Health, Sports & Rehabilitation Medicine
Vol. 20, no. 4, October-December 2019, 179–183

REVIEWS

Evaluation methods in idiopathic scoliosis

Adriana Zaharia[1], Alina Iliescu[2], Mihai Berteanu[3]
[1] *PhD Student, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania*
[2] *"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania*
[3] *"Carol Davila"University of Medicine and Pharmacy, Bucharest, "Elias" Emergency University Hospital Bucharest, Romania*

Abstract

Idiopathic scoliosis evaluation remains a challenge for both the clinician and the patient for the entire period of morphological changes related to pubertal growth. Traditionally, idiopathic scoliosis evaluation and monitoring involves repeated exposure to X-rays, which can increase the risk of cancer in children. To reduce the consequences on human health, modern computer technology has developed non-invasive methods to monitor the evolution of scoliosis, such as raster-stereography, computerized photogrammetry and ultrasonography.

The aim of the study is to identify, on the one hand, the methods of diagnosis and evaluation of scoliosis and, on the other hand, to present the advantages and disadvantages of each method, so that the clinician can establish an accurate diagnosis and risk-free monitoring over time.

Keywords: evaluation, raster-stereography, computerized photogrammetry, ultrasonography.

Introduction

Idiopathic scoliosis is an evolutive disease, characterized by a three-dimensional torsional deformation of the spine and trunk (Grivas et al., 2006), of multifactorial etiology, which has not yet been elucidated. The main diagnostic criterion is the deviation of the spine in the frontal plane with a minimum of 10° (Cobb, 1948 cited by Weiss, 2015), accompanied by the vertebral rotation (Lam et al., 2008), observable on the X-ray, of the spine. Due to its evolutive nature, scoliosis requires careful monitoring, especially during the period of maximum vulnerability of the spine to deformation, more precisely during the period of pubertal growth spurt. Both the diagnosis and the follow-up of scoliosis are based on clinical and radiological examination.

The aim of the study was to identify, on the one hand, the methods of diagnosis and evaluation of scoliosis and, on the other hand, to present the advantages and disadvantages of each method, so that the clinician can establish an accurate diagnosis and risk-free monitoring over time.

We classified the methods of diagnosis and evaluation of scoliosis as irradiating radiological options and non-irradiating non-radiological options.

Irradiating radiological methods

a) Spine X-ray

Cobb angle measurement on spine radiographs, performed in orthostatism, is currently presented as the gold standard in the diagnosis of scoliosis (Cobb, 1948).

The Cobb angle is determined manually by means of a goniometer and represents the angle formed at the intersection of the parallel lines drawn at the edge of the upper and lower plateau of the most inclined vertebrae of the scoliotic curvature (Katz et al., 1998).

Radiological evaluation usually involves two planes: posteroanterior (PA) and lateral, allowing assessment of both the Cobb scoliosis angle and the sagittal profile expressed by the kyphosis angle, the lordosis angle respectively, also with relevance in assessing the evolution of spinal deformity (Carreiro, 2009a).

Another essential parameter in the prognosis of the curvature and the monitoring of scoliotic evolution is vertebral rotation (Pinheiro et al., 2010), measured on the posteroanterior radiograph by various methods - Nash & Moe scale (Lam et al., 2008), Perdriolle method (Lam et al., 2008), or with the Raimondi "rule" (Weiss, 1995).

The rib-vertebra angle on frontal plane radiographs is a very important measurement as a prognostic factor allowing the examiner to distinguish between evolving and resolving scoliosis (Mehta, 1972).

The Risser sign constitutes a further parameter for radiographic evaluation and is useful in indicating the patient's growth status (Shuren et al., 1992).

The method, however, has significant risks. In order to obtain a "full spine" image, two (digital) radiographs are assembled together, in fact a double exposure.

Received: 2019, September 14; *Accepted for publication:* 2019, September 28
Address for correspondence: "Carol Davila" University of Medicine and Pharmacy, Bucharest. Department of Medical Rehabilitation, Dionisie Lupu Street, no. 37, Sector 2, Bucharest, Romania
E-mail: adizaharia@gmail.com
Corresponding author: Adriana Zaharia; adizaharia@gmail.com
https://doi.org/10.26659/pm3.2019.20.4.179

In addition, in order to monitor the progression of scoliosis, patients undergo periodic radiographic examination (Kim et al., 2010), sometimes requiring approximately 25 X-ray exposures during the growth period (Coelho et al., 2013), which increases the risk of cancer in children by 2.4/1000 (Levy et al., 1996).

Cancer rates are higher for breast, lung, and ovarian cancers (Nash et al., 1979).

The age of the patient at the time of exposure is also critical (Levy et al., 1996).

Due to these factors, the radiographic irradiation technique is important.

Posteroanterior radiography and the use of a protective shield have been recommended to avoid direct exposure of the breasts and genitals (Gray et al., 1983).

Breast cancer rates are only 1/3 in patients who undergo PA radiography compared to those who have been exposed to anteroposterior radiography (Ronckers et al., 2010).

b) Low radiation EOS imaging system

A solution with a reduction of radiation to at least half up to one third of the radiation dose used for general computerized X-ray imaging is the low radiation EOS imaging system which performs a "scan of the child standing, showing the actual anthropometric parameters of the child, who supports his weight - which allows to visualize the interaction between the joints and the rest of the musculoskeletal system, especially the spine, hips and lower limbs" (Mahboub-Ahari et al., 2016).

This scanning technology can simultaneously take anterior and posterior radiographs and lateral radiographs of the spine, allowing the entire body to be viewed in a single image, without the need to assemble multiple images together. This gives an accurate picture of the musculoskeletal system, which is essential for planning diagnosis and treatment.

Scanning is performed in about 15-20 seconds, and the scanned images are immediately displayed in both two-dimensional and three-dimensional form (1).

The system also has the option of reducing the dose from low-dose to ultra-low-dose radiation, resulting in a reduction of radiation of up to 1/6 - 1/9 of the standard X-ray dose (Deschenes et al., 2010).

However, it remains an exposure to radiation, the effects of which have already been stated.

It should also be considered that the cost of a scan is much higher than the cost of a traditional X-ray film, as well as that, being an AP exposure, the radiation dose varies considerably in comparison with posteroanterior exposure.

To these disadvantages, the high cost of acquisition is added, which makes the application of EOS technology inaccessible in the vast majority of countries, including Romania. X-ray imaging in the form of classical radiography remains the routine practice (Mahboub-Ahari et al., 2016).

Non-irradiating non-radiological methods

a) Instrumental: the clinical-scoliometric method

Starting from the bend forward test, called Adam's test, used to detect back asymmetry or the presence of a gibbosity, the rotation angle of the trunk could be measured using a scoliometer or an inclinometer (Carreiro, 2009b).

The scoliometer is an evaluation tool that has proven highly useful.

Scoliometer measurements showed a good correlation with radiographic measurements (Coelho et al., 2013).

As the first non-invasive and non-irradiating method, the method is used primarily in screening, justifying the execution of posteroanterior and lateral radiography in standing position for a more accurate assessment of the curvature, when the scoliometer indicates an angle of 7 degrees or more (Grosso et al., 2002; De Wilde et al., 1998).

This method has the advantage that it can be used by general practitioners, and Adam's test is widely used in the school community and among all people that are engaged in the health of children (including parents).

b) MRI imaging

Examination of the scoliotic spine by magnetic resonance imaging provides valuable information because it includes the spinal cord, soft paravertebral tissue, and allows visualization of the intervertebral discs.

Recently, studies have shown that the intervertebral disc is more involved in scoliotic deformation than the morphological alteration of the vertebra (Schlösser et al., 2014).

The disadvantages of this method are given, on the one hand, by the position in which this technique is performed, with the patient in dorsal decubitus, the deformation attenuating with the loss of gravitational forces (Knott et al., 2010), an axial loading being required to recreate this force and to provide similar images to standing radiographs, and, on the other hand, by the significantly higher cost and routine issues.

Computerized methods

Non-irradiating computerized methods have been developed as a result of algorithms used to automatically extract useful information from images. The most widespread method of investigating the anatomy of the surface body is surface topography (Komeili et al., 2015). This type of analysis came from photographic images in combination with the technique of marking anatomical landmarks. Specific software programs extract information obtained from 2D image sequences, which are subjected to qualitative and quantitative analysis leading to the collection of 3D information.

As forms of controlled energy projected on the surface of interest, both light and ultrasound were used. Thus, on the one hand, stereography was born and, on the other hand, ultrasonography, as a result of echo detection (Aroeira et al., 2016).

a) Raster-stereography

Raster-stereography is a non-invasive, non-irradiating method that performs a three-dimensional reconstruction of the surface of the back and of the vertebral spine based on optical-topographic measurements of the back, based on the "photogrammetric" concept and the "triangulation method" (Drerup, 2014), with automatic detection of anatomical landmarks.

The surface of the human body reflects to a certain extent the "spatial arrangement of the skeletal structures" that are the basis, and the sensitive changes of the body surface reflect changes in the skeletal system.

Raster-stereography has been proven to be a valid and reliable technique (Betsch et al., 2011), of high accuracy for analyzing the shape of surfaces (Knott et al., 2016).

However, it is less accurate than X-ray, because the spinal deformity is evaluated indirectly, from measurements of the surface of the back.

Raster-stereography as a non-invasive method can be a complementary and intermittent alternative method for X-ray examination - without replacing it, but only making its use less frequent. It allows to monitor scoliotic evolution and aesthetic appearance, in fact a priority for the patient (Zaharia et al., 2017).

b) Computerized photogrammetry

The computerized photogrammetric method, with wide applicability in fields such as cartography, architecture, engineering, has also been used for the control of quality and three-dimensional evaluation (Lillesand & Kiefer, 2000), as a new method for non-radiological evaluation of scoliosis (Aroeira et al., 2011).

Predominantly used in clinical practice for postural evaluation, photogrammetry also performs the assessment of the spine curvature by calculating the angle between two points on the spine (Carman et al., 1990). Thus, the angle of scoliosis is determined by joining the spinous processes in the patient in orthostatic position and subsequently measuring the amplitude of the curve formed, with the possibility of making measurements in both the frontal and sagittal plane.

The angle of scoliosis calculated by photogrammetry is not the same as the Cobb angle, the latter being measured according to the vertebral body and not according to the spinous process (D'Osualdo et al., 2002).

Studies have shown the "reliability" (Saad et al., 2009) of the method, and it has been "validated" (Letafatkar et al., 2011; Leroux et al., 2000) as an intermittent alternative method for radiation exposure, allowing non-invasive postural evaluation.

Nevertheless, "the real applicability of this method is questionable, as it remains unclear how this technique is used to monitor postural treatment" (Furlanetto et al., 2012).

c) Ultrasonographic evaluation

With the identification of vertebral bone structures such as the spinous and transverse processes, ultrasonography has opened the possibility of using ultrasound for non-invasive evaluation of the spine (Suzuki et al., 1989; Wang et al., 2015; Nguyen et al., 2015).

Using this method, the spine is scanned between T1-S1 with a linear ultrasound probe (frequency 7.5-12 MHz), equipped with a sensor to detect the position and orientation of the probe (Brink et al., 2018). The scan is performed in maximum 30 seconds, and the software allows both manual measurement of scoliotic parameters and automatic measurement, both methods being "intra- and inter-evaluator reliable, where intra-evaluator has to do with the image acquired/analyzed by the same evaluator and inter-evaluator with the image acquired/analyzed by different evaluators" (Zhou et al., 2017).

Based on the precisely identified landmarks (the spinous process and the transverse process), the scoliosis angle was calculated, which was found to have "strong linear correlations with the Cobb angle" (Zhou et al., 2017).

The data obtained by scanning, together with information on the position and orientation of the probe, are used by the analysis software to reconstruct the 3D model of the spine to measure axial rotation and deformation in the coronal and sagittal planes (Zhou et al., 2017).

The method has multiple applications:

- the possibility of evaluating the spine from different bending positions, right-left (He et al., 2017), from the seated or bent position (Jiang et al., 2018);
- evaluation of the flexibility of the spine from different positions (a) upright position (b) dorsal decubitus (c) ventral decubitus (d) sitting position (e) ventral bending (He et al., 2017);
- allows multiple scans as well as widening of the examined field, including the paravertebral musculature and ribs (Zheng et al., 2016);
- used in pre- and post-surgery monitoring (Zheng et al., 2016);
- therapeutic evaluation of the corset by examination before and after applying the corset (Zheng et al., 2016);
- used in screening and monitoring of scoliosis (Brink et al., 2018).

From the point of view of non-irradiating and non-invasive performances, of repeatability and multiple applicability in the evaluation of the spine, of information about spinal rotation, of muscles and of three-dimensional information, but also from the point of view of the lower operating costs, the method prevails over the other complementary methods (2).

The method is "feasible", although it tends to underestimate the scoliotic curve (Cheung et al., 2015).

Conclusions

1. School screening programs are recommended for the early diagnosis of idiopathic scoliosis; Adam's test should be performed for scoliosis screening purposes, using a scoliometer.
2. It is necessary to obtain an initial radiographic image that can show the vertebral morphology and the parameters to evaluate.
3. Radiological exposure should be posteroanterior rather than anteroposterior in order to reduce irradiation of breast tissue.
4. It can be considered a complementary monitoring method that can be used in the long term.
5. The patient should be evaluated by the complementary method at the same visit when the initial radiograph is also recommended, so that a comparison of the two methods can be made.
6. Follow-up can be first performed with a non-radiographic or a low-dose radiographic method, using a traditional radiograph only in the presence of a considerable change in deformity.
7. Attention will be given to imaging examination, especially when using an indirect method, such as surface topography.
8. Monitoring at shorter time intervals is recommended in order to capture changes in vertebral deformity over time.

Conflicts of interest

No conflict of interest and nothing to declare.

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