International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Cemented Bipolar Hemiarthroplasty in Chronic Kidney Disease Patients with Femoral Neck Fractures: Current Evidence and Clinical Outcomes

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Abstract

Background: Chronic kidney disease (CKD) is a progressive condition associated with reduced bone density, decreased bone turnover, muscle weakness, and increased risk of fractures. Femoral neck fractures in CKD patients represent a major clinical problem because of poor bone quality, renal osteodystrophy, dialysis-related complications, and increased perioperative morbidity and mortality. Cemented bipolar hemiarthroplasty is commonly used in these patients because it provides immediate mechanical stability, allows early mobilization, and does not depend mainly on biological osseointegration. The aim of this review was to discuss the role of cemented bipolar hemiarthroplasty in the management of femoral neck fractures in patients with chronic kidney disease, with emphasis on current evidence, functional outcomes, postoperative complications, and clinical considerations.

Conclusion: Cemented bipolar hemiarthroplasty appears to be an effective treatment option for femoral neck fractures in patients with chronic kidney disease. It provides good functional improvement, pain relief, early mobilization, and acceptable clinical and radiological outcomes. Despite the high-risk nature of this patient population, careful preoperative assessment, proper surgical technique, multidisciplinary management, and close postoperative follow-up may help reduce complications and improve quality of life. Further studies with larger sample sizes and longer follow-up periods are needed to confirm long-term outcomes.

Keywords: Chronic kidney disease; femoral neck fracture; cemented bipolar hemiarthroplasty; Harris Hip Score; renal osteodystrophy.

Introduction:

About 10% of people worldwide suffer from chronic kidney disease (CKD), which has become one of the most common noncommunicable diseases [(1)].

The biochemical and hormonal changes associated with mineral bone disorders (also known as chronic renal disease mineral and bone disorder, or CKD–MBD) are associated with a markedly elevated risk of bone fractures, cardiovascular events, mortality, and the advancement of CKD. Hyperphosphatemia, hypocalcaemia, low serum vitamin D levels, and increased parathyroid hormone (PTH) release from the parathyroid glands (secondary hyperparathyroidism, SHPT) are the primary changes associated with CKD–MBD. Renal osteodystrophy and profound changes in bone and mineral metabolism are caused by all of these disorders. According to estimates, people with end-stage renal failure (ESRF) have a hip fracture risk that is 4.4 times higher than that of the general population[(2)].

Every year, about 1.6 million hip fractures occur. Women account for 70% of all hip fractures. Hip fracture risk is higher in Caucasian females and rises exponentially with age[(3)].

A common surgical technique for treating displaced femur neck fractures is bipolar hemiarthroplasty (BHA), especially in older patients with low functional demands. The prosthesis is made up of a femoral stem that is affixed to a bipolar head that has an exterior articulation with the natural acetabulum and an interior articulation between a metal femoral head and polyethylene liner. In comparison to unipolar hemiarthroplasty, the design attempts to lessen acetabular wear, increase range of motion, and lower dislocation rates(4).

Chronic Kidney Disease-Mineral and Bone Disorder

The Kidney Disease claims that: CKD-MBD is described as "a systemic disorder of mineral and bone metabolism due to CKD manifested by either one or a combination of the following: (a) abnormalities of calcium, phosphorus, PTH, or vitamin D metabolism; (b) abnormalities in bone turn-over, mineralisation, volume, linear growth, or strength; or (c) vascular or other soft tissue calcification" in the Improving Global Outcomes (KDIGO) 2006 guidelines(5).

FGF-23, PTH, vitamin D3, and phosphorus interact in chronic kidney disease. Increased PTH, 1,25(OH)D3, and phosphorus levels from food loading enhance FGF-23 secretion. Conversely, FGF-23 suppresses PTH secretion, lowers 1,25(OH)D3 levels, decreases intestinal phosphorus absorption, and prevents phosphorus reabsorption in the proximal tubule, which increases urine output. Additionally, hyperphosphatemia lowers CASR sensitivity, which directly affects PTH synthesis, and 1,25(OH)D3 decreases PTH. Even though CKD-MBD typically begins early in the course of the disease, it only manifests as secondary hyperparathyroidism, hyperphosphatemia, and hypocalcaemia when GFR falls below 45–50 mL/min/1.73 m2 (based on the various methods to assess GFR), and it gets worse as the disease progresses (stage 3b–5) (6).

One of the mineral and bone problems associated with chronic kidney disease (CKD–MBD) is renal osteodystrophy, which is the abnormalities in bone morphology that occur in CKD patients. Nearly all individuals with stage 5 CKD have skeletal problems. In addition to having a higher risk of bone fracture than the general population, this patient group has serious implications for mortality and cardiovascular disease. Bone biopsy is the gold standard for diagnosing and assessing renal osteodystrophy(7).

Patients could have: Skeletal abnormalities, muscle weakness, and bone discomfort reduced mobility or fragility fractures in the past. Abnormalities in calcium, phosphate, parathyroid hormone (PTH), vitamin D metabolism, and bone turnover are all included in CKD-MBD. These anomalies raise the risk of fracture. Diffuse bone soreness is a sign of secondary hyperparathyroidism. weakness in the surrounding muscles or a history of pathological fractures. Related to Dialysis Results that haemodialysis patients may experience: arteriovenous fistula, oedema, pallor associated with anaemia, or skin irritation(8).

Vascular calcifications, subperiosteal bone resorption, cortical thinning, generalised osteopenia, and looser zones (pseudofractures) can all be seen on radiographs(9).

Femoral Neck Fractures and Bipolar Hemiarthroplasty

Stress or traumatic fractures can occur in the femur neck. A fractured neck in an elderly person may result from a direct fall on the hip, a fatigue fracture, or rotating the body over the hip. Femoral neck fractures in young people are typically caused by excessive use and severe trauma, such as a fall from a height or a car collision with an abducted hip(3).

Osteoporosis increases the chance of a femur fracture, and neurovascular lesions, medicines, dehydration, and cognitive impairment enhance the risk of falls. In certain parts of the United States, femur fracture mortality can reach 10%, and the risk remains significant in the first year following surgery. Older white women are more likely to experience this(10).

Elderly individuals with displaced femoral neck fractures are frequently treated with bipolar hemiarthroplasty (BHA). In order to decrease acetabular wear, increase range of motion, and improve hip stability, the prosthesis has a dual-articulation mechanism. The restoration of hip biomechanics, implant stability, load transmission, and motion distribution between the inner and outer bearings all influence the biomechanical behaviour of bipolar hemiarthroplasty. Optimising surgical results and implant longevity requires an understanding of these concepts [11].

The centers of rotation of the inner and outer components of contemporary bipolar prosthesis are slightly eccentric. Advantages consist of: better joint congruency, enhanced stability, less dislocation risk, and automatic realignment of the prosthetic head. One of the most significant biomechanical benefits of bipolar implants is thought to be the self-centering effect. The hip's center of rotation is equivalent to the geometric center of the femoral head. With proper preoperative planning, templating, and implant selection, the center of rotation should revert to its pre-disease position after hemiarthroplasty. The right neck length, neck-shaft angle, and neck offset can be chosen thanks to contemporary hip prosthesis with significant levels of modularity[12].

For proper biomechanics, leg length equality is necessary. Additionally, it is among the most difficult to assess intraoperatively. It is influenced by the implant's site and configuration in addition to the previously listed factors. The location of the hip's center of rotation, from superior to inferior, also affects the forces generated surrounding the implant. greater energy expenditure, hip instability, back pain, irregular stride, and greater joint response forces can all result from an incorrect leg length. Therefore, choosing and situating implants correctly is essential[13].

Bipolar prostheses offer increased overall range of motion, decreased neck-cup impingement, decreased torque transmission, and enhanced functional mobility because movement takes place at two articulations. This quality is especially crucial while engaging in activities that call for hip flexion and rotation. If the head neck's length doesn't change, large heads have the potential for a greater range of motion (increase in size = increase in range) [14].

Surgical Technique

Prior to considering performing a HA on any patient, a comprehensive history and physical examination are necessary. Patients should be questioned regarding previous procedures and therapies. Prior joint replacements, arthroscopic procedures, or other surgeries performed near the hip should be taken into consideration as they may have a significant impact on the planned procedure and/or prosthesis chosen. Prior to considering HA, all patients should undergo a thorough medical evaluation, receive medical clearance, and undergo risk stratification[15].

It is advised to take preoperative radiographs, which should include AP/lateral images of the hip(s) involved. In cases of hip dysplasia, a false profile view is taken into consideration. It is advised to get a preoperative CT scan with thin (1-mm) cuts when the surgeon is dealing with cases of severe hip dysplasia and thinking about using customized components[16]. (Fig. 1)

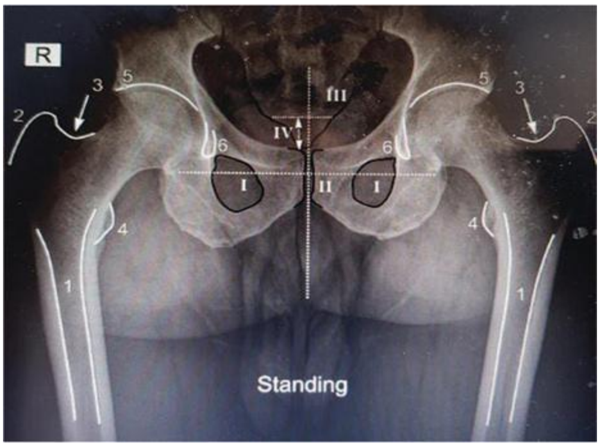

Fig.(1): Standing AP hip X-rays suitable for templating. Anatomical Landmarks: (1) femoral medullary canal; (2) greater trochanter; (3) saddle; (4) lesser trochanter; (5) acetabular roof; (6) teardrop; (I) obturator foramina; (II) symphysis pubis; (III) sacrococcygeal joint; (IV) distance to measure for pelvic tilt observation.

Place the patient on the operating table in lateral position, with the hip to operate on the top. Adequate padding is then required with double support, on the front for the superior iliac spine and back for the sacrum, to keep the patient's position and sustain the bony pelvis[17]. (Fig. 2).

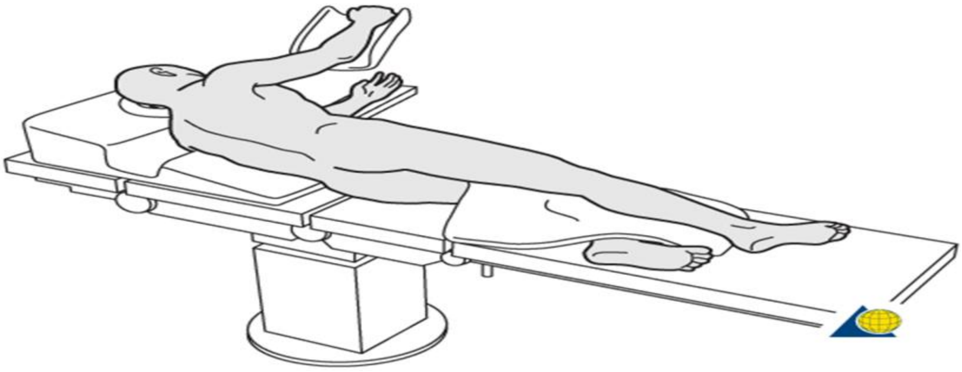

Fig. (2): Position of patient on lateral position on the operating table for lateral approach[17].

Cut the deep fascia beneath the fat in the same direction as the skin incision. Pull the gluteus maximus posteriorly and the tensor fasciae latae anteriorly by retracting the fascia's cut edges. Sharp dissection should be used to separate any gluteus medius fibres that are attached to the deep surface of this fascia. Now that the gluteus medius and vastus lateralis are exposed (Fig. 3,4) [18,19].

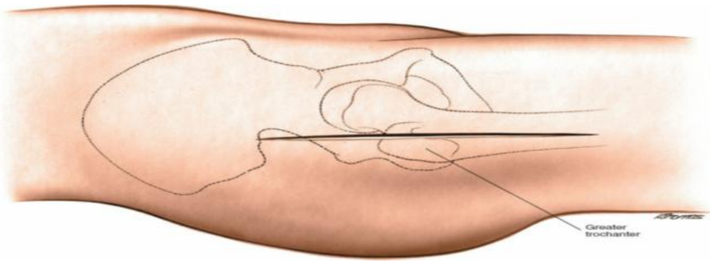

Fig. (3): Make a longitudinal incision centered over the tip of the greater trochanter in the line of the femoral shaft[17].

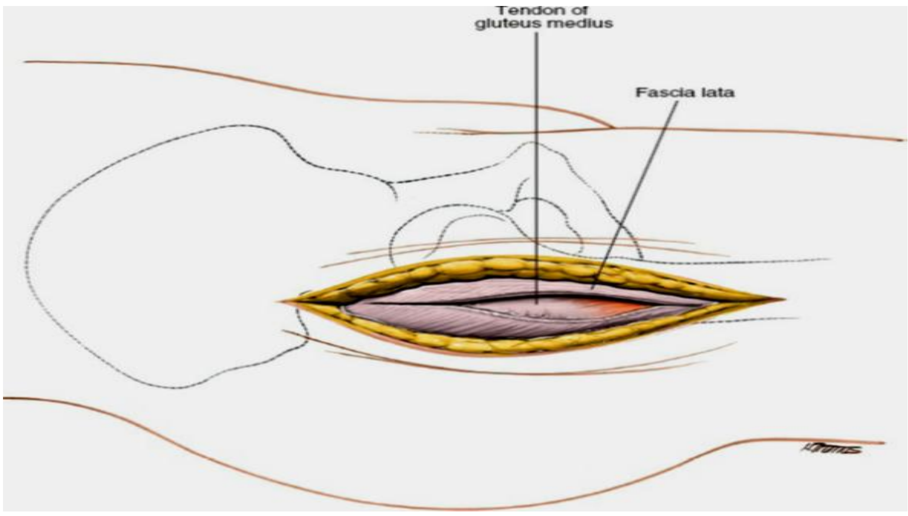

Fig. (4): Divide the deep fascia in the line of the skin incision, retracting the fascial edges to pull the tensor fasciae latae anteriorly [18,19].

Using a longitudinal T-shaped incision, enter the capsule (Fig. 5). Dislocate femur from hip joint by doing figure of four of the operated lower limb. Cut the femoral neck in half. Using a corkscrew, extract the femoral head. Complete exposing the acetabulum by placing the proper retractors around it [18,19].

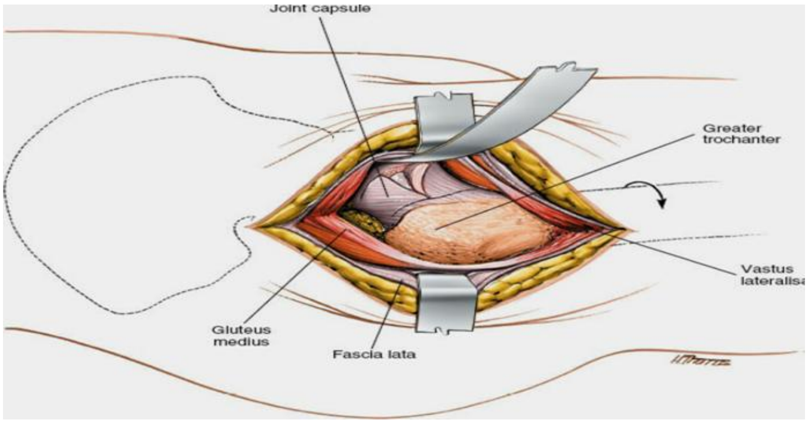

Fig. (5): Enter the capsule using a longitudinal T-shaped incision[18,19].

While cleaning and examining the articulating surfaces, thoroughly flush out the joint with saline. With great care, lower the hip so as not to allow impact between the parts. Final evaluation of leg length, stability, and range of motion [20].

Complications

A large variation has been reported in the perioperative mortality rate, which has ranged from less than 1% to as high as 30 %. The potential risk factors which are associated with a significant increase in mortality rates include old age, female gender, and history of cardio-respiratory disease, chronic diseases, and long waiting period for surgery. In the CKD patients, who made hemiarthroplasty have significantly a 10–20 times greater risk of inpatient mortality[21].

Distal deep vein thrombosis (DVT) can asymptomatic and may lead to long term valvular damage resulting in chronic venous insufficiency. Proximal propagation can result in more serious pulmonary embolism[22].

DVTs that propagate proximally have the potential to embolise in the lungs resulting in pulmonary embolism (PE). Mild emboli can be asymptomatic, whereas massive embolism can be fatal, and PE is one of the leading causes of mortality post HA[23].

During insertion of the femoral component, rises in intramedullary pressure can force medullary fat and marrow contents into the venous circulation via the metaphyseal vessels. Fat and marrow embolus can then pass into and through the pulmonary circulation depending on the size of the emboli[24]

Measures to reduce the risk of fat embolism include medullary lavage to reduce the fat load during cement pressurisation. Vacuum cementation techniques using drainage cannulae have also been shown to be effective in reducing the intramedullary pressure rises during cementation therefore reducing the risk of emboli[25].

5. Renal-related complications: such as fluid overload and electrolyte abnormalities[26].

Infection post HA is potentially one of the most catastrophic complication due to low immunity of most CKD patients and comorbidties[26].

Periprosthetic fractures more commonly affect the femoral component of the HA due to early loosening of the implant because of poor bone quality of CKD patients[27].

Chronic Kidney Disease-Mineral and Bone Disorder (CKD-MBD), has now been used to describe the spectrum of conditions of bone pathologies (e.g., hyperparathyroid bone disease, adynamic bone disease, osteomalacia, mixed uremic osteodystrophy). This pathology leads to poor bone quality and unsatisfactory support, resulting in failure at the bone-cement interface; higher failure rates in a cemented stem for this group of patients is possible[28].

Aseptic loosening is the bone loss that results from biological processes occurring at the metal-bone or cement-bone interface, and it causes failure of hemiarthroplasty. The phenomenon of aseptic loosening is a consequence of the host response to debris originating from the prosthetic devices. This debris may originate from several interfaces comprising the joint reconstruction including the articulating surfaces, modular component surfaces, fixation surfaces, and devices used for adjuvant fixation. For the femoral stem, loosening may be suspected when there is: Stem subsidence (sinking) greater than 3–5 mm compared with previous radiographs or Progressive radiolucent lines (>2 mm) around the stem in multiple Gruen Zones[29].

Progressive medial migration of the bipolar prosthetic head beyond the normal acetabular boundary due to cartilage degeneration and bone loss. The bipolar prosthesis articulates with the native acetabular cartilage. Repetitive loading causes: progressive cartilage degeneration, loss of joint space and increased contact stress on subchondral bone. Over time, this results in medial migration of the prosthetic head. Radiographically, protrusion is identified when the acetabular floor migrates medial to the ilioischial (Köhler's) line. [30]

Clinical Outcomes

The Harris Hip Score (HHS) demonstrated a highly significant improvement following surgery. The mean preoperative HHS was 6.61 ± 2.65, with a median of 6 (range: 3–15), whereas the mean postoperative HHS markedly increased to 84.78 ± 6.39, with a median of 86.5 (range: 72–93). This represents a statistically significant increase in functional outcome after surgery ($P < 0.0001$) [31].

Analysis of the Harris Hip Score pain domain demonstrated a statistically significant postoperative improvement ($P = 0.002$). Preoperatively, 17 patients (94.44%) were totally disabled with pain in bed and 1 patient (5.56%) had marked pain, while none reported mild or no pain. Postoperatively, there was a significant decrease in severe pain categories, with no patients remaining totally disabled or markedly painful (0%). Pain was absent or ignored in 11 patients (61.11%), slight and occasional in 5 patients (27.78%), mild rarely moderate in 1 patient (5.56%), and moderate in 1 patient (5.56%)[31].

Conclusion

In conclusion, this study demonstrates that cemented bipolar hemiarthroplasty offers promising outcomes and is a highly effective surgical intervention for femoral neck fractures in patients with chronic kidney disease, providing a statistically significant improvement in functional outcomes, pain relief and enhanced quality of life. Despite the systemic fragility of this patient population, the procedure allowed for successful early mobilization with a low rate of postoperative complications and a transition from poor to predominantly "Good" or "Excellent" Harris Hip Scores. While factors like age, BMI, and fracture classification did not significantly influence final functional results, the borderline association between longer operative duration and poorer outcomes suggests that surgical efficiency remains a critical factor in optimizing recovery for this high-risk group.

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