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Short Communication

Primary Utilization of Bioabsorbable, Antibiotic-Loaded Calcium Sulphate Beads in Bacteremic Patients Undergoing Hip Hemiarthroplasty

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Abstract
Antibiotic-loaded calcium sulphate beads (ALCSB) have been effectively used in revision arthroplasty for prosthetic joint infections (PJI), but their use in primary arthroplasty as a prophylactic measure remains limited. This study presents the first reported experience using ALCSB in bacteremic patients undergoing hip hemiarthroplasty (HA) for displaced femoral neck fractures—a group at high risk for PJI. Four elderly patients (mean age 71.5) with confirmed preoperative bacteremia from various sources (pneumonia, infected ulcer, endocarditis) received ALCSB during HA. Beads were loaded with vancomycin and/or tobramycin based on microbial sensitivities and placed around the joint capsule and gluteal muscles. Over a mean follow-up of 18 months, none of the patients developed PJI, required revision, or experienced persistent wound drainage. One patient died postoperatively due to unrelated cardiac causes. The findings highlight the potential of ALCSB as a localized prophylactic strategy in high-risk HA patients, especially where systemic infection is present preoperatively. Although the sample size is limited, the absence of infection or wound complications supports the feasibility of this approach. Larger studies are needed to validate these findings and assess cost-effectiveness.

Keywords: calcium sulphate beads, hip hemiarthroplasty, bacteraemia, prosthetic joint infections

1. INTRODUCTION

Calcium sulphate is a biocompatible material that when implanted, undergoes a process of resorption, releasing calcium and sulphate ions which are uptaken by infiltrating osteoclasts [1]. The dynamic interaction between the beads and surrounding tissue leads to the formation of a mineralized matrix, facilitating new bone formation. Additionally, their porous structure allows for the potential incorporation of growth factors or antibiotics, further enhancing their therapeutic efficacy [1]-[3]. Several studies have proven the successful use of calcium sulphate beads as bone void fillers in orthopedic surgery, allowing for the management of traumatic and oncological bone defects [1][2]. When combined with antibiotics, their biocompatibility allows for gradual and slow release of the loaded antibiotic which has been proven beneficial in the management of osteomyelitis and prosthetic joint infections (PJI) [3][4].

2. RISK FACTORS OF PROSTHETIC JOINT INFECTIONS (PJI)

PJI is a devastating complication that is often associated with high morbidity and mortality [5] [6]. Several risk factors have been identified for PJI, including body mass index (BMI) > 40 kg/m^2, diabetes mellitus, nosocomial infections, low serum albumin < 3 g/dL, concomitant malignancy, steroid therapy, rheumatoid arthritis, active wound infections, revision arthroplasty cases, excessive blood transfusion, increased operative time > 120 min [7], and bacteraemia (especially staphylococcal, B Haemolytic Streptococcal) [8]. Given their devastating sequelae, identifying measures to decrease the incidence of PJI has always been a point of interest in the orthopedic research [9]. It is understood that elective arthroplasty cases should undergo proper preoperative optimization and management of all potential risk factors before undergoing arthroplasty to decrease the risk of PJI. In arthroplasty cases for displaced femoral neck fractures, efforts should be made to perform the surgery as soon as possible to

restore the patient's mobility, while taking all the possible precautions to decrease the risk of PJI in potentially high-risk patients.

3. OUTCOMES OF ANTIBIOTIC LOADED CALCIUM SULPHATE BEADS IN ARTHROPLASTY

Several studies have shown successful outcomes of ALCSB in revision arthroplasty regarding their impact on increasing the success of single- or two-stage revision and minimizing the re-infection risk [3][10][11]. Their use as a prophylactic material in primary arthroplasty, however, has seldom been reported [12]. de Lachica et al. conducted a randomized controlled study, analysing the incidence of infection in PJI-high-risk patients undergoing total hip (THA) and total knee arthroplasty (TKA) and divided all arthroplasty patients into two groups [12]. One group received local antibiotic-loaded calcium sulphate beads, while the control group received standard care without the beads. The results revealed a significant reduction in acute PJI rates among patients who received the antibiotic-loaded beads, highlighting the efficacy of this innovative approach in enhancing postoperative outcomes and minimizing PJI. To the best of our knowledge, this is the only study that reported the primary use of ALCSB in total joint arthroplasty as a prophylactic agent. Surgeons should weigh, however, the benefits of using such calcium sulphate beads against their potential shortcomings, which include hypercalcemia, increased postoperative wound dehiscence, heterotopic ossification along with their potential increased cost [13].

The risk of hypercalcemia following calcium sulphate beads insertion in arthroplasty patients remains significant, reaching 4.2% in one systematic review [10]. While it is mostly transient and asymptomatic, there is a small risk of persistent, symptomatic hypercalcemia that requires management in susceptible, high-risk patients such as those who have impaired renal function. Other patients with a high risk of elevated calcium levels or increased risks of calcium precipitation include patients with sarcoidosis, autoimmune disorders, malignancy, granulomatous diseases, heterotopic ossification, and hyperparathyroidism. Symptoms of hypercalcemia may include nausea, vomiting, confusion, and, in severe cases, arrhythmias or renal failure. Careful monitoring of calcium levels is essential to prevent complications, especially in patients at higher risk [14].

Another potential complication after calcium sulphate use is the risk of wound dehiscence or persistent wound drainage. With an average incidence of 3.8% [15], this complication remains of significant concern among orthopedic surgeons. The beads, designed to slowly dissolve and release local antibiotics, may irritate surrounding tissues, leading to increased fluid accumulation, prolonged wound drainage, and a higher risk of wound breakdown (dehiscence) which may predispose to infection at the surgical site, particularly in cases of subcutaneous use of high volume of ALCSB in patients with poor tissue healing, diabetes, or compromised immune function. Proper wound care and monitoring are crucial to detect and manage these issues early, ensuring optimal healing and preventing further complications. In case prolonged wound drainage is detected for more than 4–7 days, many surgeons advise aggressive surgical intervention in the form of surgical debridement with or without replacement of the antibiotic delivery system [15].

Despite their successful use in PJI that was reported in Abosala and Ali [10], the high cost of ALCSB may limit their use, especially in limited resource facilities, in light of the limited evidence regarding their superiority in the management of PJI. Flierl et al. reported a 48% reinfection rate after DAIR with ALCSB insertion and concluded that CS beads are not recommended for routine use in the management of PJI due to high costs and complications [16]. Studies are required to review the cost-benefit analysis of calcium sulphate use in the management of PJI.

4. AUTHORS EXPERIENCE

In our multi-hospital health system, which includes a level 1 trauma center, we have been successfully utilizing ALCSB in very specific cases, including primary total joint arthroplasty in patients potentially at high risk for PJI due to unmodifiable risk factors such as patients with concomitant malignancies and patients on chronic

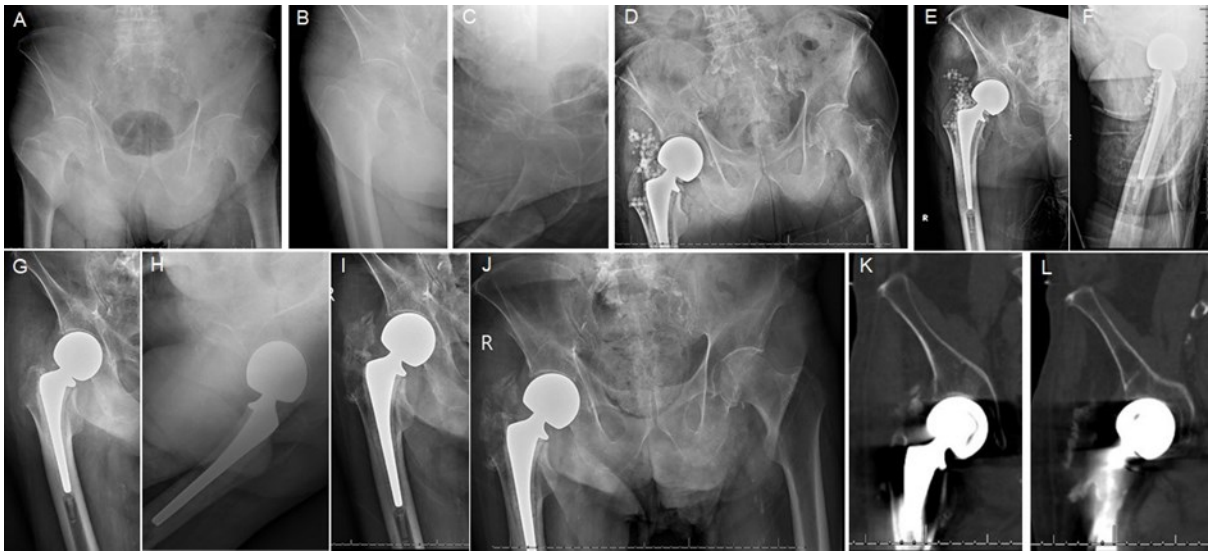

Figure 1. Prosthetic joint infections.

corticosteroid therapy. In acute trauma settings, ALCSB can be utilized in bacteraemic hip fracture patients undergoing primary hip hemiarthroplasty (HA) to decrease the incidence of postoperative PJI, which has not been particularly reported before in the literature. Hip hemiarthroplasty is a different setting compared to THA, and the characteristics of trauma patients undergoing HA, being elderly patients with several risk factors may be the reason behind the increased risk of PJI [17] and the higher likelihood of treatment failure, higher morbidity, and mortality in HA patients with PJI compared to THA [18]. When bacteraemia, a known risk factor for PJI [8], is present in such elderly, hip fracture patients undergoing HA, this may further increase the risk of PJI, causing significant morbidity and mortality.

4.1. Patients

After IRB approval, all hemiarthroplasty cases performed in our institution have been reviewed using the procedural codes for surgery and the implant names to extract all cases who received ALCSB during the primary HA surgery. Out of 2477 HA cases, 4 bacteremic patients received ALCSB at the primary HA surgery as a prophylactic measure to decrease the potential risk of PJI. Patients were 2 males and 2 females, with a mean age of 71.5 years at the time of surgery. All patients were bacteremic as proven by blood cultures preoperatively and all were admitted with displaced femoral neck fractures. Two patients presented with deteriorated level of consciousness along with fever and declining respiratory function secondary to pneumonia, one patient had bacteremia secondary to infected decubitus ulcer and one patient had a known history of chronic endocarditis and bacteremia.

The utilization of ALCSB in bacteraemia patients undergoing HA in our institution depends on the surgeon's discretion. After inserting the hip hemiarthroplasty and performing final irrigation, calcium sulphate beads are mixed with 2–4 g of antibiotics as per the manufacturer's recommendation. Three patients received vancomycin and tobramycin combinations and one received only vancomycin, depending on the results of preoperative blood culture and sensitivity. Two patients had streptococcal, one patient had acinetobacter and one had enterococcal bacteremia. The beads are then inserted around the joint capsule and in between the gluteal muscles before wound closure is performed, without a drain device. Serial clinical and radiographic follow-up examinations are then performed to ensure successful control of the infection risk (checking the wound status), along with the stability of HA components and the absence of any identifiable implant loosening.

4.2. Results

The mean follow-up for all cases is 18 months. One patient died 8 days after the HA surgery for cardiac complications. None of the patients

developed prosthetic joint infections, persistent wound drainage or required revisions (Figure 1).

Figure 1 case presentation is (a)-(c) plain pelvic and hip radiographs in an 81-year-old male with tobacco use disorder who sustained a right displaced femoral neck fracture after a fall at home. The patient was admitted directly into a respiratory intensive care unit due to respiratory distress, delirium, and fever, and the patient was diagnosed with bacteremia secondary to chronic obstructive lung disease with over added pneumonia. The patient had other medical comorbidities in the form of heart failure, chronic kidney disease, and Parkinsonism. After medical clearance, the patient underwent a right hip cemented unipolar hemiarthroplasty 3-days later with the application of ALCSB (Fig. 1(d)-(f)). Immediate postoperative radiographs (Fig. 1(d)-(f)). A 3-week postoperative plain radiographs showing stable arthroplasty components and resorption of ALCSB (Fig. 1(g)-(h)). A 3-month postoperative plain radiographs showing the formation of Brooker (Fig. 1(i)-(j)) class 3 peri-trochanteric heterotopic ossification at the ALCSB insertion site [19]. CT scan 4 months postoperatively showing deep heterotopic ossification in the gluteal muscles (Fig. 1(k)-(l)). The patient lived one year after the index HA surgery without developing PJI and expired secondary to respiratory complications.

4.3. Discussion

The utilization of ALCSB as a prophylactic measure against PJI in high-risk patients receiving joint arthroplasty is a relatively novel application. To the best of our knowledge, only one study examined the outcomes of utilizing ALCSB in patients with non-modifiable risk factors undergoing total hip or total knee arthroplasty [12]. In a randomized controlled trial study [12], de Lachica found acute PJI to occur in 27 patients (67.5%) in the patients who did not receive ALCSB compared to 4 patients (9.3%) in the intervention group who received ALCSB ($p < 0.0001$). Additionally, the intervention group had a shorter hospital stay, averaging 4.60 days, compared to 15.25 days in the control group ($p < 0.001$). The authors concluded that local prophylaxis using calcium sulphate beads significantly reduced the incidence of acute knee or hip PJI in patients with non-modifiable risk factors, compared to standard prophylaxis with preoperative parenteral antibiotics. For hip hemiarthroplasty, which has been one of the most widely utilized and successful treatment options for displaced femoral neck fractures in the elderly [20][21], the use of ALCSB may present a promising indication for high-risk trauma patients, especially who has bacteremia or other non-modifiable risk factors.

5. CONCLUSIONS

Our results in these patient settings have been successful, although the paucity of cases necessitates careful interpretation. A large case series is required to justify the use of antibiotic-loaded calcium sulphate beads and adequately study its efficacy in decreasing the PJI in bacteremic patients undergoing arthroplasty, and potentially in bacteremic patients undergoing any implant-associated orthopedic surgery. Also, further studies are needed to discuss the cost-effectiveness of ALCSB in preventing PJI compared to other ordinary methods for PJI prophylaxis.

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A. N. M. was involved in the manuscript writing. A. N. M., B. C., W. M., M. S., and D. S. H. were involved in the conception, design, methodology, and manuscript editing. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

Conflicts of Interest

The authors declare that there is no potential conflict of interest relevant to this article.

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