Three-dimensional computed tomography in the assessment of congenital scoliosis

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Abstract Objective. Patients with congenital vertebral anomalies frequently are afflicted with kyphoscoliosis, with the curvatures often being severe and progressive. Spinal fusion almost always is the treatment of choice in such patients. This report examines the use of three-dimensional computed tomography (3D CT) in the preoperative investigation of patients with congenital scoliosis.

Design and patients. Twelve spinal CT examinations on 11 pediatric patients with congenital scoliosis underwent image processing to produce 3D images. The 3D images were compared with both the axial sections from the CT examinations and multiplanar reformatations with regard to the detection of malformations liable to cause progression of scoliosis (i.e., hemivertebrae and unsegmented bars).

Results and conclusions. In six of the 12 cases, the 3D images provided improved depiction of the congenital anomalies and their interrelationships compared with planar CT images. This work suggests that 3D CT can be a useful tool in the assessment of patients with congenital scoliosis.

Key words Scoliosis · Computed tomography · Three-dimensional imaging · Spinal anomalies · Spine surgery

Introduction

Congenital scoliosis is defined as lateral spinal curvature secondary to congenital anomalies of vertebrae and their supporting structures. It was first recognized by Winter et al. [1] that scoliosis secondary to certain asymmetric congenital vertebral malformations can have a serious prognosis, resulting in what are often rigid, progressive spinal curvatures that are a difficult management problem for orthopedists compared with idiopathic or neuromuscular spinal curvatures [2]. In patients with progressive congenital scoliosis, conservative treatment is almost never successful, and surgical fusion is the accepted treatment. The goal of fusion is to stop further progression of the curve, as the deformity in such patients is rarely, if ever, amenable to full surgical correction.

The vertebral malformations in congenital scoliosis can be classified as segmentation defects and formation defects. Segmentation defects can be eccentric or symmetric. Eccentric defects take the form of unsegmented bars, which are solid bars of bone fusing the disc spaces and apophyseal joints of two or more vertebral segments on one side of the spine, leaving the other side unaffected. Asymmetric unsegmented bars can be anterolateral, traversing the intervertebral disc between two contiguous vertebral bodies, or posterior, such as pedicle bars. Unsegmented bars have a high correlation with progressive spinal curvatures. Symmetric defects lead to block vertebrae, which do not by themselves lead to progressive curvatures. Formation defects are those anomalies in which one or more of the embryologic precursors of a vertebra is anomalous or absent. Formation defects include hemivertebrae, cleft vertebrae, and derangements of the neural arch which lead to spina bifida. Frequently associated neurologic abnormalities in patients with neural arch formation defects, such as in patients with dia-
stematomyelia and spinal dysraphism, complicate the management of congenital scoliosis. Four different types of hemivertebrae are recognized, differing in their potential to cause progressive spinal curvatures (Fig. 1). Approximately 20% of the anomalies causing congenital kyphoscoliosis are complex or unclassifiable (Fig. 2) [3].

Prompt detection of patients with congenital spinal malformations is crucial in identifying candidates for surgery, as those with anomalies known to have a high potential for causing progressive curvatures are best served by early fusion. Estimation of the potential for curve progression in such patients requires the clinician to identify both the specific anomalies and their interrelationship. Although radiography alone will often suffice to define the anomalies in patients with congenital spinal malformations, especially in younger patients, adequate radiologic evaluation of more complex congenital spinal curvatures has traditionally required either tomography or computed tomography with multiplanar image reformatation. However, the complex three-dimensional nature of many vertebral malformations makes their characterization by planar cross-sectional imaging methods difficult. Based on the usefulness of three-dimensional computed tomography (3D CT) in the evaluation of other abnormalities in the spine [4–6], we have employed this modality in the assessment of the vertebral malformations in pediatric patients with congenital scoliosis.

**Subjects and methods**

Eleven patients with scoliosis in whom radiographs showed that the curvature appeared to be secondary to congenital vertebral anomalies were chosen for this study. These patients all had radiographs deemed insufficient for definitive evaluation of their anomalies by one of the authors, an experienced pediatric orthopedic surgeon. The patients ranged in age from 10 months to 14 years. One of the patients had anomalies in two separate regions of the spine, which were imaged with two noncontiguous sets of axial CT sections during the same session, producing two separate image data sets for 3D reconstruction. Sedation with oral chloral hydrate was administered in accordance with the pediatric conscious sedation protocol of our institution about 1 h before imaging to uncooperative patients in our series, as well as those under 3 years of age.

A GE HighLight Advantage (Milwaukee, Wis.) CT scanner was used exclusively. As helical CT became available during the course of our study, this technique was utilized for only two of the patients in our series. The examinations were all performed without intravenous contrast, and used section thickness of 1 mm or 3 mm spaced every 1 mm or 2 mm respectively (9 patients) or helical 1 mm or 3 mm scanning (2 patients). A targeted field of view centered over the spine was used, with 120–140 kV, 200–340 mA, and 1–2 s scan times. Raw data from the examinations were reconstructed in a soft tissue algorithm to optimize the quality of the 3D images. The axial images from the examinations were also reconstructed in a high-frequency, edge-enhancing bone algorithm, and were used to produce sagittal and coronal reformatted images. An ISG Allegro workstation (ISG Technologies, Toronto, Ontario) was used to generate the 3D images using density threshold seeding. As any voxels on the axial images over the threshold density were in-

**Fig. 1** The four classes of hemivertebrae. Due to the presence of an open intervertebral disc on both sides of the anomaly, segmented and incarcerated hemivertebrae have the greatest potential to cause progressive spinal curvatures.

**Fig. 2** Classification scheme of anomalies in congenital scoliosis. (Adapted with permission from McMaster [3], p. 228)