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Osteoporosis and Spinal Cord Injury

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Osteoporosis

Osteoporosis is a medical condition characterized by low bone mass and structural deterioration of bone tissue. This increase in bone fragility increases the affiliated individual's risk of life-threatening fractures of the hip, spine, and wrist and consequently affects mortality, morbidity, and related medical expenses (Conference Report, 1991; National Institute of Neurological Disorder and Stroke, 2012). Deriving its origin from two Greek words osteon and poros meaning "bone" and "hole, passage" respectively, osteoporosis is fast becoming a national health concern in the United States (National Osteoporosis Foundation, n.d.). Prevalence data suggests there are an estimated 44 million individuals in the United States with osteoporosis, the majority of whom (55%) are aged 50 or over (National Institute of Health (NIH), 2012).

Although widely diagnosed, agreement on a definition for this condition was not reached until 1990 when a consensus development conference defined osteoporosis as "a disease characterized by low bone mass, microarchitectural deterioration of bone tissue leading to enhanced bone fragility, and a consequent increase in fracture risk" (Conference Report, 1001, p. 1). The World Health Organization (WHO) estimates the lifetime prevalence of an osteoporotic fracture to range from 30% to 40% in developed nations such as the United States (WHO Summary, 2004). Often described as a "silent disease" because of the frequent occurrence of undetected bone loss, osteoporosis is becoming a cause for concern (NIH, 2012).

Jarvinen and Kannus (1997) state "Osteoporotic fractures are a major public-health problem not only because of the associated morbidity and mortality but also because of the health-care costs that they generate" (p. 263). By 2004, the cost of annual osteoporosis-related medical treatment surpassed $22 billion (Vanness & Tosteson, 2005). Due to the increased ageing population in the U.S., costs associated with treatment care of osteoporosis are also expected to rise. A study conducted by Vanness and Tosteson (2005) estimates osteoporotic fracture-related medical costs in 2004 projects the financial costs of these future medical expenses by 2025 will exceed $32 billion per year.

Osteoporosis is more prevalent in women than in men, and more common in South Asian and Caucasian races/ethnic women. Nonetheless, prevalence rates in males and individuals of all ethnicities are on the rise (Melton, 2001). This medical condition causes a variety of fractures but much of the morbidity and mortality rates are due to hip fractures. Hip fractures statistically result in an estimated 12% -20% of deaths primarily among elderly persons within one year post-injury, and indirectly, is among one of the leading causes of death and disability in the U.S. (Conference Report, 1991). These fractures lead to hospitalizations, disability, and related loss of independence for approximately 300,000 people annually (Ray, Chan, Thamer, Melton, 1997). The two other commonly found osteoporosis-related fractures are vertebral and

wrist (Colles') fractures (Wasnich, 1997).

Medical Aspects of Osteoporosis

Osteoporosis is the most common metabolic disorder of the bone worldwide (Kim, Vacarro, 2006). Bones are active growing tissue within the human body that require the presence of collagen and calcium phosphate to maintain strength and harden the skeletal framework. The combined efforts of both these elements are essential for bones to withstand daily stress (NIH, 2012). The National Institute of Health indicates a diet rich in calcium can help avoid low bone mass, rapid bone loss, and high fracture rates (NIH, 2012). The process of resorption (removal of old bone and formation of new bone) continues throughout one's lifetime. Formation exceeds resorption in the childhood and teen years and then begins to reverse at approximately age 30 (NIH, 2012). Resorption changes include micro-architectural deterioration of the bone, decreased bone strength, and increased propensity for fractures (Silver & Einhorn, 1995). Poole & Compston (2006) indicate osteoporosis often presents as a clinically visible fracture following a low trauma fall such as falling from standing height; however, can also arise from non-trauma causes such as backache, height loss, spinal deformity, or radiological osteopenia.

Risk factors. Several researchers have identified potential risk factors for osteoporosis. These include genetic predisposition, increased age, being a Caucasian or Asian female, delayed puberty, hormonal imbalances, nutritional deficiencies, low body weight, varied medical illnesses, and substance usage (Christiansen, 1995; Cooper, 1989; Cornell, 1990). Genetic factors strongly influence development of peak bone mass, as indicated by Bonjour, Theintz, Law, Slosman, & Rizzoli (1994). With osteoporosis most prevalent in postmenopausal women, effects of female gender, hormonal imbalances, and increased age are associated with its development (Poole & Compston, 2006). Petite, thin-boned women are also at greater risk for development of osteoporosis due to decreased bone strength (NIH, 2012).

Aside from the aforementioned inherent risk factors, the development of osteoporosis may also be attributed to certain preventative factors. One of these factors involves the lack of adequate amounts of calcium in the diet. The Food and Nutrition Board (2010), suggest a daily calcium intake of 1,000 to 1,300 mg for most individuals between the ages of 4 to 70. Nonetheless, national nutrition surveys indicate current average consumption of less than half this amount in most individuals (NIH, 2012). Low vitamin D levels are also cited as preventable risk factors for development of osteoporosis. Low estrogen levels in women and testosterone levels in men also increase the risk of the disease. Other preventable risk factors include a sedentary or non-exertional lifestyle, cigarette smoking, excessive alcohol consumption, long-term usage of glucocorticoids and certain anticonvulsants, and Anorexia Nervosa (NIH, 2012).

Osteoporosis and Spinal Cord Injury

Jiang, Jiang, and Dai, (2006b) cite osteoporosis as "one of the most frequent complications following spinal cord injury" (SCI, p. 6). Otam and Al-Ahmar (2012) detected abnormal bone mineral density values in 80% of patients treated at a Spinal Cord Injury Center leading them to the conclusion that SCI patients are at high risk of developing osteoporosis. Additionally, declining bone mineral density and bone mineral content were detected radiologically in the paralyzed limbs of patients within six weeks after the onset of SCI (Jiang, Dai, & Jiang, 2006a).

Causal Mechanisms. Although development of osteoporosis in individuals with SCI is

well documented, the exact causal mechanisms are unclear; though most researchers attribute onset to the lack of use of one's skeletal framework (weight-bearing) as the cause for pathogenesis (Jiang, Jiang, & Dai, 2006b). Nonetheless, recent clinical research has highlighted the need to study neural mechanisms more closely in order to identify the path of disease causation. Along with the required focus on mechanical and neuronal mechanisms, a need for clinical focus on hormonal changes is also suggested (Finsen, Indredavik, & Fougner, 1992; Jiang et al., 2006b; Sabo et al., 2001). Identification of the pathogenic pathways of development of osteoporosis after SCI can help identify possible treatment interventions (Jiang et al., 2006b).

The level of lesion in SCI also has the potential to influence osteoporosis development depending on the extent to which it affects motor and sensory functions. Jiang, Dai, and Jiang (2006a) further found that complete lesions appear to have more severe loss of bone mass than individuals with incomplete SCI lesions. In addition, there have been conflicting results as to whether spasticity functions to minimize the loss of bone mass density when compared to flaccid persons with SCI (Jiang et al., 2006a). These authors and others also cite risk fracture caused by reduced bone mass density (BMD) of persons with SCI increases with age and loss of mobility (Demirel, Yilmaz, Paker, & Onel, 1998; Fattal et al., 2011; Lazo, Shirazi, Sam, & Giobbie-Hurder, 2001; Sabo et al., 2001).

Prevalence of Osteoporosis in Spinal Cord Injury

One of the most common and inevitable secondary complications to SCI is osteoporosis, characterized by a decrease in bone mineral content (BMC) and bone mineral density (BMD). The prevalence of osteoporosis following SCI varies among studies, ranging between 50% to 70% following disability onset (Biering-Sorensen, Bohr, & Schaadt, 1999; Frey-Rindova, de Bruin, Stussi, Dambacher, Dietz, 2000). Edwards, Schnitzer and Troy (2013) note that much of the bone loss occurs following SCI within the first year throughout the skeleton with the exception of the skull, and progresses rapidly during the first 4 months post-injury (Garland et al., 1992). Although bone loss below the pelvic region is rapid, loss of bone mass in areas of the endoskeleton and above this region stabilizes between 4-16 months post-injury (Garland et al. 1992).

The prevalence of reduced bone mass and osteoporosis in patients with SCI was further supported by Lazo et al. (2001) in a study of 41 patients with SCI in a Veterans Administration Hospital. The authors found that 75% of the study veterans had BMD levels below the average threshold which suggested a diagnosis of osteoporosis. Jiang et al. (2006b) found the incidence of lower extremity fractures in patients with SCI to range between 1% to 34% while Fattal et al. (2001) also found the highest incidence of bone fracture to be in the lower extremities in similarly diagnosed patients with SCI. Bone loss in the lower extremities occurs with relatively similar frequencies among individuals with paraplegia and tetraplegia (Demeril, Yilmaz, Paker & Onel, 1998). Researchers; however, have found variations in upper extremity bone loss in response to remaining degrees of upper extremity functioning in those with tetraplegia (Demeril et al., 1998). Conflicting findings exist; however, regarding the prevalence of upper extremity bone loss in persons with paraplegia. Demeril et al. (1998) for example found that bone loss was unaffected in their study of persons with paraplegia, while Wilmet et al. (1995) found bone loss presence in participants with paraplegia that occurred independently of the presence or absence of muscle activity.

In a study of 46 male patients with SCI whose average age was 32 and whose injuries ranged between one to 26 years, Sabo et al., (2001) found that when compared to an age-

related non-SCI control group, participants with SCI were classified as having severe osteoporosis diagnosed by BMD when compared with age-related controls. Additionally, BMD was found to be significantly lower in patients with complete lesions, although there were no significant differences between the level of lesion and the ability to ambulate (Sabo et al., 2001). Nonetheless, in a systematic review of major changes of bone metabolism in SCI patients with paralysis, Uebelhart, Demiaux-Domenech, Roth and Chantraine (1995) found that although the first six months post-injury is a period correlated with significant bone loss, after 12 to 16 months, overall bone loss stabilizes at approximately two-thirds of the original bone mass.

Characteristics of Osteoporotic Fractures

Osteoporotic fractures occur in response to minor trauma and sometimes spontaneously in individuals with spinal cord injuries (Uebelhart et al., 1995). Recent estimates of risk of fracture suggest that upwards of 50% of individuals with complete SCI will be treated for fractures in their lifetime (Morse et al., 2009a).

Morse et al., (2009a), conducted an evaluation of fracture characteristics among a sample of 315 veterans with spinal cord injuries. Results indicated that tibia and fibula fractures (47.5%) resulted in the most hospitalizations over a course of eight years. The remaining causes of fractures in descending order were distal femoral metaphysic (20%), proximal femur (15%), phalanx fractures (7.5%), humerus (5%), and metatarsal (5%). Reported causes of fractures identified included wheelchair falls (51%), transfers (14%), and catching lower extremities on doorframes while operating wheelchairs (6%). Morse et al. also found that medical complications occurred in 53% of the fracture cases reviewed. Demographic factors such as age, education level, BMD category, and smoking history were not significantly related to fracture-induced hospitalizations (Morse et al., 2009a). Moreover, researchers have found that although alcohol did not increase the actual pathogenesis of osteoporotic fractures after injury, consumption of alcohol was directly related to a three-fold risk of hospitalizations for fracture (Morse et al., 2009a).

Current Trends

Despite the increased frequency of expected fractures in individuals with SCI, the medical community and other researchers appear to lack a thorough understanding of the most efficient time for osteoporotic intervention (Morse et al., 2012b). Results of a systematic review of literature pertaining to treatment of bone loss after SCI revealed no studies conclusively showed an effective intervention for clinical use (Biering-Sorensen, Hansen & Lee, 2009, p. 508). Nevertheless, some researchers suggest that implementation of interventions in the beginning stages of recovery may be the best to reduce bone loss (Edwards, Schnitzer, & Troy, 2013). The former Director General of the World Health Organization, Dr. Brundtland stated "WHO sees the need for a global strategy for prevention and control of osteoporosis focusing on three major functions: prevention, management, and surveillance" (Genant et al., 1999, p. 20).

Medical professionals should provide psycho-education about the increased risk of developing osteoporosis post-SCI to patients and their families. Fattal et al., (2011) suggest the provision of three categories of psycho-education: theoretical, functional, and medical. Theoretical education aims to provide individuals with awareness of the prevalence, co-morbidity, and risk factors regarding pathogenesis of osteoporosis. Functional education increases the understanding of risky behaviors that may contribute to further degeneration of

the bone and risk for fractures. Patient knowledge of the effects of their behaviors and external causes (such a faulty wheelchair lifts, transfers, maneuvers, hazardous exercises, strained body postures, navigating inaccessible areas, and using inadequate protective gear) is encouraged in the functional education category. Last, education and awareness entails information designed to encourage adoption of healthy behaviors such as increased calcium intake, decreased substance usage (caffeine, alcohol, cigarettes), and managing a healthy weight (Fattal et al., 2011). Overall, the noted categories of psycho-education aim to inform patients with SCI about risk factors, prevention strategies, and how bone loss or subsequent fractures can develop.

In a study of 450 medical practitioners within the Veterans Affairs Hospital system, Morse et al., (2012a) found variations in current treatment protocol for osteoporosis-related bone loss in patients with SCI. Over half of these providers (54%) suggested pharmaceutical interventions (ranging from medications such as bisphosphonates for SCI-induced bone loss) to prescriptions of Vitamin D to enhance bone growth. Some practitioners (23%) cited the lack of effective treatment guidelines for clinical care and management of SCI induced osteoporosis (Morse et al., 2012a).

Researchers are exploring the benefits of a variety of pharmaceuticals for treatment of bone loss following acute SCI. Bisphosphonates are a class of drugs commonly known as "antiresorptive" medicines because they prevent resorption of bone tissue and consequently help maintain bone density (Maimoun et al., 2006). This class of drugs has been established as beneficial in preventing further loss of bone mass in acute SCI patients for over 20 years.

Bubbear et al., (2011) found significant improvements in BMD levels for patients with acute SCI who received IV zoledronic acid treatment. This treatment appeared to contain bone turnover caused by resorption among patients with SCI well after 12 months. Positive benefits have been reported by clinical studies testing either first-generation bisphosphonates such as etidronate, or newer treatments such as tiludronate, pamidronate, and alendronate (Maimoun et al., 2006). However, clinical results of even newer bisphonate drugs like ibandronate and zolendronate that are between 10 to 10,000 times more potent than the previous generation drugs are still not validated due to dearth of clinical trials. Nonetheless, if their predecessors are any indication of their ability to maintain loss of bone in SCI-induced bone loss, magnified positive results are expected.

Supplemental forms of therapy such as functional electrical stimulation (FES) performed shortly after SCI recovery may also enhance the body's bone healing and growth process. In a review of studies using this technique, Biering-Sorensen et al. (2009) found inconsistencies in its effectiveness immediately following injury; however, after initial recovery, a regimen of increased frequency of trainings 2-3 times per week appears to help reduce BMD loss and Maimoun et al., (2006) suggest FES should be part of the long-term care protocol. Belanger et al., (2006) found that although FES was initially designed to reduce muscle atrophy, it has since been found to at least reduce bone loss due to the physiological effect of muscle contraction and subsequent tension on the skeleton. Belanger and his colleagues suggest that daily sessions of one hour increments have shown to be significant in reducing bone loss post-injury.

Osteoporotic bone fractures can require extensive hospital stays in some cases. In Morse et al., (2009a) eight year-long study with 315 veterans with SCI, the majority required at least one hospital stay that averaged 35 days due to osteoporotic fractures. In this study, the prolonged hospital length of stay occurred because 87% of those with fractures were treated with a combination of bed rest and extension bracing. In addition, approximately 9% required

surgery to treat the osteoporotic damage (Morse et al., 2009a).

In their literature review regarding approaches to prevent bone loss in patients with SCI, Maimoun et al., (2006) found support for passive standing via standing frames, tilt tables, or other aided walking systems soon after injury; however, this intervention was not found to be effective for individuals with chronic bone loss problems long after injury. The authors also cited the detrimental effects of prolonged bed rest on bone mineral density.

The use of weight bearing mechanisms during mobility exercises has also been found to be beneficial in the maintenance of BMD (Goemare, Van Laere, Neve, & Kaufman, 1994). Mobilization exercises utilizing vibrating mechanisms such as vibrating frames were found to have some positive effects. Nevertheless, due to inconclusive data on clinical trials, Maimoun et al., (2006) noted that "it thus appears that verticalization alone is not a sufficient therapeutic means to prevent bone demineralization, although it may limit it (p. 205)." A lack of widely accepted standardized exercise protocols (including suggested weights and frequency/intensity of exercise regimen) causes further fluctuations and inconsistencies in results.

Conclusion

Beginning at the onset of trauma, osteoporosis and related loss in bone mineral density and bone mass are issues of medical concern in individuals with spinal cord injury. With approximately two-thirds of patients with SCI susceptible to bone loss and more than half with strong propensity of developing skeletal fractures, this metabolic syndrome is one requiring careful monitoring by patients and health care professionals. The increasing costs associated with providing medical care for this secondary complication add to the already high medical costs accompanying the care for patients with spinal cord injury. Treatment and rehabilitation delays encountered as a result of fractures may also affect the quality of life of individuals comprising this specialized population.

Increased economic, health, and personal costs associated with treatment of SCI-induced osteoporosis indicate that care must be undertaken to prevent, rehabilitate, and better manage the associated physiological changes that occur post-injury. Psycho-education regarding risk and preventative factors is essential in all groups of individuals involved in the process of care; medical professionals, rehabilitationists, families, and the patient. Although several prevention, management, and rehabilitation interventions are currently utilized, further research is warranted to explore the overall effectiveness of these techniques to allow for the establishment of improved and widely accepted guidelines for best practices.

For life care planners, deciding on the appropriate consult questions for treating specialists regarding osteoporosis, the medical probability of complications (e.g., bone fractures), long-term care, and beneficial equipment needs (e.g., FES, standing frame), all become important considerations that many physicians may otherwise not think about or consider recommending. The difficult part as with all secondary complications is determining which ones are likely more medically probable and should therefore be part of the overall cost damages, versus those that are noted as potential complications, but not added to overall cost.

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