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Assessment of skeletal maturity in scoliosis patients to determine clinical management: a new classification scheme using distal radius and ulna radiographs

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Abstract

BACKGROUND: Assessment of skeletal maturity in patients with adolescent idiopathic scoliosis (AIS) is important to guide clinical management. Understanding growth peak and cessation is crucial to determine clinical observational intervals, timing to initiate or end bracing therapy, and when to instrument and fuse. The commonly used clinical or radiologic methods to assess skeletal maturity are still deficient in predicting the growth peak and cessation among adolescents, and bone age is too complicated to apply.

PURPOSE: To address these concerns, we describe a new distal radius and ulna (DRU) classification scheme to assess skeletal maturity.

STUDY DESIGN: A prospective study.

PATIENT SAMPLE: One hundred fifty young, female AIS patients with hand x-rays and no previous history of spine surgery from a single institute were assessed.

OUTCOME MEASURES: Radius and ulna plain radiographs, and various anthropomorphic parameters were assessed.

METHODS: We identified various stages of radius and ulna epiphysis maturity, which were graded as R1–R11 for the radius and U1–U9 for the ulna. The bone age, development of sexual characteristics, standing height, sitting height, arm span, radius length, and tibia length were studied prospectively at each stage of these epiphysis changes.

RESULTS: Standing height, sitting height, and arm span growth were at their peak during stages R7 (mean, 11.4 years old) and U5 (mean, 11.0 years old). The long bone growths also demonstrated a common peak at R7 and U5. Cessation of height and arm span growth was noted after stages R10 (mean, 15.6 years old) and U9 (mean, 17.3 years old).

CONCLUSIONS: The new DRU classification is a practical and easy-to-use scheme that can provide skeletal maturation status. This classification scheme provides close relationship with adolescent growth spurt and cessation of growth. This classification may have a tremendous utility in

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improving clinical-decision making in the conservative and operative management of scoliosis patients.

Keywords: Skeletal; Maturity; Classification; Distal; Radius; Spine; Scoliosis; Adolescent

Introduction

Assessment of skeletal growth in children and adolescents is an important tool in managing growth related problems, such as scoliosis, hormonal disorders and in the application of expandable prosthesis in young children with severe deformities [1–4]. Many studies on adolescent idiopathic scoliosis (AIS) further highlight the importance of growth and rapid progression of the curve during the peak of growth spurt [5–9]. The understanding of the patient's growth potential and end-stage, or near end-stage, growth carries an important implication in the prognosis and provides guidance to the treating physician in deciding the treatment modality (eg, observation interval, timing to initiate bracing therapy, cessation of bracing, timing of instrumentation, and fusion).

Clinical or radiologic methods are commonly used to assess the patient's growth potential (eg, menarche age, triradiate cartilage fusion, Risser's sign) [10]. However, most of these measures have their own deficits and are not able to directly indicate the peak growth spurt or when the growth has ended. Although the measurements of standing height or arm span directly measure growth, they require few serial follow-ups to determine growth trends. Though digital skeletal age assessment using the Tanner and Whitehouse (TW3) [11–13] or the Greulich and Pyle [14] methods have improved the assessment accuracy of the patient's skeletal maturity, these techniques are time-consuming and difficult to use in the outpatient clinical setting.

Sanders et al. [15] reported the close relationship of peak height velocity (PHV) to various stages of finger epiphysis maturation according to the TW3 method. The authors noted that the PHV occurred at early adolescents and that the start of menarche and the Risser sign appear after the peak of adolescent growth spurt. However, the authors claimed that distal radius and ulna (DRU) epiphysis were found to have the least correlation with growth. These stages of DRU in the TW3 method were originally designed to be used in combination with the epiphysis of the finger phalanges and its use alone in predicting growth spurt may not be accurate because of the wide interval between each stage.

Because the DRU physes progression spans the whole period of skeletal growth and is the last one to close, we want to refine the TW3 classification and see whether it can be used in isolation. The following descriptive study addressed a new and practical classification scheme to assess skeletal maturity in early adolescents by utilizing a modified TW3 method for the radius and ulna. Based on this new classification, known as the DRU classification scheme, we further assessed its utility in relation with common clinical growth parameters, such as standing height, sitting height, arm span, menarche age, bone age, and long bone growth of the radius and tibia.

Methods

Based on prospective anthropometry records of scoliosis patients at the Duchess of Kent Children's Hospital, Pokfulam, Hong Kong, between 1975 and 2000, we studied the DRU epiphysis radiologic morphology and the relationship of our new classification with growth trend among female Chinese AIS patients. The exclusion criteria were patients who were male, had undergone surgical treatment for scoliosis, had less than 4 years of follow-up, were older than 17 years of age, incomplete data (missing hand x-ray, data form), and scoliosis with secondary causes.

All cases included in this study had spine and left hand wrist x-rays taken during each visit. Biometric measurement, such as standing height, sitting height, arm span, radial length, and tibial length, was recorded. The radial length was taken with the elbow in 90° flexion and rested on a table, and the length between the radial head and radius styloid process was measured. While in the sitting position, tibial length was assessed as the as length between the medial tibial joint line and medial maleolus. In addition, all patients also had records on their menarche age, the development of the breast according to the four-stage scale described by Reed and Stuart [16]; the rating of development of the pubic hair was made following the five-stage scale by Reynolds and Wines [17]. A bone age assessment was performed according to the method described by Greulich and Pyle [14]. Scoliosis curve types and alignments (based on the Cobb's angle) were determined based on posteroanterior standing radiographs. Radiographic measurements were in millimeters and were obtained using a DICOM based Radworks 5.1 (Applicare Medical Imaging BV, Zeist, The Netherlands) computer software program. Two individuals (LBS, SG) conducted the radiographic data assessment and on two separate occasions. Our new classification for DRU radiologic morphology (DRU classification) is illustrated in Table 1 and based on clinical observation. Because the aim of the study was to assess skeletal changes at early adolescents, our study focused on radius stages R5 to R11 and ulna stages U2 to U9.

Because records were taken as part of the clinical follow-up for AIS patients, the interval of follow-up varied; the younger patients had follow-up between 3 and 6 months, whereas an older child may have had a longer