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Osteoporosis in Spinal Cord Injury Patients: Why sticks and stones break my paraplegic friends' bones

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PROJECT TITLE: Osteoporosis in Sports and Injury Patients

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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Comments (Optional):
Osteoporosis in Spinal Cord Injury Patients

"Why sticks and stones break my paraplegic friends' bones"

Carl Goins
May 3, 2004
Mentor: Jeffrey S. Hecht, MD
Introduction

Osteoporosis is commonly observed in patients with spinal cord injuries (SCI). Osteoporosis is a condition in which the bone becomes spongy due to the loss of bone density. A loss of bone mineral density has been noted in the hips and knees of patients with paraplegia and tetraplegia. The SCI leads to an increase in bone resorption that outpaces that of bone deposition leading to the development of osteoporosis in the hips and below. (S.P. Changlai and C.H. Kao. Bone Mineral Density in Patients with Spinal Cord Injuries. Nuclear Medicine Communications 1986;17:385-388). The result of this phenomenon is the development of osteoporosis in the hips and below.

Bone density is calculated several ways; one is through the use of dual energy x-ray absorptiometry (DEXA) machines. DEXA scans have been found to be one of the most accurate ways of measuring bone mineral density. DEXA is a more accurate method of measurement than either dual-photon absorptiometry or single photon absorptiometry (Sabatier JP, Guaydier-Souquieres G. Non-invasive methods of bone-mass measurement. Clinical Rheumatology 1989;8 Suppl 2:41-5).

Subjects and Methods

Subjects were recruited from the patient population attending a spinal cord clinic within a university medical center. A total of 71 patients were originally screened for the study. Twenty-five (25) were excluded for various reasons
including heterotrophic ossification, ischemic and other types of non-traumatic paralysis, incomplete demographic information, and incomplete DEXA scan information. This left 37 patients (30 males and 7 females) with a history of traumatic SCI. The patients' ages ranged from 21-71 years. Bone density was measured using DEXA scan. The Lunar DPX (Madison, WI), was used in 97 percent of the tests. Other machines included the Hologic and Excel DEXA.

Patients with heterotrophic ossification and ischemic and non-traumatic paralysis were excluded from the study.

The history was obtained through oral interviews and with a thorough review of the charts of the subjects. The data recorded included age, SCI history, drug history, and DEXA information. The SCI history included the time since injury, the American Spinal Injury Association (ASIA) level, level of the SCI, cause, associated injuries, and extent of SCI (complete or incomplete). Level and completeness of SCI was based on the American Spinal Injury Association (ASIA) classification.

The DEXA scans were performed on the lower spine (L2-L4) and on either the left femoral neck or both, if possible. The standard method was used to measure the bone density of those areas. The reports included the results in g/cm², sex matched young adult comparison (t-score), and sex and age matched comparison (z-score). For this study, the t-score was the preferred method of comparison.

The study was performed looking at the whole group in one set of charts and then just the complete and incomplete injury patients in another. Because
subjects entered the study at different time points after injury and because their pre-injury bone density was unknown, a measure was developed to better reflect the change in bone density with each subject that could be and for group comparisons. It was assumed that the premorbid bone mineral density of the hips and spine were equal.

Analysis

The subjects were first analyzed as a whole group. The 37 subjects included complete and incomplete, paraplegic and tetraplegic, and 30 male and 7 female. The Figure 1, Figure 2 and Figure 3 showed all patients. Over half of the patients showed little to no decrease in spinal bone density when compared to the young adult reference group. Eighteen (18) of the patients (47%) even appeared to have an increase in spinal bone density when compared to young adult reference data. Patient 26 is notable because the patient was on bed rest for the first three years post injury.

Comparing the complete and incomplete L-spine t-scores (Figure 4 and Figure 5), the complete were slightly above the normal, where as the incomplete were on par with the normal scores. The difference would be slight enough to where it could be ignored.

The complete and incomplete hip bone density on the other hand showed that the difference in the complete and incomplete injuries were very slight
(Figure 6 and Figure 7). They were basically the same in terms of average and the graph.

The complete and incomplete hips versus time (Figure 8 and Figure 11) show an entirely different scenario. The complete hips over time show a continual loss of bone density. There is a wide scattering of data, but the trend is still noticeable. The incomplete hips, on the other hand, showed a trend that was slightly upward. There were outliers that hardly lost any bone density at all even very far from the time of injury. It is clear that patients entering SCI were at different levels of bone density. This led to the search for a tool that could be used to better demonstrate comparative bone changes over time.

The patients with multiple DEXAs were transposed onto a graph, Figure 9. Three of the patients showed a decrease of both bone densities, but a more marked one the hips (Patients 2, 3, and 6). Two patients had a rise in L-spine density as hip density decreased (Patients 4 and 5). Two had a rise in hip density as L-spine density decreased (Patients 1 and 7). Three of the patients, though, showed a trend that was completely opposite of the expected one.

This technique is to subtract spine t-score from the hip t-score to reflect the relative change. The trend of the graph is that there is a continued loss over time of bone mineral density of the individual patient’s hip when compared to his or her own spine. This technique is more effective at demonstrating the pattern of the relative bone loss. Figure 10 shows the continued loss trend.
Discussion

Overall, the expected trend showed through the graphs. The trend was shown on most of the graphs that were presented, with the exception of the multiple DEXA graph. The trend appears to be that there is a much greater decrease in the bone density of the hip than of the spine. It is speculated that the reason for this appears to be that there is weight bearing on the spine, whereas the hips of most able bodied spinal cord patients do not experience the weight bearing activities of either an able bodied person or even the spine of a SCI patient. Another analysis examined the comparison of the hip bone density compared to the time spent per week in a standing frame. There was no discernable pattern showing the effects of standing on the hip t-scores. However, our study depended on patient's oral history and included no patients standing even one hour daily—most were only 5 hours per week. A study done by Biering-Sørensen also could not find a positive correlation between standing and bone mineral density (Biering-Sørensen F, Bohr H, Schaadt O. Bone mineral content of the lumbar spine and lower extremities years after spinal cord lesion. Paraplegia 1988;26:293-301.). One study showed that use of prolonged electrically induced cycle training helped increase the hip density, but would immediately disappear after the exercise was stopped (Mohr T, Podenphant J, Biering-Sorensen F, Galbo H, Thamsborg G, Kjaer M. Increased Bone Mineral Density after Prolonged Electrically Induced Cycle Training of Paralyzed Limbs in Spinal Cord Injured Man. Calcified Tissue International, 1997. 61:22-25.).
The multiple DEXA charts showed the trend that was expected for four of the patients and different patterns for the other three. Some of these inconsistencies could be attributed to the studies being performed at multiple sites. Another explanation is that the machines were calibrated differently, which led to the increase in bone density in the patients. An inconsistency of machine, technicians and comparative data could have resulted in skewed data. Another reason that there was such a difference could be the treatment effect on the different patients or also just the inherent differences between patients in their patterns of bone absorption and deposition.

The complete and incomplete comparison makes for a more interesting discussion. With the incomplete SCI patients, there is either some feeling or movement in areas below the level of the injury. The complete patients were ASIA or Frankel A, while the incomplete patients in this study were ASIA or Frankel B and C. There were no ASIA D patients who had the ability to walk. The comparison shows that there is significant difference between both the hips and the spine in the two different groups. There is a "noticeable" difference in the average of the t-score values of the two groups. The patients with incomplete injuries had a lower average for both areas. Perhaps, the additional neural innervation affects the bone density. Electrical stimulation, stimulating muscle use and bone stresses, has been shown to lead to increased bone density and decreased bone loss. One would expect, standing to help retard osteoporosis, but our study does not have enough statistical power to clarify the situation. Goemaere et al found that standing did significantly prevent bone loss at the
femoral shaft (Goemaere S, Van Laere M, De Neve P, and Kaufman J M. Bone Mineral Status in Paraplegic Patients Who Do or Do Not Perform Standing. Osteoporosis International 1994; 4:138-143.). The amount of standing time might have been insufficient to have had a positive effect on the bone mineral density of the hips. Also, there is a chance the historical information was inaccurately given.

Figure 10 showed the expected trend of developing osteoporosis very well. It showed that there was a continued degradation of the hip over time, even when the spine in half the patients continued to get denser. There have been studies that have looked at the hip bone mineral density and found that there is the most bone loss in the first 6 months with stabilization within 12-16 months (Gülçin Demirel, Hürriyet Yılmaz, Nurdan Parker and Selma Önel. Osteoporosis after spinal cord injury. Spinal Cord Injury 1998; 36, 822-825). This data shows the different trend. Ongoing loss is seen. Figure 10 takes into account the hips and spine bone mineral density of each patient. This method compares the hips and spine to each other, therefore factoring in the differences in the bodies of each patient. Since this method does take into account the differences of human bodies, it is the most accurate way of looking at the hip and spine bone mineral density for the purposes of this study. The hip minus spine data shows that there is long term loss of bone mineral density, well after the time when the loss is supposed to level off.

This way this study was conducted posed many problems to obtaining correct, reliable data. DEXA scans were not all performed at the same office, by
the same technician, on the same machine. Therefore, the results are hard to compare due to the different calibrations and technicians. The multiple DEXA chart clearly illustrates the difficulties of using data from a variety of sources. All the tests were performed on a Lunar DEXA machine, but the way the calibrations were performed is what made the difference. There were differences of the comparative data when computing the t-score. At one test site, some middle-aged patients' Z-score was worse than the t-score. National statistics are recommended. However, this indicates the value of comparing the hip and spine of the same patient. While there is the error associated with multiple test sites, it was assumed that the sites were close enough to provide worthwhile data.

The data could also have been affected by medications that were taken by the subjects. According to both chart and oral histories, there were three patients that were who were known to have taken drugs that enhance bone deposition, such as calcium supplements before their DEXA. Eleven subjects took drugs that negatively impacted bone density, such as coumadin or heparin. Five patients took both types of medicines and there were twenty-six that were unknown for their studies. The medicine effects were not taken into account in this study, though. Therefore, the assumption was that the medicines did not affect the bone density enough to take into consideration. There appears to be a worsening of the bone density despite the treatment of some individuals with biphosphates.

The final issue is that despite the finding of significant osteoporosis in the hips of the patients, there was only one incidence of fracture. There is a high
rate of incidence of lower extremity fractures in these patients (Changlai).

Perhaps there was a mentoring effect. This clinic considers evaluation of bone density part of SCI health maintenance. These studies are performed and patients are warned of the potential complications that are common with their injuries. Perhaps counseling and treatment as well as attention to the issue of osteoporosis are factors in the low incidence of fracture. In this setting, patients are educated on causes of fracturing, such as osteoporosis. When osteoporosis is diagnosed with a t-score of -2.0, patients are prescribed medicines to help with the condition, usually biphosphates such as Alendronate Sodium or Risedronate Sodium, and followed up to keep the condition in control. Due to rapid bone loss noted, it is recommended that a DEXA scan be prescribed annually for the first three years. If one does not have an early baseline, back-to-back studies are recommended to follow for the trend. Currently Medicare covers DEXA scans every two years for high risk patients. We recommend a review of the Medicare policy and change to cover one baseline study and annual follow up for three years. If intervention can truly prevent fractures, then benefits of this relatively inexpensive test far outweigh the costs.

A prospective study is needed to corroborate the information found in this study. The prospective study would allow for accurate study of the prophylaxis of standing and medicinal effects. The study should be a double blind with placebo controls.
Hips and Spine T-score, Figure 1

Patients and Months Since Injury

Legend:
- Average L1/L2-L4
- Total Left Hip
Hip and Spine T-score, Figure 2

Patients and Months Since Injury

- Average L1/L2-L4
- Total Left Hip
Hip and Spine T score, Figure 3

Patients and Months Since Injury
Incomplete SCI Patients L-Spine T-scores, Figure 4
Complete Time vs Left Hip, Figure 8

-0.5 0 0.5 1
-2 0 2 4

-3.5 -3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1

Series1
Linear (Series1)
Linear (Series1)

$y = -0.0075x - 1.2963$

$R^2 = 0.2159$
Multiple DEXAs, Figure 9

Months Since Accident and Names

- Lumbar Spine
- Left Hip
Hip minus spine versus time, Figure 10

\[ y = -0.0257x - 1.4355 \]

\[ R^2 = 0.3453 \]
Incomplete Time vs Left Hip, Figure 11

Time from injury, in months

$y = 0.0177x - 3.347$

$R^2 = 0.3548$