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Longitudinal Pilot Analysis of Radiation Exposure During the Course of Growing Rod Treatment for Early-Onset Scoliosis

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Abstract

Study Design: Retrospective consecutive case series.
Objectives: To estimate the amount of ionizing radiation (IR) exposure in growing rod (GR) surgery for early-onset scoliosis.
Summary of Background Data: There is substantial evidence of the health hazards attributed to IR exposure. However, no studies have estimated the amount of IR exposure in GR surgery.
Materials and Methods: A consecutive single-center series of GR patients were retrospectively reviewed. Of 28 total patients, 24 had a minimum 2-year follow-up and complete records available for analysis. All spine-related IR imaging studies excluding intraoperative fluoroscopy were tabulated and IR estimated based on historical controls in millisieverts (mSv).
Results: Initial x-ray evaluation for scoliosis was performed at a mean age of 4.0 years (range = birth to 9.7). Mean radiographic period was 8.5 years (range = 2.2 to 19.4). There was a statistically significant inverse correlation between patient age at time of initial IR and total mean IR ($p < .05$). Total IR was 3.4 times greater than that of estimated background radiation (2.4 mSv per year). Mean IR before index surgery and during the first postoperative year were 22.41 mSv and 10.78 mSv, respectively. Annual IR after the first postoperative year averaged 7.02 mSv (range = 2.25 to 13.45). Patients who underwent at least one revision surgery experienced significantly higher IR than nonrevision patients (79.95 vs. 46.58 mSv; $p < .05$). Overall, 89% of total IR was attributed to x-rays and 11% from computed tomography.
Conclusions: Compared to the general public, GR patients had 3.4 times more IR than the estimated background radiation for the same duration of time. Younger patients and those requiring revision surgery had significantly higher IR doses. This study underscores the importance of recognizing the amount of IR used in the management of GR patients and its potential long-term risks.
Level of Evidence: III.

Keywords: Early-onset scoliosis; Ionizing radiation exposure; Growing rod technique; Radiographic imaging

Introduction

Health hazards related to ionizing radiation (IR) exposure from medical imaging have been well-reported in the literature [1-7]. Children in particular are at increased risk of carcinogenic effect: they have a longer life expectancy in which to express risk as well as being more sensitive to the effects of ionizing radiation than adults [6]. Numerous epidemiologic cohort studies of childhood exposure to

Institutional Review Board: This study was approved by the IRB at Rady Children's Hospital San Diego before the study's initiation.

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radiation for treatment of benign diseases have demonstrated radiation-related risks of cancer of the thyroid, breast, brain and skin, as well as leukemia, but fewer studies have evaluated risk following diagnostic radiation exposure in children. Bone et al. found that surgically treated scoliosis patients' risks for developing leukemia, breast cancer, or a heritable defect, respectively, were 0.8%, 2.1%, and 3.0% higher than baseline risks and concluded that use of serial radiographs during the treatment of idiopathic scoliosis, hip dysplasia, and leg-length discrepancy appears relatively safe [3]. The increased risk of carcinogenesis or hereditary defects in these patients was minimal. GR surgery with subsequent periodic surgical spinal distractions requires multiple radiographic studies during the course of treatment. The purpose of this study was to quantify radiation exposure (IR) among this group of patients in the hopes to have a better idea of lifetime risk and determine if there are ways to decrease exposure.

Materials and Methods

Patients who underwent GR surgery between 1991 and 2009 were retrospectively reviewed at a single institution. Of 28 patients, 24 patients met the inclusion criteria: 1) were diagnosed with early-onset scoliosis, 2) had undergone GR surgery, 3) had a minimum of 2-year radiographic follow-up, and 3) had complete surgical and radiographic history available for analysis. All x-rays, computed tomographic (CT) scans, and other IR-emitting imaging modalities excluding intraoperative fluoroscopy were tabulated for each patient. Each imaging study was then given an estimated radiation exposure measured in millisieverts (mSv), and a cumulative amount was recorded for each patient.

Per the American College of Radiology–Radiological Society of North America committee on radiation safety, the estimated amount of radiation was based on the average IR exposure (in millisieverts) for any given study for an ''average-size'' adult. The average IR exposure (in millisieverts) for each radiographic study is as follows: spine x-ray, 1.5 mSv; extremity x-ray, 0.001 mSv; chest x-ray, 0.1 mSv; cervical spine CT, 2 mSv; thoracic spine CT, 2 mSv; lumbar spine CT, 2 mSv; and chest CT, 7 mSv. The amount of background radiation exposure per year is estimated at 2.4 mSv, which is the highest average amount for any given location in the United States [8].

Results

Twenty-four patients (8 syndromic, 8 neuromuscular, 6 idiopathic, and 2 congenital) underwent initial x-ray evaluation for scoliosis at a mean age of 4.0 years (range = birth to 9.7 years). Overall, 15 females and 9 males had a mean age at index surgery of 6.7 years (range = 1.7 to 10.8 years). Mean radiographic period was 8.5 years (range = 2.2 to 19.4 years). There was a statistically significant

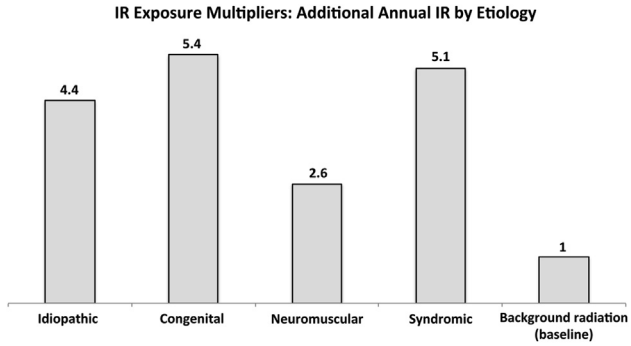

Fig. 1. Additional annual IR exposure for each etiology shown using multipliers from baseline, where baseline is estimated background radiation (×1).

inverse correlation between patient age at time of initial IR and total mean IR ($p < .05$). The greatest IR exposure was before index surgery and during the first postoperative year (22.41 and 10.78 mSv, respectively) and annual IR after the first postoperative year averaged 7.02 mSv (range = 2.25 to 13.45 mSv).

When patients were analyzed by etiology, the total IR from initial spine x-ray to 1 year after index surgery was greatest in congenital patients (63.220 mSv; n = 2), followed by syndromic (34.560 mSv; n = 8), idiopathic (28.590 mSv; n = 6), and neuromuscular (27.769 mSv; n = 8) (Fig. 1). Sixteen of 24 patients underwent at least one revision surgery, and these patients had 1.7 times more IR exposure than nonrevision patients (46.583 vs. 79.953 mSv; $p < .05$). Of the 9 patients who underwent ''final'' spinal fusion, the total mean IR was 36.546 mSv after fusion, with an average annual IR of 7.173 mSv (Fig. 2). Total IR was 3.4 times greater than that of estimated background radiation (2.4 mSv per year) during the radiographic period, and 89% of total IR was attributed to x-rays and 11% from CT (Table).

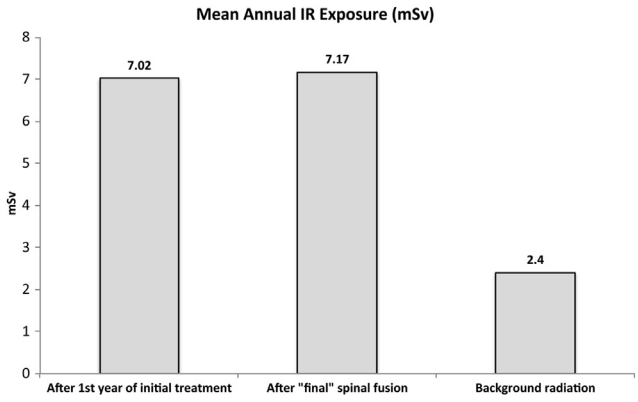

Fig. 2. Mean annual IR exposure after the first year of GR treatment and after ''final'' spinal fusion compared with baseline, where baseline is estimated background radiation (2.4 mSv per year).