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Bone Mineral Density After Spinal Fusion Surgery for Adolescent Idiopathic Scoliosis at a Minimum 20-Year Follow-up

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Abstract

Study Design: A retrospective, long-term follow-up study.
Objective: We investigated the incidence and risk factors for osteopenia at a minimum of 20 years after spinal instrumented fusion for adolescent idiopathic scoliosis (AIS).
Summary of Background Data: Surgically treated AIS patients may be likely to have osteopenia in adulthood because the association between AIS and osteopenia has been well documented. However, the long-term results of AIS surgery on BMD have not been evaluated.
Methods: Twenty-one (19 women; mean age, 45.3 years) of 45 consecutive patients with AIS who underwent spinal instrumented fusion surgery between 1973 and 1994 consented to inclusion in the current analysis. Based on their T scores for bone mineral density (BMD) of the left hip, participants were divided into an osteopenia/osteoporosis group (group P, T score < -1.0) and a normal group (group N, T score $\geqslant -1.0$). Z scores of the left hip were used for analyses of the association between bone mineral status and individual factors.
Results: Eleven participants (52.4%) were categorized into group P. Mean body weight (kg) at survey (46.6 vs. 56.8) and mean body mass index (BMI) at both surgery (17.2 vs. 19.5) and survey (18.7 vs. 23.2) were significantly lower in group P than in group N ($p < .05$). Moreover, body weight at survey (Spearman rank correlation coefficient, $r_S = 0.49$), as well as BMI at both surgery ($r_S = 0.67$) and survey ($r_S = 0.61$) demonstrated positive correlations with the Z-score ($p < .05$).
Conclusion: More than half of the participants had osteopenia or osteoporosis, and both preoperative and postoperative low BMI were risk factors for osteopenia in adulthood.
Level of Evidence: Level IV.

Keywords: Body mass index; Body weight; Bone metabolism; Osteopenia; Osteoporosis

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that affects 2% to 3% of adolescents, mainly peripubertal girls [1]. Although AIS is a multifactorial disease and its primary etiology remains unclear, Li et al. [2] reported, based on their review of the literature, that 20% to 38% of patients with AIS have a bone mineral density (BMD) 2 standard deviations below the mean value in age-matched healthy control subjects during the peripubertal period. Moreover, several follow-up studies conducted up until skeletal maturity have demonstrated that osteopenia in patients with AIS is a persistent phenomenon, and a lower rate of BMD increase has been observed for patients with AIS and osteopenia than for control subjects [2]. Osteopenia weakens the spinal architecture, and although controversy exists, this might be an important risk factor for curve progression [3]. Thus, patients with severe scoliosis who need surgical treatment may be at a greater risk

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for osteopenia or osteoporosis in adulthood. Long-term follow-up studies on spinal instrumented fusion surgery have found that the correction of the radiologic deformity on the coronal plane remains good, with high patient satisfaction and good functional outcomes [4-6]. However, to the our knowledge, no studies have assessed whether osteopenia persists into adulthood for patients with AIS who have undergone spinal instrumented fusion surgery. The purpose of this study was to investigate BMD and risk factors for osteopenia at a minimum of 20 years after spinal instrumented fusion for AIS.

Materials and methods

This study was reviewed and approved by the ethics committee of the Niigata University Graduate School of Medical and Dental Sciences. Data from 45 consecutive patients with AIS who underwent spinal fusion with instrumentation at our hospital between 1973 and 1994 were collected from medical charts and standing radiographs. All of the patients were Japanese. Curve types were classified according to the Lenke classification [7], based on preoperative standing and side-bending radiographs of the whole spine. All 45 patients were invited to participate in the clinical and radiologic examinations of the current study, and 21 patients (46.7%) consented. Six patients (13.3%) responded to our invitation but did not consent because of pregnancy (n = 2), difficulties with child care (n = 1), job pressures (n = 2), or disease (n = 1). The other 18 patients (40%) did not respond to the invitation because of an unknown address (n = 15) or nonresponse to the invitation (n = 3). The study was conducted between May 2015 and December 2015.

After obtaining written consent, each participant completed clinical and radiologic examinations, which included anthropometric measurements, full standing radiographs, BMD and bone metabolism assessments, and health-related quality of life (HRQOL) questionnaires. The loss in body height (BH) resulting from the spinal deformity was calculated using the equation described by Ylikoski [8] (height loss [cm] = $0.0062*\chi + 0.0024*\chi^2$; where χ is the major plus the minor curve magnitude [°]) and was used to compute the corrected BH (cBH). The body mass index (BMI) was calculated by dividing body weight (BW, kg) by the cBH squared (m^2). At the survey, relative BMI (rBMI, %) was calculated as the percentage of age- and sex-matched average BMI in the Japanese population, as researched by the Japanese ministry in 2014 [9].

Because spinal instruments remained in the lumbar vertebrae at the final follow-up in about half of the participants, the BMD of the left hip was assessed using dual-energy x-ray absorptiometry (Hologic Discovery QDR Series Densitometer, Hologic Inc., Bedford, MA). The BMD of the total proximal femur and femoral neck was measured, and the site with a lesser BMD T score was utilized as representing the bone mineral status of the left hip. The T score was defined as the number of standard deviations away from the mean BMD for healthy young adults, and the Z score as the number of standard deviations away from the mean BMD for an age- and sex-matched healthy Asian population. In accordance with World Health Organization (WHO) criteria, osteopenia was defined as a T score between −1.0 and −2.5, and osteoporosis was defined as a T score < −2.5. The measurements were carried out by a trained specialist, and the instrument was regularly checked for functionality with standard modules. To assess bone metabolism, serum levels were measured for procollagen type I N-propeptide (P1NP), a bone formation marker, and tartrate-resistant acid phosphatase 5b (TRACP-5b), a bone resorption marker. The HRQOL at the final follow-up was assessed using the Japanese version of Short Form−36 (SF-36) [10], the Scoliosis Research Society Instrument−22 (SRS-22) [11].

Based on their T-score, participants were divided into two groups. The osteopenia/osteoporosis group (group P) included individuals whose left hip BMD T score was less than −1.0. The normal group (group N) included individuals with a T score greater than or equal to −1.0.

Statistical analysis

Statistical analyses were performed using SPSS software (version 19; IBM Corp., Armonk, NY). Continuous data were expressed as means and ranges. Statistical comparisons between groups P and N were performed using the Mann-Whitney *U* tests for continuous variables and using the χ^2 test or Fisher exact test for categorical variables. Differences between the values before and after surgery were evaluated using Wilcoxon signed-rank tests. The association between bone mineral status and individual factors was evaluated using Spearman rank correlation coefficient (r_S). A p value less than .05 was considered statistically significant.

Results

Demographic data for the 21 participants and 24 nonparticipants are shown in Table 1. There were no significant differences between participants and nonparticipants in the presurvey characteristics. Among the 21 participants, 13 patients (61.9%) were treated using the posterior-only approach with Harrington instrumentation (n = 8), Luque segmental spinal instrumentation (n = 2), or Cotrel-Dubousset (CD) instrumentation (n = 3). Six patients (28.6%) were treated using the anterior-only approach with Dwyer instrumentation (n = 3) or Zielke instrumentation (n = 3). Two patients (9.5%) were treated using the combined anterior-posterior approach with Zielke and Harrington instrumentation (n = 1) or CD instrumentation (n = 1). In 11 patients (52.4%), the posterior spinal instruments were removed at an average of 5.0 years (2−11 years) after the spinal fusion surgery.

The overall outcomes of the 21 participants are summarized in Table 2. The average age and follow-up period were 45.3 years (range, 33−56 years) and 30.2 years (20−39 years), respectively. The average rBMI at survey was 93.5% (75.3%−129.3%) and was significantly lower than was the age- and sex-matched average values of BMI (p = .011). The average BMD, T score, and Z score of the left hip were 0.69 g/