bone cement implantation syndrome

	Total cases of BCIS:	**19/100 (26%)**
Grading of BCIS	GRADE-1	14/19 (73.6%)
	GRADE-2	3/19 (15.7%)
	GRADE-3	2/19 (10%)
BCIS in Knee Arthroplasty		5 (26.3%)
BCIS in hip arthroplasty		14 (73.6%)

Discussion

Bone cement implantation syndrome is an underappreciated complication of procedures involving cement implantation [10]. In the literature, the incidence of BCSI is high in hip arthroplasty procedures, at 31% [12], with the overall incidence of BCIS ranging from 28-37% [2,11,12,13] across all cemented procedures. The incidence in our study is 19%, which is lower than that reported in the literature. Of these 19, hip arthroplasty procedures constitute around 73.6%.

Among the BCIS grades in our study, Grade 1 occurred in 73.6%, Grade II in 15.7%, and Grade III in 10%, consistent with the literature. [13] The mortality rate with Grade-III BCIS was 100% in our study, which is also comparable to the study done by Rassir et al. [12]

Factors associated with BCIS include female gender, ASA-III and ASA-IV, previous history of myocardial infarction, patients taking Angiotensin-converting enzyme inhibitors (ACEI) OR Angiotensin-receptor blockers (ARBs), diuretics, and patients who underwent both sides of the knee or hip arthroplasty at a time. [15]

In this study, among 19 patients with BCIS, 5 (26.3%) received general anaesthesia alone, 8 (42.1%) received spinal anaesthesia, and 6 (31.55%) received CSE. There is a high incidence of BCIS in neuraxial anaesthesia, which is in contrast to what is found in the literature. As per Zastro et al., general anaesthesia is associated with a higher incidence of BCIS, whereas neuraxial anaesthesia is considered safer for cemented arthroplasty procedures. [16] So, we concluded that this type of anaesthesia is not associated with the incidence of BCIS.

In the current study, cemented hip arthroplasty (14, 73.6%) has a higher incidence of BCIS than knee arthroplasty (5, 26.3%). A plausible explanation in the literature is that a larger and more challenging femoral canal in hip arthroplasty can increase intramedullary pressure during implant insertion, thereby increasing the risk of fat and bone marrow embolism. [15]

Pre-existing ischemic heart disease is considered a risk factor for perioperative cardiac complications, but as far as the incidence of BCIS is concerned, as per a study done by Yuenyongviwat et al., pre-existing ischemic disease does not correlate with BCIS incidence. [17]

Different perioperative measures by the orthopaedic team can reduce the risk of BCIS. These include medullary lavage, good haemostasis before cement insertion, preventing excessive cement pressurization, using low-toxicity monomeric cement, minimizing the length of the prosthesis, vacuum cement mixing, retrograde application with a cement gun and suction catheter, an intramedullary plug, and venting the medulla. [18]

A multidisciplinary plan is needed, involving both the orthopaedics and anaesthesiologists, to reduce the incidence of BCIS. A cement curfew should be announced by the surgical team at mixing of cement and other than the surgical manoeuvres described above, pre-hydration by anaesthetist, vigilant monitoring as per ASA- standards of monitoring, prophylactic injection of epinephrine five micrograms at time of cementation, presence of senior anaesthesiologist at time of cementation, and ready vasopressors at the back-end.

This is a single-centre study, and a small sample size may affect the study's outcome, but its strength lies in its prospective design.

Conclusion

Bone cement implantation syndrome is a fatal complication that can be avoided and controlled by good team communication, a multidisciplinary approach, vigilant monitoring, the orthopaedic team adhering to recommended practices, pre-hydration, a prophylactic epinephrine (5 micrograms) bolus, and good preoperative assessment and postoperative care.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC--24)

Consent for publication

Approved

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Conflict of interest

The authors declared no conflicts of interest.

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