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SYMPOSIUM: BONE QUALITY: FROM BENCH TO BEDSIDE

Short-term and Long-term Orthopaedic Issues in Patients With Fragility Fractures

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Abstract

Background Patients with impaired bone quality who suffer a fragility fracture face substantial challenges in both their short- and long-term care. In addition to poor bone quality, many of these patients have multiple medical comorbidities that alter their surgical risk and affect their ultimate functional recovery. Some medical issues can contribute to the altered bone quality and must be addressed to prevent future fractures.

Questions/purposes This review summarizes the modifications in perioperative management and fracture fixation in patients with common fragility fractures who have impaired bone quality. It also summarizes the postoperative diagnosis and treatment of secondary causes of impaired bone quality in these patients.

Methods We performed a PubMed search, and literature published after 2000 was prioritized, with the exception of benchmark clinical trial studies published before 2000.

Results Patients with altered bone quality require rapid perioperative management of multiple medical comorbidities. Implant selection in patients with poor quality bone should permit early weightbearing, and constructs should maximize surface area contact with the remaining bone. Long-term diagnosis and treatment of other disease states contributing to poor bone quality (vitamin D deficiency/insufficiency, hypothyroidism, hyperthyroidism, hyperparathyroidism, Cushing's disease, and hypogonadism) must occur to minimize the chances of future fractures.

Conclusions Recognition of patients with impaired bone quality and proper treatment of their special needs in both the short and long term are essential for their best opportunity for maximal functional recovery and prevention of future fractures.

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Introduction

Patients with altered bone quality who suffer a fragility fracture face many challenges in the treatment and recovery from their fracture. Fragility fractures are defined as fractures occurring from a fall from a standing height or less. Despite their mechanism, fragility fracture may display a high-energy fracture pattern and can be challenging to treat.

Patients who present with fragility fractures frequently have numerous medical comorbidities [29]. These comorbidities will often determine the patient's survival and ultimate level of functional recovery from their injury and must be carefully evaluated before any surgery [88]. Despite advances in medical care over the past 40 years, perioperative mortality with hip fracture remains at 10% at 1 month, 25% at 1 year for women, and 30% at 1 year for men [17] and few of the patients will recover their preinjury level of function. These medical comorbidities increase the risks of anesthesia and the surgical procedure [34, 88]. Most patients will benefit from a comprehensive medical evaluation and stabilization before surgery [6, 29]. Common comorbidities include cardiac disease, renal disease, pulmonary disease, malnutrition, sarcopenia, and dementia. Acute issues such as dehydration and delirium can also complicate perioperative care. During care of the patient with fragility fracture, identification of unrecognized disease states contributing to the impaired bone quality should also be sought [64, 65, 95]. Failure to recognize and treat correctable causes of poor bone quality places the patient at increased risk of future fragility fracture and may impair their recovery from their current injury [22, 40, 85].

Orthopaedic surgeons encounter patients with impaired bone quality in many aspects of their practice, but a comprehensive understanding of identification and care of these patients is especially important in the setting of fragility fractures. This review will (1) describe the importance of systematic preparation of patients with fragility fracture for surgery, (2) present an overview of treatment of common fragility fractures (hip, radius, distal femur, proximal humerus and vertebrae), and (3) review the diagnostic workup and treatment in the postfracture setting of disease states contributing to impaired bone quality including osteoporosis.

Search Strategy and Criteria

We searched PubMed using the terms bone quality, osteoporosis, and fragility fracture combined with the following terms: geriatric (81 articles), perioperative mortality hip fracture (12 articles), medical comorbidities (15 articles), polypharmacy (19 articles), timing of hip fracture surgery (seven articles), perioperative care for hip fracture (nine articles), dementia (25 articles), delirium (four articles), perioperative pain management (10 articles), fracture fixation (569 articles, subsequently subdivided into femoral neck fracture fixation, pertrochanteric hip fracture fixation, periprosthetic fracture, proximal humerus fracture fixation, and diaphyseal fracture fixation), polymethylmethacrylate for fracture augmentation (64 articles), secondary causes of osteoporosis (72 articles), laboratory evaluations for diagnosis of osteoporosis (182 articles), vitamin D deficiency (593 articles), vitamin D insufficiency (547 articles), low testosterone levels (101 articles), hypothyroidism (82 articles), hyperthyroidism (97 articles), hyperparathyroidism (426 articles), Cushing's disease (37 articles), estrogen deficiency (339 articles), and osteoporosis treatment after fracture (229 articles). English literature published after 2000 was prioritized, with the exception of classic clinical trial studies that determined benchmarks for care published before that date. Articles were then sorted and selected for this review if they provided Level I research evidence for the selected topic, provided meta-analysis data from smaller studies for the selected topic, or represented the conclusion of symposia on selected topics to establish clinical care paradigms. Review articles from high-impact journals on selected topics were chosen to assist with the identification of landmark articles for topics where primary research articles are limited. This review is limited by the choice of one database for our search and does not represent an exhaustive systematic review of all available literature in all languages. The review is intended to summarize landmark articles and current treatment paradigms for the perioperative treatment of patients with fragility fracture and raise questions as to where further systematic research is needed.

Preoperative Assessment and Preparation for Surgery

Medical comorbidities and physiologic changes that occur with aging present multiple challenges when caring for the patient with acute fragility fracture. Early surgery is important when managing these patients. Many studies recommend performing surgery for patients with hip/femur fracture within the first 24 to 48 hours of admission [16, 32, 61, 65, 77, 84]. Early surgery has been associated with reduced minor and major complications [2, 54]. Early surgery also reduces the negative effects of immobility on the patients. Immobility after a fracture increases the risk of infections, pressure sores, morbidity, and mortality [5, 38]. It is desirable to mobilize patients promptly after surgical repair of their fractures, with early weightbearing being permitted for all proximal femur fractures [5, 38, 62, 74, 80]. This helps to improve functional outcomes and prevent the mentioned complications [5, 38, 80].

Improving a patient's medical status before surgery should be accomplished promptly to allow for early surgery. Medical comanagement of the patient with fragility fracture can offer the patient and surgeon many advantages. The geriatrician or hospitalist is usually in the best position to coordinate the overall medical care and should remain involved before and after the surgery [29]. This promotes a culture of "shared patient ownership" and if done well will foster a good collegial relationship that benefits the patient [28, 29]. Cardiology consultations are a common reason for delay of surgery, but with medical comanagement, cardiology consultations are rarely necessary for the patients with fragility fractures [28, 29]. These consultations are best ordered by the geriatrician or hospitalist when additional assistance is required for a complex cardiac condition [29]. Nearly all patients with fragility fractures enter the hospital dehydrated, often after having fallen at night while walking to the bathroom [29]. Rapid hydration with normal saline is indicated and repletion of the patient's red cell mass should also be undertaken. Proper hydration in the preoperative period reduces the risk of hypotension on induction of spinal or general anesthesia.

Another serious issue seen in patients with fragility fracture is polypharmacy. Polypharmacy is an excess number of medications taken by the patient. It is caused by the addition of new medications by the patient's various medical physicians as an outpatient. As the number of medications increases, so does the risk of having a drug-drug interaction [46]. Often additional medications are prescribed to manage the side effects of the existing medications and the list lengthens. A good medical consultation will address this issue and harmful and problematic medicines should be discontinued [29].

Dementia and delirium are common in patients with fragility fractures [59, 83]. Dementia is a chronic cognitive condition characterized by gradually progressive memory loss, disorientation, agitation, and loss of executive function. Delirium, by contrast, is characterized by an acute onset of symptoms with a fluctuating course of disorientation, confusion, agitation, and decreased attentiveness. There are hyperactive, hypoactive, and mixed forms of delirium. The hypoactive state is considered to have the worst prognosis by most authors [43, 83]. Delirium is more common in patients who have pre-existing dementia and patients who have been delirious during previous hospitalizations [43, 83]. Delirium worsens the prognosis and increases the complication rates after fracture surgery [43, 83]. Additionally, cognitive dysfunction can impair the patient's rehabilitation after surgery. Up to 61% of patients with hip fracture experience postoperative delirium [83].

Pain management in the perioperative period is critical to reducing risks of delirium [65]. Small frequent preoperative doses of morphine or hydromorphone are typically effective [65]. Postoperative pain can be managed the same way or with oral oxycodone. NSAIDs impair renal function and fracture healing. NSAIDs should be avoided or used with great caution when caring for patients with fragility fracture [45, 79]. Other medications to avoid are the centrally acting antihistamines, meperidine, most antiemetics, benzodiazipines, and H2 blockers [29]. Anticoagulants including warfarin or clopidogrel are commonly seen in this population. Management of these medications should be discussed with the medical consultant. Management of the warfarin-anticoagulated patient presents many challenges and is controversial. Warfarin may be reversed with oral vitamin K or with fresh-frozen plasma infusions or by waiting until the liver synthesizes new coagulation factors. Specific treatment must be individualized for the patient by the medical team. The international normalized ratio level should be less than 1.5 before performing the surgery. Clopidogrel is a platelet inhibitor commonly prescribed to patients with cardiac disease. Clopidogrel is considered to be a contraindication to neuraxial anesthesia in the commonly used ASRA guidelines [4]. The bleeding risks posed by clopidogrel must be balanced against the need for emergent or urgent surgery [4]. For most patients with hip fractures who are on clopidogrel, early surgery can occur using general anesthesia [29]. Some centers use platelet transfusions when managing these patients.

Perioperative care of patients with hip fractures remains an important area to focus on to reduce the likelihood of complications. Published literature has shown mixed outcomes on perioperative morbidity and mortality with medical comanagement of patients [29, 49, 78, 91, 104]. Some recent literature has demonstrated improved patient outcomes using a patient-centered protocol-driven care approach to patients with hip fracture [28, 29]. Reductions in time to surgery, fewer postoperative infections, decreased overall complication rates, and shorter lengths of stay are reported by proponents of this approach [28, 29].

Operative Fixation of Fragility Fractures

Recognition of the poor bone quality by the surgeon is essential [97]. With aging, several changes occur to the bone that change its biomechanical properties, making it more prone to fracture and more difficult to repair using standard techniques. The decreased cortical thickness and porosity combined with the loss of trabecular bone make it more difficult to obtain good purchase with standard fixation hardware [90]. Thus, when fixation is planned in osteoporotic bone, implants and constructs should be chosen that will maximize surface area contact with the remaining bone. In patients with good-quality bone, implant failure may occur if the fracture fails to heal. In these situations, the hardware itself generally breaks after repeated cyclical loading. By contrast, osteoporotic fracture failures occur generally at the bone-implant interface resulting in cutout, fracture subsidence, or plate pull-off [33, 63, 69]. For that reason, locking head screws, larger-diameter screws with greater surface contact area, bicortical screws, angular stable blades, and hardware designed to provide more load bearing rather than load sharing are preferred to fix fractures in patients with impaired bone quality [100].

Geriatric patients also cannot maintain limited weightbearing due to other physical limitations and cognitive limitations (delirium or dementia) during their postoperative rehabilitation care. This means patients should be weightbearing as tolerated or limited to bed-to-chair transfers until enough healing has occurred at the fracture site to allow weightbearing [68]. Hardware choices should allow for early weightbearing and mobilization of these patients as extended periods of nonweightbearing are associated with substantial morbidity in these patients. Four basic principles then help to guide the choice of hardware. Osteoporotic fractures maintain stability by impaction of the fracture site, functional fracture reduction, splinting of the fracture over a long area, and the use of materials to augment the strength of the bone where needed [64]. The use of fixed-angle devices can help to create stability for the fracture [100]. Prosthetic replacement is an alternative technique to consider when there is substantial destruction of an osteoporotic joint.

Treatment choices for femoral neck fractures depend upon the degree of displacement of the fracture and the overall activity level and general health of the patient. Nondisplaced fractures can be treated with three cannulated screws or a sliding hip screw with an antirotation pin, which allow impaction of the femoral head onto the femoral neck with weightbearing, to stabilize the fracture [76]. Displaced femoral neck fractures in physiologically older patients with poor bone quality are generally treated with joint arthroplasty [73] because approximately 40% of these patients treated with internal fixation require reoperation [72]. Hemiarthroplasty with either a unipolar or bipolar prosthesis is preferred in physiologically older, low-demand patients [72, 75]. Controversy exists over the use of cemented or press-fit stems [72]. There is limited evidence that cemented stems are a slightly better choice [72]. For geriatric patients with a femoral neck fracture who are physiologically younger and active, THA reduces reoperation rates and the rate of hip pain reported [39, 44, 57, 58].

For pertrochanteric hip fractures, fixation is generally provided by a sliding hip screw or trochanteric entry nail, depending in part upon the fracture pattern [7, 72]. These implant choices allow for a fixed angle of support to be provided while allowing for impaction of the fracture site through the sliding action of the screw or blade placed into the femoral neck and head. Position of the tip of the lag screw or blade within the femoral head is important [8]. When the implant is positioned in the center of the femoral head, fixation failure is less likely [8]. A tip-apex distance is measure in both AP and lateral planes and the sum of these two distances is used. A tip-apex sum of less than 27 mm did not demonstrate cutout in clinical review, while a tip-apex sum of more than 45 mm was associated with a 60% cutout rate in sliding hip screws [8]. Subtrochanteric fractures are best treated with trochanteric entry nailing using a long nail [53]. Plating techniques of unstable pertrochanteric fractures are associated with an increased rate of mechanical failure and malunion, with studies of intramedullary nails reporting lower failure rates [53, 74].

Distal femur fractures are also a commonly seen injury in the geriatric age group and often involve both metaphyseal and distal diaphyseal injury. Two general treatment options exist for these injuries, plating or retrograde intramedullary nailing. Many of these injuries are treated with plating [30, 100]. Standard plates can be used in select circumstances with the more simple fracture patterns. The 95° condylar blade plate has served as a good choice for this fracture for more than 40 years [51]. It is an inexpensive, anatomically contoured, strong implant, but it is also an unforgiving implant that few surgeons have mastered. The distal femoral anatomically shaped locking plates work well for most native and periprosthetic distal femur fractures [30, 100]. They are strong and offer many fixed-angle screws to fix more challenging fractures. They are relatively easy to insert and can be placed percutaneously as a minimally invasive plating [100]. On the negative side, they are costly and require intraoperative fluoroscopy to install them. Intramedullary nailing is chosen by many surgeons for distal femur fractures in osteoporotic bone. It has a biomechanical advantage but only offers limited distal fixation, making it useful for simpler fracture patterns. It can be used in selected periprosthetic fracture cases with enough opening in the prosthesis to accommodate the nail. The nails are also costly and require intraoperative fluoroscopy to insert them. Blocking screws may be needed to prevent angular malalignment [68].

Proximal humerus fractures are also common injuries in the osteoporotic patient. These cover a wide range of injuries from relatively simple surgical neck fractures to comminuted four-part fractures. Many options are available to treat these fractures. Simple and minimally displaced fractures have been successfully treated for many years with nonoperative techniques [23]. This results in satisfactory outcomes for most of these fractures and is the preferred treatment for many fractures [23]. For displaced simpler patterns, locked plating can be a successful technique [100]. This technique requires restoration of the medial bony contact to succeed in the osteoporotic patient. The lack of a medial buttress in the osteoporotic patient will result in varus collapse and hardware penetration of the humeral head in a high percentage of cases [69]. This technique requires the use of five or six locking screws in the head fragment as well. Careful reduction and placement of hardware with intraoperative fluoroscopy can help lessen the chance of intra-articular screw placement [69]. Prosthetic replacement is typically used in the complex four-part fractures and head-splitting fractures [52]. Standard and reverse prostheses are available for use [60]. These have inconsistent levels of functional recovery and thus should be reserved for the most complex injuries.

The distal radius fracture is a very common injury in osteoporotic patients. It may be the presenting sign of osteoporosis and this must be considered [39]. Undisplaced fractures can be immobilized, but displaced fractures seem best managed with volar locked plating [31]. This technique has been employed globally over the past several years [55]. In severe osteoporosis, the screws must be carefully placed distally to prevent fracture subsidence and must not be too long or they will penetrate dorsally and cause attritional extensor tendon rupture [9].

Vertebral compression fractures are one of the most common fragility fractures in patients with altered bone quality. Approximately 750,000 vertebral compression fractures occur annually in the United States. An estimated two-thirds of compression fractures are asymptomatic or minimally symptomatic and present only incidentally on radiographs or after height loss or kyphosis is noted [86]. However, 10% of patients will require hospitalization for pain associated with their fracture [50]. Patients with a vertebral compression fracture are also five times more likely to suffer a second vertebral compression fracture or a hip fracture compared to their fracture-free peers [50]. Patients with symptomatic fractures are generally managed with nonoperative care aimed at providing pain control, return to function, and stabilization of the fracture deformity. Analgesics, activity modifications, and bracing can be used to help facilitate pain control and rehabilitation. Acetaminophen and NSAIDs should be used as initial pain control agents, with low-level narcotics added for short periods of time if necessary. All pain agents should be used with caution in this population [82]. Calcitonin nasal spray has been associated with improved pain control in vertebral compression fractures and can a useful adjuvant agent [56]. Cruciform anterior spinal hyperextension and Jewett extension bracing can provide pain relief by restricting flexion and providing some support to muscles. Braces are often poorly tolerated by elderly and obese patients, and careful fitting is required [82]. If substantial pain persists after 1 to 2 months of nonoperative therapy, vertebral augmentation surgery with polymethylmethacrylate (PMMA) cement (vertebroplasty or kyphoplasty) can be considered. Operative treatment is controversial. Two placebo-controlled randomized clinical trials that included patients with back pain up to 12 months after diagnosis of their fractures showed no difference in pain scores for patients at 1 month and 6 months [19, 47]. The trials were criticized for the inclusion of patients up to a year after their injury, which many consider outside the window of the definition of an acute fracture. The Fracture Reduction and Evaluation study randomized patients to kyphoplasty or nonoperative care and demonstrated improvements in SF-36 scores in the kyphoplasty treated group at 1 month but no difference at 1 year [102].

Augmentation of osteoporotic bone is not a new concept. Material that can be used to augment porotic bone, including PMMA cement, calcium phosphate-based cements, and cortical allograft struts, have all been described to increase structural stability during the repair of fragility fractures. Allograft struts can be placed along a diaphyseal surface to act as a long splint that provides additional structural cortex to hold screws or stabilize cerclage wires [37]. PMMA cement and calcium phosphate cements are used through direct application into the fracture site to provide immediate stability (similar to the concept of vertebroplasty) or to fill gaps left by severely comminuted bone [64]. Cement has been injected into screw holes or the intramedullary canal of long bones to improve screw purchase and strength at the bone-implant interface [64].

Diagnosis and Treatment of Diseases Associated With Impaired Bone Quality After a Fragility Fracture

It is estimated at least 30% of postmenopausal patients with osteoporosis have a secondary cause contributing to their bone fragility [71]. The incidence is higher in patients considered at lower risk for osteoporosis, with up to two-thirds of men and premenopausal women with osteoporosis demonstrating a secondary cause contributing to their disease [70]. Secondary causes of osteoporosis vary widely from autoimmune disease, glucocorticoid therapy, malignancy, hormonal suppressive agents for breast or prostate cancer, hypercalciuria, HIV, celiac disease, and diseases of malabsorption [24]. The cause for many of the patients will be an endocrinopathy that will only be diagnosed if considered and appropriate laboratory tests ordered [24]. These endocrinopathies include vitamin D deficiency/insufficiency, hypothyroidism, hyperthyroidism, hyperparathyroidism (primary and secondary), Cushing's disease, and hypogonadism (testosterone or estrogen deficiency). The majority of these reversible secondary causes of osteoporosis can be identified through a laboratory panel. Recommended tests include a basic biochemistry panel with serum calcium levels, 24-hour urine calcium measurement, 25-hydroxy-vitamin D level, thyroid-stimulating hormone (TSH) level, and parathyroid hormone (PTH) level. Additional tests can be ordered depending upon these results and other concerns elicited from the patient's history and examination. It is estimated 2% to 5% of patients undergoing vertebroplasty or kyphoplasty for a first fracture demonstrate an occult malignancy on vertebral biopsy [89]. The majority of these biopsies reveal the presence of multiple myeloma, metastatic disease, or lymphoma [81]. A complete blood count including platelet count and a serum protein electrophoresis is often necessary in the workup of an individual with a fragility fracture [18].

Vitamin D deficiency and insufficiency are common in the fragility fracture population. An estimated 70% to 90% of patients with hip fracture have insufficient levels of vitamin D [25]. Vitamin D insufficiency is defined as serum 25-hydroxy-vitamin D levels below 32 ng/mL (80 nmol/L). In patients older than 70 years, insufficient vitamin D levels have been associated with increased fracture risk. Levels lower than 10 ng/mL (25 nmol/L) are associated with secondary hyperparathyroidism as reflected by increased serum PTH levels and decreased serum calcium levels [41]. The National Health and Nutrition Examination Survey III study demonstrated improved gait speed and performance on lower extremity function tests in women older than 60 years with increasing levels of 25-hydroxy-vitamin D up to 94 nmol/L (40 ng/mL). Reduced physical performance such as speed of gait, speed of rising from a chair, and balance adjustments may be noted in patients with vitamin D levels of less than 20 ng/mL [103]. Fall risk was reduced 19% to 23% with vitamin D supplementation in individuals older than 65 years with more than 700 IU vitamin D3 daily, as long as patient 25-hydroxy-vitamin D levels were brought above 60 nmol/L [13].

All patients with a fragility fracture should have their 25-hydroxy-vitamin D level assessed and corrected to more than 32 ng/mL (80 nmol/L) [11]. Oral supplements can be given to patients in multiple forms to achieve this goal. There is no universal agreement on the ideal supplement or dosing schedule. Vitamin D supplements come in two forms: ergocalciferol (vitamin D2), which comes from plant and yeast sources, and cholecalciferol (vitamin D3), which is derived from animal sources and produced in the skin. Ergocalciferol is available in 50,000 IU gel caps by prescription and can be given weekly, monthly, or more frequently if needed. Ergocalciferol is more rapidly cleared from the body than cholecalciferol. Long-term dosing with 50,000 IU ergocalciferol is equivalent to 10,000 IU cholecalciferol [34]. In our experience, supplementation to normal range levels with ergocalciferol can be achieved rapidly in postfracture patients. Many protocols exist [41], but we find eight doses of 50,000 IU ergocalciferol over 5 to 8 weeks correct patients with baseline levels of 20 to 30 ng/mL. Sixteen doses are required for levels of 10 to 19 ng/mL and 24 doses for levels of less than 10 ng/mL (Table 1). After repletion of vitamin D, patients are advised to take 2000 IU cholecalciferol (vitamin D3) per day in addition to any vitamin D contained in their multivitamin or calcium supplements as long-term therapy. Meta-analysis of vitamin D3 supplement regimens showed 25-hydroxy-vitamin D levels of 32 to 44 ng/mL provided optimal health benefits and were only achieved with 1800 to 4000 IU vitamin D3 daily [13]. Mean serum calcium levels were not adversely affected by dosing regimens that included doses up to 10,000 IU vitamin D3 daily [12]. Current recommendations for vitamin D supplementation are under review, but mounting evidence suggests all patients with fragility fractures should have their vitamin D levels normalized.

Table 1. Suggested perioperative vitamin D supplementation for the patient with impaired bone quality and low vitamin D levels

Serum vitamin D level (ng/mL)	Aggressive ergocalciferol (vitamin D2) supplement
20–30	50,000 IU once weekly over 8 weeks
10–20	50,000 IU twice weekly over 8 weeks
< 10	50,000 IU three times weekly over 8 weeks

Note high-dose supplementation should be followed by vitamin D level testing and regimen repeated as needed at the appropriate dose until level has increased to more than 32 ng/mL; all high-dose supplementation should be followed by chronic vitamin D supplementation at a lower dose (often 1000–2000 IU daily, if not greater).

Malignancy must be a concern with all patients with hypercalcemia, but primary hyperparathyroidism is another common cause of hypercalcemia. It is most commonly seen in patients older than 50 years, affecting women three times more frequently than men [27]. The hallmark of primary hyperparathyroidism is elevated serum calcium levels in conjunction with elevated serum PTH levels [10]. Eighty percent of cases are associated with a single benign parathyroid adenoma [87]. Cortical bone is thinned more substantially than cancellous bone in primary hyperparathyroidism and bone mass improves considerably in the first 3 years after treatment. Hypercalciuria with an increased risk of kidney stones can be seen [92]. Diagnosis is established by laboratory values and confirmed with a sestamibi radionuclide scan. After diagnosis, a referral to a head and neck surgeon is required. Most patients now undergo minimally invasive parathyroidectomy with immediate reductions in PTH levels. If multiglandular disease is suspected, removal of all four glands and reimplantation of half of one gland continues to be performed [92]. Patients with asymptomatic hyperparathyroidism or patients who are poor surgical candidates can be managed medically with regular laboratory testing and bone mass assessment by an endocrinologist [92]. Some patients do not demonstrate hypercalcemia despite the presence of a parathyroid adenoma and elevated PTH, in part due to low vitamin D levels. Patients with very low vitamin D levels but a high normal calcium level should have serum calcium levels watched carefully during vitamin D supplementation. Restoration of adequate vitamin D stores may unmask a case of simultaneous primary hyperparathyroidism.

Both low and high thyroid hormone levels can be problematic for bone. Patients with hyperthyroidism have an increased risk of osteoporosis due to increased bone turnover associated with elevated thyroid hormone levels. Again, cortical bone appears to be disproportionately affected. Recent basic science work has suggested TSH independently exerts an effect on bone remodeling by suppressing bone resorption [1]. Patients with hyperthyroidism may suffer the effects of both events, which result in their increased osteoporosis rates [36]. In the geriatric population, up to 20% of women and 8% of men will be hypothyroid. While patients with untreated hypothyroidism do not demonstrate diminished bone density [35], they do demonstrate increased fracture rates compared to patients with normal thyroid hormone levels [26, 99]. These patients are also at increased risk of cardiovascular disease and cardiac arrhythmias [16]. Patients with hypothyroidism who are treated with exogenous thyroid medication must be carefully managed to avoid oversuppression of TSH and an increased risk of osteoporosis and increased bone remodeling.

Cushing's syndrome can result from adrenal tumor, adrenal hyperplasia due to excessive pituitary hormone production, or most commonly from prolonged use of glucocorticoids. Symptoms of Cushing's syndrome include osteoporosis, muscle weakness and easy fatigability, hypertension, emotional lability, truncal obesity, and in some patients, diabetes. Patients with iatrogenic Cushing's syndrome secondary to steroids generally recover to normal function after steroids are withdrawn, although some patients may have persistent symptoms [20]. Patients with adrenal-based hypercortisolism may have increased serum and urine cortisol levels [67]. An overnight dexamethasone suppression test in which dexamethasone administration fails to suppress serum cortisol levels can aid in diagnosis [66]. Most patients with iatrogenic Cushing's disease can be identified by history and medication usage. Patients suspected to have true Cushing's disease should be referred to an endocrinologist for further workup. Cushing's disease can also occur due to ectopic production of adrenocorticotropic hormone by lung cancer tumors. Treatment of noniatrogenic Cushing's disease involves the resection of the neoplastic or hyperplastic tissue causing the disease [67].

Hypogonadism with low testosterone levels is common in men with osteoporosis and fragility fractures [21]. An 8 am testosterone level and percentage of free testosterone measurement are often added to the osteoporosis workup panel for men. The utility of testosterone supplementation remains controversial. Experimental models suggest testosterone may play an important role in suppressing bone turnover and may have a weak anabolic effect on osteoblasts [48]. Testosterone supplementation is currently used in men with osteoporosis and other symptoms of hypogonadism, including sexual dysfunction, depression, and muscle mass loss. Supplementation does improve bone mass [93] but is not absolutely required. It is important to recognize men with low testosterone levels are at increased risk of osteoporosis and workup including bone density measurement should be pursued in these patients. Recent clinical evidence suggests total estradiol levels are actually better predictors of osteoporosis in men [10]. Animal models in male rats have also demonstrated estrogen pathways to have important skeletal effects [98, 101].

Estrogen deficiency has long been recognized as a risk factor for osteoporosis in women. At menopause, the loss of estrogen results in a dramatic increase in bone resorption and the new bone formation is unable to compensate for this rate of bone loss [31]. This results in the high bone turnover state commonly seen during perimenopause, with bone loss rates up to 2% to 3% per year [94]. Estrogen suppresses RANK ligand (RANKL) production and increases osteoprotegerin production [15]. Loss of estrogen allows for more RANKL to reach its receptor RANK on the osteoclast, resulting in increased osteoclastic activity and lifespan [42, 96].

Patients who suffer a fracture from a fall from standing height or less by definition demonstrate impaired bone quality and merit a workup for osteoporosis. Despite this knowledge, rates of osteoporosis assessment and treatment after a fragility fracture remain low. At the turn of the millennium, only 16% of patients with low-energy-induced hip fractures received therapy for osteoporosis [3]. A decade later, that number is essentially unchanged at 20%. Similar rates of treatment are seen after osteoporotic wrist fractures [70]. Patients who have suffered a fragility fracture are at increased risk for future fracture and thus all deserve an assessment for osteoporosis and other causes of impaired bone quality and appropriate treatment. Patients with fragility fractures should have a dual-energy xray absorptiometry scan, testing of basic laboratory values (basic biochemistry panel, including serum calcium, 25-hydroxy-vitamin D, PTH, possibly TSH, 24-hour urine calcium, and markers of bone turnover), and prescriptions of calcium and vitamin D supplements. After diagnosis, a prescription of a medication for osteoporosis treatment should be provided with instructions for its use. Involvement of the orthopaedic surgeon in the process is essential for the diagnosis and treatment of osteoporosis in patients with fragility fractures. A program for patient assessment and treatment or a plan to provide appropriate referral of these patients to another provider is needed [14].

Discussion

Fragility fractures in patients with impaired bone quality are common and require modifications in standard fracture fixation techniques and perioperative care to maximize potential functional recovery and minimize future fracture risk. In this review, we described the importance of systematic preparation of patients with fragility fracture for surgery, presented an overview of treatment of common fragility fractures (hip, radius, distal femur, proximal humerus and vertebrae), and reviewed the diagnostic workup and treatment in the postfracture setting of disease states contributing to impaired bone quality including osteoporosis.

This review and the published literature are subject to a number of limitations. First, the concept of bone quality, the role bone quality plays in fracture and fracture healing, and which elements comprise bone quality are still being defined. Second, there have been few randomized prospective clinical trials performed in orthopaedic surgery that allow us to provide Level I evidence to guide our surgical techniques and implant choices. Third, the vast literature on osteoporosis and secondary causes of bone fragility spans several decades and treatment recommendations in these areas are also evolving. It is certain the orthopaedic surgeon will encounter patients with fragility fractures and impaired bone quality and this patient population is expected to grow as the elderly population increases in number. Recognition of the unique needs of these patients is required. Specific research questions will need to focus upon this subgroup of the population and their unique needs in fracture care.

In their encounters with patients with fragility fractures, orthopaedic surgeons must be able to identify patients with impaired bone quality and then modify their perioperative management to address their impaired bone quality. Medical comanagement can assist with systematic preoperative evaluation and rapid preparation for surgery. Implant selection should allow for immediate weightbearing even when bone quality is poor. Implant choices and surgical techniques will vary with the individual fragility fracture site (hip, radius, distal femur, proximal humerus, and vertebrae). The general principles of care include the possible need to augment the fracture site to maintain maximal stability. In addition, any secondary diseases contributing to poor bone quality, including osteoporosis, must be identified and treated in these patients to minimize future risk of additional fragility fractures.

After injury, preparation of patients with impaired bone quality for the operating room can be a challenge due to their multiple medical comorbidities. Despite substantial medical advances over the past 40 years, mortality after hip fractures has changed very little. One of the current controversies is whether models of coordinated care partnering a geriatrician with an orthopaedic surgeon can improve outcomes in terms of morbidity and mortality. Literature has shown mixed results using this medical comanagement model, but some recent reports for hip fracture patient comanagement protocols have demonstrated improvements in mortality rates, fewer postoperative infections, decreased overall complications, and shorter lengths of stay [88]. Clearly this is an area where further research is warranted. Patients often present on a large list of medications, many of which can complicate surgery for either the anesthesiologist or the orthopaedic surgeon. Judicious management of these medications in the perioperative period is another area of current controversy, particularly since perioperative delirium is associated with increased postoperative complication rate. Very little is understood about the exact role dementia and delirium play in perioperative outcomes and further research is needed.

Operative techniques may need to be modified when managing fractures in patients with impaired bone quality. The bone itself represents the weak link in the repaired construct and both hardware types and techniques need to address this weakness. Load-bearing, fixed-angle devices help to provide stability to these fractures. The use of larger-diameter bicortical screws when possible helps to increase contact area between the remaining bone and the hardware. Long-spanning implant constructs help to splint the remaining bone over a large area, again distributing forces across the remaining bone. The actual choice of hardware depends on the anatomic location of the fracture, but patient factors including prior injury or joint arthroplasty may limit hardware choices. Although it may seem obvious, good surgical technique is required in the care of fractures in patients with poor bone quality. The most common reason for hardware failure is cutout of the hardware from the weak surrounding bone. Careful placement of the hardware, reduction and impaction of the fracture site, and use of materials to augment the bone when needed all appear to improve outcomes for fractures in patients with impaired bone quality. Even with this knowledge, substantial controversy remains over the best choice of implants and specific details of techniques that will optimize outcomes. Despite extensive research over several decades around the operative care of hip fractures, controversies continue to evolve. A clinical trial is currently ongoing for minimally displaced femoral neck fractures comparing sliding hip screw constructs with cannulated screws. The best choice is unknown. A similar controversy exists in the care of displaced femoral neck fractures. A randomized, head-to-head comparison of modern cemented stems to modern press-fit stems has not been performed and the superiority of one technique over the other continues to be debated.

Patients with impaired bone quality often have another unrecognized disease state contributing to their diminished bone quality. Workup and correction of the problem (if possible) are warranted in all patients who present with a fragility fracture. Beyond that statement, the exact protocols and extent of this evaluation remain controversial. One of the most common and most controversial situations in these patients involves vitamin D. Vitamin D is important in the absorption of calcium and mineralization status of bone. It has been recently recognized vitamin D receptors are present on cells in multiple tissues and it may play a role in modulating multiple disease states. The ideal level for serum vitamin D levels and recommendations for supplementation have been in constant debate over the past several years. Current guidelines suggest, for optimal bone health, serum 25 vitamin D levels should be maintained above 32 ng/mL, as that is the level where PTH secretion stabilizes. If vitamin D does play an important role in muscle strength, neuromuscular control, and the immune system, ideal serum levels for these areas have not established. The Institute of Medicine released revised recommendations for vitamin D supplementation in late 2010, but even those recommendations are unlikely to settle the debate over optimal vitamin D status. Thyroid disease, parathyroid disease, Cushing's disease, and hypogonadism all affect bone quality. Recognition of these secondary issues in patients with fragility fracture is important as they are known to impair bone quality. Treatment of these diseases and the true effects this treatment has on fracture healing outcomes and future fracture risks remain unclear.

In summary, there are many challenging issues encountered when treating patients with fragility fracture. These issues must be addressed to improve patient outcomes. Surgical technique issues include proper implant selection, thoughtful preoperative planning, accurate fracture reduction, and gentle surgical technique. Early weightbearing should be planned for whenever possible to permit patient mobility. Perioperative comanagement of the patient's comorbid medical conditions with a medical colleague should be considered. A systematic approach to care of the patient will likely improve outcomes. The patient's bone quality issues should be diagnosed and treated to help prevent additional fractures. Treatable causes of secondary osteoporosis should be sought and treated. Fragility fractures are a major global public health problem that most orthopaedic surgeons will treat with increasing frequency over the next 20 years. We must be prepared to face this challenge.

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