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Fracture Management in Chronic Kidney Disease: Challenges and Considerations for Orthopedic Surgeons

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Orthopedic surgeons treating fractures need to consider comorbidities, including chronic kidney disease (CKD), which affects millions worldwide. CKD patients are at elevated risk of fractures due to osteoporosis, especially in advanced stages. In addition, fractures in CKD patients pose challenges due to impaired bone healing and increased post-fracture complications including surgical site infection and nonunion. In this article, we will discuss factors that must be considered when treating fractures in CKD patients. Perioperative management includes careful adjustment of hemodialysis schedules, selection of anesthetic methods, and addressing bleeding tendencies. Tourniquet usage for fractures in limbs with arteriovenous fistulae should be cautious. Pain medication should be administered carefully, with opioids like hydromorphone preferred over nonsteroidal anti-inflammatory drugs. Medical management after fractures should address underlying factors and include physical rehabilitation to reduce the risk of subsequent fractures. A comprehensive approach to fracture management in CKD patients can improve outcomes.

Keywords: *Chronic kidney disease-mineral bone disorder, Chronic kidney disease, Osteoporosis, Distal radius fracture, Tourniquets*

For orthopedic surgeons, who may want to primarily focus on fractures, it is sometimes burdensome but crucial to consider comorbidities such as chronic kidney disease (CKD) that patients may have. CKD is a progressive condition characterized by the gradual loss of kidney function over time.[1] A recent systematic review and meta-analysis indicated that the global prevalence of CKD remains consistent around 11%–13%.[2] It affects millions of people worldwide and poses a significant burden on healthcare systems.[3] With its diverse etiology and progressive nature, CKD poses substantial challenges to healthcare professionals across various medical specialties.

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CKD encompasses a range of progressive kidney disorders, classified into stages based on the estimated glomerular filtration rate (eGFR) (Table 1).[1] These stages, from mild to severe, help gauge the degree of kidney function impairment and provide valuable insights into disease progression. CKD is not only prevalent in older adults but also increases in incidence and importance with advancing age.[4] The physiological changes associated with aging, coupled with the cumulative effects of comorbidities, contribute to the complex management of CKD in this population.

In the realm of CKD assessment, cystatin C, a low-molecular-weight protein, has emerged as a valuable biomarker.[5] Traditionally, eGFR based on serum creatinine is routinely used to evaluate kidney function. However, in certain individuals like those who are senile or sarcopenic, eGFR based on serum creatinine tends to underestimate kidney function. As a superior alternative filtration marker for eGFR in this specific population, cystatin C has been shown to be more accurate and reliable in assessing kidney function.[6]

Table 1. Stages of Chronic Kidney Disease

Stage	eGFR (mL/min/1.73 m^2)	Uremic symptom
Stage 1: Normal function	≥ 90	Asymptomatic
Stage 2: Mild	60–89	Asymptomatic
Stage 3: Moderate	30–59	No or mild symptoms
Stage 4: Severe	15–29	Mild to moderate symptoms
Stage 5: ESRD	< 15	Moderate to severe symptoms Requires dialysis if highly uremic

eGFR: estimated glomerular filtration rate, ESRD: end-stage renal disease.

Chronic kidney disease-mineral bone disorder (CKD-MBD) is a complex syndrome characterized by disturbances in mineral metabolism, commonly seen in patients with chronic kidney disease. This disorder can result in various complications, including anemia, hypertension, an increased risk of cardiovascular disease, and skeletal problems such as osteoporosis and fractures.[7] CKD-MBD progresses subtly and becomes more apparent in the advanced stages of CKD. In advanced CKD stages, patients are not only at risk of low bone mass but also of poor bone quality, which further increases the risk of fractures.[8]

Among the myriad of complications associated with CKD, fractures represent a significant concern, necessitating careful management and tailored treatment strategies. Fracture management can be challenging due to the presence of comorbidities and complications associated with CKD. These patients may be at increased risk for poor healing and complications after a fracture due to factors such as malnutrition, anemia, and hormonal imbalance. In this article, we aimed to address issues related to the management of fractures in CKD patients.

FRACTURES OF CKD PATIENTS

Fracture Incidence in CKD Patients

Given that CKD is an independent risk factor for osteoporosis,[9] it is not surprising that fracture incidence is elevated in CKD patients. Numerous researches have explored the relationship between CKD and fracture risk, accounting for variables such as CKD stages, dialysis status, and kidney transplantation (KT) status. According to a recent meta-analysis, there is a graded risk for falls and fractures as kidney function deteriorates.[10] The incidence rates of fractures are more than 4 times higher in CKD patients,[11] and studies have shown a reverse correlation between glomerular filtration rate (GFR) and fracture risk.[12,13] The fracture incidence progressively increases by 15.0, 20.5, 24.2, 31.2, and 46.3 per 1,000 person-years for CKD stages 1 to 2, 3a, 3b, and 4, respectively.[14] Additionally, the risk for incident hip fracture rises by 16% for each standard deviation increment in cystatin C level.[15] Patients with end-stage renal disease (ESRD) have a risk of fracture up to 8 times higher than that of the general population.[16]

Dialysis Status and Fracture Risk

A study using the Swedish Renal Registry[17] found that the incidence rate of hip fractures began to sharply increase 3 months before dialysis initiation, peaked at initiation, and then declined thereafter. In contrast, the incidence rate of non-hip fractures remained stable during the transition period and gradually increased over time. A meta-analysis analyzed 47 studies and showed that the overall incidence of hip fracture was higher in the hemodialysis (HD) group compared to the peritoneal dialysis (PD) or KT groups.[18] Furthermore, HD patients had significantly lower trabecular volumetric bone mineral density and microarchitecture at the tibia than the PD patients.[19] The differences in fracture risk between dialysis populations may be attributed to hyperparathyroidism in HD patients. PD patients exhibit a lower response of calcium turnover to the action of parathyroid hormone (PTH),[20] which provides some protection against secondary hyperparathyroidism-induced high bone turnover disease.[18]

KT and Fracture risk

KT is considered the optimal treatment for most patients with ESRD and is superior to dialysis in terms of potential complications due to CKD-MBD, including fractures, cardiovascular disease, and all-cause mortality.[21] However, a significant decrease in bone mineral density has been observed in the first 6 months after KT, leading to an increased risk of fractures during this period.[22]

Risk factors of fractures after KT include older age, female sex, diabetes, dialysis vintage before transplantation, previous history of fracture, and receipt of a kidney from a deceased donor rather than a living one.[18] While hip fractures are more common among dialysis patients,[16,17] studies[22,23] have shown that peripheral fractures, such as forearm or foot fractures, may be more common than hip fractures after KT. Although the overall incidence of hip fractures in HD patients is higher than that in PD or KT patients during the first 1 to 3 years after KT, the incidence of hip fractures among KT patients exceeds that among dialysis patients.[24] The study also showed that the

relative risk of hip fracture becomes lower in KT recipients than in dialysis patients approximately 630 days after KT. This may be due to a rapid increase in bone turnover and mineralization after transplantation, which can lead to temporary bone fragility. Furthermore, immunosuppressive therapies used in KT may have adverse effects on bone metabolism, leading to bone loss and increased fracture risk. Therefore, it is important to closely monitor bone health in KT patients to prevent possible fractures.

Complications of Fractures

CKD patients are at an elevated risk of post-fracture complications and morbidities, such as nonunion, infection, and prolonged recovery, further compounding the burden of fractures. This is due to renal osteodystrophy-related low bone density and altered bone turnover, which impede bone healing and tissue regeneration. Moreover, CKD patients suffer from a variety of hormonal imbalances such as hyperparathyroidism, serum calcium-phosphate imbalance, vitamin D deficiency, and chronic metabolic acidosis, which can impair bony union and exacerbate post-fracture complications.[25]

Skin wound healing can be problematic in CKD patients. A murine study[26] found significant decreases in re-epithelialization and granulation tissue deposition rates in uremic mice due to the underlying chronic inflammatory state and low rate of vascularization and cell proliferation. These tendencies of delayed wound healing in the uremic condition were also observed in human studies.[27,28]

Patients with ESRD who underwent surgical fixation for lower extremity fractures had a 3.6 times higher risk of postoperative complications compared to non-ESRD patients.[29] In an epidemiological study,[30] renal insufficiency was found to be a risk factor for nonunion fractures, with the ulna, tibia, and humerus being the 3 most commonly affected bones. Patients with femoral neck fracture and CKD have a higher risk of nonunion and subsequent surgical revision.[31] Patients with proximal humerus fractures and ESRD were at increased risk of any complication (odds ratio [OR], 2.48), blood transfusion (OR, 1.85), systemic infection (OR, 2.00), and surgical site infection (OR, 1.52).[32] Patients who underwent bipolar hemiarthroplasties for femoral neck fractures had a significantly higher mortality rate of 21% in the HD group compared to 4% in the general group. The survival rate of the prosthesis at 5 years was also significantly lower in the HD group, with a rate of 44% compared to 96% in the general group. A study[33] examining total joint arthroplasty found that CKD and ESRD were associated with a greater risk of surgical site infections (OR, 1.4), wound complications (OR, 1.1), transfusions (OR, 1.6), deep vein thrombosis (OR, 1.4), and mortality (OR, 2.101) compared to non-CKD/ESRD patients.

PERIOPERATIVE MANAGEMENT

Hemodialysis

For patients with ESRD who undergo HD, the schedule of HD is crucial. Delaying the schedule causes increased fluid and electrolyte retention that can cause cardiac death.[32,34] The timing of HD in relation to surgery plays a significant role as a determining factor in perioperative risk. Therefore, it is crucial to adjust the timing of HD before and after surgery. The duration of surgery can vary, and there may be a need for intravenous fluid replacement due to factors such as bleeding during the procedure, which increases the necessity for dialysis. Various research findings and expert opinions recommend undergoing HD 1 day prior to elective surgery.[35] However, a consensus has not been reached on this matter. Factors such as electrolyte imbalances, extracellular fluid retention, patient-specific considerations, the condition of the fracture, and the emergency nature of the surgery should be considered when scheduling HD.

In the postoperative period, it is recommended to continue regular HD at the same frequency as in the outpatient setting, typically 3 times per week. This ensures that adequate removal of waste products, maintenance of fluid and electrolyte balance, and management of uremic symptoms are maintained during the recovery phase after surgery. By adhering to the regular HD schedule, the patient's kidney function can be effectively supported, and complications associated with renal impairment can be minimized.

Peritoneal Dialysis

Perioperative scheduling for PD is generally simpler compared to HD because most PD patients undergo daily treatments. However, there are some considerations for PD patients undergoing surgery. Before surgery, the peritoneal fluid should be drained to ensure comfortable positioning, especially if the surgery requires the patient to be in the prone position.[36] It can be challenging to effectively perform PD if the patient must be immobilized or maintain a certain body position after the surgery. In such cases, it is important to consider alternative methods of renal replacement therapy before proceeding with fracture surgery.

Maintaining ambulation is essential in preserving the patency of the catheter used for PD. Extended periods

of immobilization or non-ambulation can lead to catheter migration, which may require surgical repositioning.[37] Therefore, efforts should be made to encourage ambulation and minimize immobilization after surgery to support successful PD.

Anesthesia Considerations

Regional and neuraxial anesthesia are considered appropriate anesthetic options for patients with CKD.[38] Despite the risk related to bleeding tendency,[39] they offer several advantages over general anesthesia, including the provision of intraoperative and postoperative analgesia. This reduces the reliance on analgesic medications and minimizes the need for invasive monitoring and postoperative intensive care unit care. Specifically, brachial plexus block and epidural anesthesia are commonly employed for surgeries involving the upper and lower limbs, respectively.

However, when administering local anesthetic agents, caution must be taken to prevent complications, especially in patients with ESRD who are often prescribed antiplatelet medications to prevent cardiovascular disease and to maintain the patency of their arteriovenous fistula (AVF). Preoperative evaluation of coagulation status is necessary to ensure patient safety. Additionally, it is noteworthy that patients with a platelet count of less than 100,000/mm^3 are at an increased risk of developing hematomas following an epidural block.[40]

Bleeding Tendency

Paradoxically, patients with CKD are not only at a higher risk of thrombosis but also at an increased risk of bleeding with declining kidney function. Studies have shown that anticoagulation strategies are needed to prevent cardiovascular complications in these patients.[41] However, increased bleeding tendency affects major complications that might occur perioperatively, including epidural hematoma during anesthesia, intraoperative bleeding, which lengthens operative time, and postoperative bleeding related to postoperative complications such as surgical site infection, or longer hospital stay. Therefore, managing bleeding risk should be taken into consideration when planning surgical treatment. In general, it is recommended that aspirin should be discontinued for 6 days before surgery, and clopidogrel should be discontinued 7 days before surgery to ensure complete platelet functional recovery.[42] In situations where there is insufficient time allowed for adequate recovery of platelet function due to the urgency of the surgical intervention, the consideration of general anesthesia with meticulous attention to hemostasis becomes paramount. This approach aims to minimize the aforementioned complications associated with impaired platelet function.

Tourniquet Usage

It is common for patients with CKD who undergo HD to have an AVF in their forearm. There has been reported a variety of complications associated with the usage of tourniquets including limb-threatening complications such as compartment syndrome.[43] The Association of perioperative Registered Nurses has listed "extremities with dialysis access" as a relative contraindication of tourniquet use; however, no specific reference was cited for this inclusion.[44] There is no literature investigating the link between the tourniquet time and the possible complications of AVFs, including thrombosis formation and further stenosis. Although Naito et al.[45] found no complications in AVFs after using a pneumatic tourniquet during carpal tunnel release surgery in patients with chronic renal dialysis, there is still concern about using tourniquets in patients who have both distal radius fractures (DRFs) and an ipsilateral AVF. Therefore, it is up to the surgeon to decide whether to use a tourniquet on the arm with an AVF. Factors such as AVF patency, skin status, estimated surgery time, and patient's opinion should be taken into consideration when making this decision.

In guidelines and review articles on the use of pneumatic tourniquets, AVF is not listed as a contraindication for exsanguination.[43,44,46] However, mechanical compression caused by tourniquet application may result in additional tissue damage at the site of the fracture and possibly to the AVF. Therefore, it is more appropriate to use the Bier technique, which involves elevating the arm rather than direct mechanical compression. The Bier technique involves compressing the brachial artery in the cubital fossa before elevating the arm and inflating the tourniquet (Figs. 1 and 2).[47,48]

Management of DRF

For patients with DRF having an AVF, there is no established gold standard for the method of treatment. The treatment of choice for stable DRF is closed reduction and cast immobilization. However, in HD patients, maintaining vascular access and auscultation through the AVF is necessary, which is hard to be performed with casted state. Additionally, due to their fragile skin and higher risk of swelling, prolonged cast fixation may not be suitable for this population. Pin fixation, on the other hand, may not provide enough rigidity in cases of osteoporotic bone. Ishiguro et al.[49] proposed the use of percutaneous pinning, aided by Chinese finger trap reduction, combined

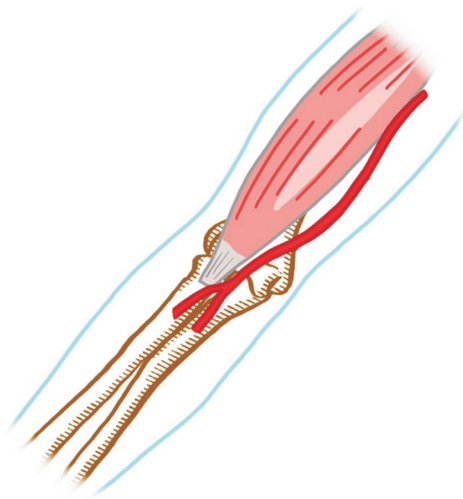

Fig. 1. Diagram representing the position of the brachial artery and biceps tendon around the cubital fossa. The artery can be palpated on the medial side of the biceps tendon.

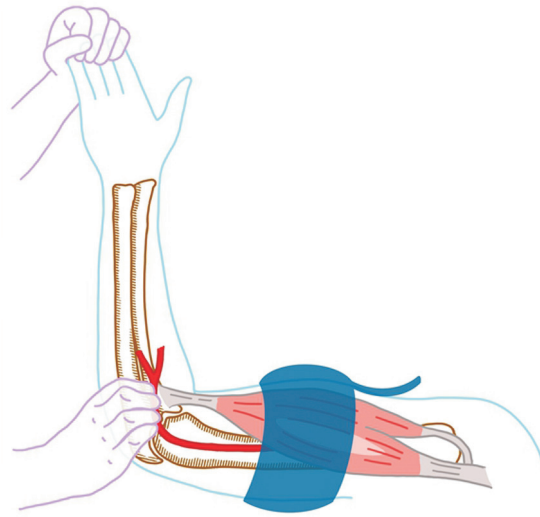

Fig. 2. While maintaining digital pressure on the brachial artery, the arm is elevated. The tourniquet is inflated after 30 seconds.

with cavity creation using a pediatric urologic balloon and calcium phosphate cement augmentation, without the use of a tourniquet. Sugiyama et al.[50] reported 3 cases of DRFs occurring in the ipsilateral forearm with an AVF, which were successfully treated with volar locking plate fixation without the use of tourniquets. Chang et al.[51] reported on the management of 13 cases with DRF, without the use of a tourniquet in 8 cases. The authors[51] suggested that meticulous hemostasis without a tourniquet may be appropriate in patients with an ipsilateral AVF. On the other hand, Im et al.[52] reported on treating 11 cases of DRF with volar plating, in which tourniquets were used during all surgeries; however, no complications such as hematoma or fistula occlusion were observed. Additionally, Hyatt et al.[53] suggested that dorsal bridge plate fixation may be the optimal treatment for patients with an ipsilateral AVF, multiple comorbidities, osteoporotic bone, and a need for immediate weight-bearing.

Pain Medication

Cautious consideration is necessary when administering pain medication to CKD patients with fractures. Increased drug levels and associated adverse effects may occur due to reduced renal clearance and reduced protein binding associated with hypoproteinemia or acidemia.[54]

The benefits of patient-controlled analgesia (PCA) include tailoring pain management to individual patients' needs by giving them control over their pain, providing a relatively fast onset of action, and minimizing the impact of individual pharmacodynamic and pharmacokinetic differences.[55] When selecting an opioid agent for PCA, hydromorphone is considered superior to morphine due to its advantageous pharmacokinetic features.[56] Hydromorphone's distribution to the central nervous system is accelerated thanks to its keto group compared to morphine's hydroxyl group. Furthermore, hydromorphone does not form an active 6-glucuronide metabolite, which is eliminated through the kidneys and can cause severe opioid side effects.

Acetaminophen can be considered as a first-line oral medication due to its lack of nephrotoxicity and can be administered without requiring dose adjustment[57] Nonsteroidal anti-inflammatory drugs (NSAIDs) have direct nephrotoxic effects, including afferent vasoconstriction that can result in reduced glomerular filtration.[58] Baker and Perazella[59] have recommended that short-acting NSAIDs may be utilized on a short-term basis (up to 5 days) for patients with CKD stages 1–3, with cautious use in those with CKD stage 4, and complete avoidance in patients with CKD stage 5. On the other hand, for patients receiving maintenance HD or PD, where there is less need to preserve GFR, NSAIDs are among the most commonly prescribed medications in the United States.[60] Nonetheless, use of NSAID's in ESRD population has not been extensively investigated and the available data are insufficient.[61] The administration of NSAIDs in this population should be approached with caution, as recent studies have reported an association between NSAID use and cardiovascular risks in dialysis patients.[62,63] Furthermore, there have been concerns regarding the association between NSAIDs and nonunion or delayed union, particularly with

Cox-2 selective inhibitors.[64,65] Opioids can be considered as cautious alternatives to NSAIDs. However, the accumulation of renally excreted opioids and their toxic metabolites can potentially lead to severe neurological complications, including excessive sedation, myoclonus, seizures, respiratory suppression, and even death.[54] Safer opioids for CKD include oxycodone, hydromorphone, fentanyl, and tramadol. Oxycodone is one of the most commonly prescribed opioids for kidney disease patients in the United States.[66] These opioids are predominantly hepatic metabolized and have a low risk of accumulation. While tramadol is generally considered safer for individuals with CKD due to its atypical, centrally-acting nature and lower abuse potential,[54] it is important to note that tramadol and its more potent metabolite, O-desmethyltramadol (M1), are primarily excreted in urine. This characteristic may pose a risk of accumulation in advanced stages of CKD, warranting careful monitoring and consideration of alternative pain management strategies in such cases.[67]

The dose guidelines for commonly used pain medications in CKD patients are provided in Table 2.[57,68,69] For mild pain (visual analog scale [VAS] 1–3), acetaminophen is the recommended choice. For moderate pain (VAS 4–6), tramadol or oxycodone can be added. In cases of severe pain (VAS 7–10), hydromorphone may be considered. Table 2 also includes the common adverse effects of these medicines.[70] It is important to note that adverse effects may be more prevalent in individuals with CKD and ESRD, and distinguishing them can be challenging. This difficulty arises because many side effects of opioid therapy are often similar to symptoms commonly observed in ESRD or during dialysis treatment.

MEDICAL MANAGEMENT AFTER FRACTURE

Fracture management in patients with CKD is essential to restore their previous level of activity and prevent subsequent fractures, as the subsequent fracture rate is considerably higher in this patient population compared to those without CKD. In addition to surgical treatment, medical management plays a crucial role in the management of fractures in CKD patients.

Clinicians need to address several underlying factors that contribute to frailty in CKD patients. Anemia

Table 2. Summary of Recommended Pain Medication for CKD Patients

Medication	MME	Metabolism	Normal dose	Dose adjustment	Common adverse effect
Acetaminophen	-	Hepatically metabolized Excreted in the urine primarily as nontoxic metabolites High oral bioavailability 85%–98%	650 mg every 4–6 hr	Max daily dose 4,000 mg CLCr 10–50 mL/min: 650 mg q 6 hr prn CLCr < 10 mL/min or dialysis: 650 mg q 8 hr prn	Hepatotoxicity
Tramadol (short acting)	0.1	Hepatically metabolized to more potent opioid analgesic metabolites M1 High oral bioavailability 87%–95% Excreted renally	50–100 mg every 4–6 hr	Start at 25 mg every 12 hr CLCr 30–50 mL/min: 50–100 mg every 8–12 hr CLCr < 30 mL/min: avoid using	Constipation, nausea, CNS depression
Oxycodone (short acting)	1.5	Hepatically metabolized High oral bioavailability 50%–87%	10–30 mg every 4–6 hr	Start at 5 mg every 4–6 hr prn CLCr 10–50 mL/min: 10 mg q 6 hr prn CLCr < 15 mL/min not on dialysis: 2.5–5 mg q 8–12 hr	CNS and respiratory depression, hypotension, nausea, constipation, pruritus
Hydromorphone (short acting)	4	Hepatically metabolized Low to moderate oral bioavailability	2–4 mg every 4–6 hr	Start at 1 mg every 6 hr prn CLCr 30–50 mL/min: dose reduction CLCr < 30 mL/min: increase dosing interval Well dialyzed, but no supplemental dose required post-HD	CNS and respiratory depression, hypotension, nausea, constipation, pruritus
Fentanyl (long acting)	2.4	Hepatically metabolized 10%–20% excreted renally Low oral bioavailability	Dose variable based on opioid equivalent dose of patient's oral medication	Should only be initiated in patients with chronic pain who have been on opioids prior Start at 12.5–25 μg patch	CNS and respiratory depression, hypotension, nausea, constipation, pruritus

CKD: chronic kidney disease, MME: morphine milligram equivalent, CLCr: creatinine clearance, CNS: central nervous system, HD: hemodialysis.

is a common complication of CKD and can lead to reduced bone density and an increased risk of fractures. Erythropoiesis-stimulating agents, together with iron supplementation, are the treatment of choice in anemia of CKD.[71] Hormonal imbalances, particularly in vitamin D and PTH, and following mineral abnormalities including calcium and phosphate can also lead to bone loss and fragility and should also be addressed in the management of fractures.[14] For patients with secondary hyperparathyroidism, the recommended initial action is to lower PTH levels to reduce cortical bone loss and limit the risk of peripheral fractures. These conditions can be managed through medical interventions such as cinacalcet or surgical procedures like parathyroidectomy, depending on the patient's medical condition and mineral status.[14]

Osteoporosis plays a crucial role in fracture risk among CKD patients, especially those with CKD-MBD. To prevent subsequent fractures and improve prognosis, it is essential to evaluate the osteoporotic condition and implement appropriate medical treatment. Dual-energy x-ray absorptiometry (DXA) is recommended for all CKD patients who have experienced fractures to assess their bone density.[72] Bone turnover markers, such as C-terminal telopeptide of type 1 collagen (CTX), osteocalcin, or procollagen type 1 N-terminal propeptide (P1NP), are commonly used to evaluate bone metabolism. However, these bone turnover markers are retained with loss of kidney function and are not very reliable in patients with advanced CKD. Instead, bone-specific alkaline phosphatase and tartrate-resistant acid phosphatase 5b (Trap-5b) are reliable and widely used in patients with CKD.[25] Following the evaluation, appropriate osteoporosis medication should be prescribed based on the patient's medical condition. For those with eGFR > 30 mL/min per 1.73 m^2, treatments such as raloxifen, bisphosphonates, and teriparatide follow the same recommendation as in non-CKD patients. Correction of low 25-hydroxyvitamin D (25(OH) D) is also recommended.[14] There have been some issues with the treatment of osteoporosis in advanced CKD patients. Anti-resorptive agents such as bisphosphonates have nephrotoxicity and can accumulate highly in the condition of reduced renal clearance. The administration of bisphosphonates in patients with CKD remains a topic of controversy and requires further studies.[11,25,73] Therefore, considering other medications such as denosumab or anabolic agents would be safer. Available pharmacological options for osteoporosis in CKD are summarized in Table 3.[11] If necessary, consulting with a nephrologist to address CKD-MBD and ensure delicate medical management is essential for optimal patient care. By addressing osteoporosis and managing CKD-MBD, healthcare providers can significantly reduce the risk of subsequent fractures and enhance the overall outcomes for CKD patients.

Physical rehabilitation is an essential component of fracture management in CKD patients. Patients with CKD may be at an increased risk of falls, which can result in further fractures, and therefore, appropriate fall prevention strategies and physical rehabilitation should be implemented to minimize this risk. Physical rehabilitation can help CKD patients to maintain muscle strength, balance, and flexibility, which can reduce the risk of falls and subsequent fractures.[74,75] Specifically, exercises that strengthen lower extremities and back muscles can significantly reduce the risk of falls and fractures.[76] A meta-analysis demonstrated that a supervised exercise program, including aerobic training, resistance training, balance training,

Table 3. Summary of Recommended Anti-osteoporosis Medication for CKD Patients

Drug	Dosage	FDA-approved eGFR cutoffs	Effects on mineral metabolism
Alendronate	70 mg PO once weekly	eGFR > 35 mL/min	Hypocalcemia, hypophosphatemia
Ibandronate	150 mg PO once monthly or 3 mg IV every 3 mo	eGFR > 30 mL/min	-
Risendronate	5 mg PO daily or 35 mg PO weekly	eGFR > 30 mL/min	Hypocalcemia, hypophosphatemia, increased PTH levels
Abaloparatide	80 μg subcutaneously once daily	Any eGFR, not studied in ESRD	Hypercalcemia, hypercalciuria
Teriparatide	20–40 μg subcutaneous daily	eGFR > 35 mL/min	Hypercalcemia, hypocalcemia, hypercalciuria
Denosumab	60 mg subcutaneous every 6 mo	Any eGFR	Hypocalcemia, hypophosphatemia
Romosozumab	210 mg subcutaneous monthly	Not studied in CKD	-

CKD: chronic kidney disease, FDA: Food and Drug Administration, eGFR: estimated glomerular filtration rate, PO: per oral, IV: intravenous, -: unknown, PTH: parathyroid hormone, ESRD: end-stage renal disease.

or stretching, has significant beneficial effects on walking ability, muscle strength, and overall survival in CKD patients.[74] The most suitable training method should be chosen based on the individual patient's characteristics, including physical function, comorbid conditions, nutritional status, and motivation to exercise.

In summary, fracture management in CKD patients should be comprehensive, incorporating surgical treatment, medical management, and physical rehabilitation. Addressing underlying factors contributing to skeletal fragility, such as anemia, hormonal imbalances, calcium and phosphate metabolism abnormalities, malnutrition, and fall prevention strategies can help to reduce the risk of subsequent fractures and improve the quality of life in CKD patients.

CONCLUSIONS

Orthopedic surgeons often face challenges when treating CKD patients, particularly in cases involving fractures. These patients are more prone to complications, including wound problems that may increase the risk of surgical site infections. In this article, we addressed the issues related to fracture management in CKD patients. CKD-MBD is a complex syndrome characterized by disturbances in mineral metabolism that result in various complications, including an increased risk of fractures. The incidence of fractures in CKD patients is more than 4 times higher than that in the general population, and the risk for incident hip fracture rises with decreased GFR. The status of dialysis affects the risk of fractures, and hip fractures are consistently higher in HD patients than in PD or KT groups. KT is considered the optimal treatment for most patients with ESRD but carries a risk of fractures in the first 6 months after transplantation. CKD patients are also at an elevated risk of post-fracture complications, including nonunion, infection, and prolonged recovery. The hormonal imbalances associated with CKD, such as hyperparathyroidism, serum calcium-phosphate imbalance, vitamin D deficiency, and chronic metabolic acidosis, can impair bony union and exacerbate post-fracture complications. Hence, careful monitoring of bone health and early intervention for the prevention and management of fractures and complications is crucial in CKD patients. Further research is required to develop optimal strategies for the prevention and management of fractures in CKD patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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