The validity of rasterstereography: a systematic review

Melvin Mohokum,1 Samuel Schülein,2 Adrian Skwara3
1Fachhochschule für Gesundheit, Gera;
2Geriatrics Center Erlangen, Waldkrankenhaus St. Marien, Erlangen;
3Orthopädische Gemeinschaftspraxis Borken, Germany

Abstract

To investigate and monitor the progression of scoliosis and other spinal deformities in patients following idiopathic scoliosis (IS), non-invasive and radiation-free techniques are recommended because of the need for repeated radiographs. In a clinical setting, spine parameters can be quickly, cheaply and easily assessed using rasterstereography (RS). To assess the validity of the radiation-free technique RS based on surface topography compared with radiographs. MEDLINE, the Cochrane Library and EMBASE were systematically searched for studies which investigate the validity of rasterstereography compared with x-ray measurements. Studies published between January 1, 1990 and July 31, 2013 in English, German and French were included. Studies dealing with magnetic resonance imaging were excluded. Twelve studies with 570 patients were included; these articles were published between 1990 and 2013. The majority of studies investigated patients with IS, but other spinal pathologies included were thoracic hyperkyphosis and Scheuermann’s disease. With regard to the quality assessment criteria for the included studies, three out of twelve studies were evaluated using a twelve point scale and two used a scale with eleven points. We conclude that RS facilitates clinical practice by analysing the spinal column. It is completely radiation-free and could help to monitor scoliosis progression.

Introduction

Various subjective and objective methods have been developed to analyze and quantify scoliosis and other spinal deformities.1-5 To evaluate the degree of deformity in the diagnosis and treatment of scoliosis and other spinal deformities examinations such as roentgenograms or computed tomography are frequently used.6,7 The use of two-dimensional anterior-posterior (a.p.) full-length spine radiologic investigation is accepted as the mainstay to attest the medical diagnosis of idiopathic scoliosis, despite providing data only in two dimensions.8 The obvious disadvantage of such instrumental assessment method is the fear of increased carcinogenic risk and infertility from repeated exposure to ionizing radiation.9-12

The reason for the repeated radiographs is the requirement to measure the type, the flexibility and progression of the spinal curvatures in follow-up examinations in definite time intervals, which is obtained from two-dimensional a.p. spine radiographs.4 In the study of Nash and colleagues teenage girls with idiopathic scoliosis received over a treatment period of three years 22 roentgenograms.11 One alternative examination suitable for this purpose is the light-sectioning method rasterstereography (RS), which is a precise, radiation-free and inexpensive and that is in routine clinical use in many scoliosis centers throughout the world.13 The method, which was developed by Drrerp and Hierholzer in the 1980s, has been confirmed to be reliable both in pre- and postsurgical scoliosis patients for supplementing radiological and clinical examinations.14-18 By detecting anatomical landmarks with characteristic shape parameters - the vertebra prominens and the two spina iliaca posterior superior – coordinate data of back surface points and the line of symmetry can be determined.19 RS provides a reliable method for three-dimensional back shape analysis and reconstruction of spinal deformities.20-21 Several studies have evaluated the validity of RS compared with X-ray.22-25 Therefore, the aim of the present research was to evaluate the validity and accuracy of RS compared with X-ray in a systematic literature review.

Inclusion criteria and study identification

A systematic review of the literature was conducted in July 2013 using the PubMed data base of the National Library of Medicine, Embase and the Cochrane library for relevant trials indexed between January 1, 1990, and July 31, 2013. To be included in the literature review, articles had to meet the following criteria: i) original studies that investigated the validity of RS compared with X-ray measurement and II) published between January 1, 1990, and July 31, 2013, in the English, French or German language. The following search items were used: rasterstereography, rasterstereographic AND X-ray, rasterstereography OR rasterstereographic. Studies were also excluded if they lacked standard X-ray measurement of the spine, e.g. MR tomography or a lack of evaluation of spine parameters or if they analysis of difference in leg length or pelvic obliquity.

Those papers satisfying these criteria were retrieved and included in the review.

Data abstraction

An abstraction form was created. Data were extracted independently on the basis of their full text by one reviewer, and verified by a second. The reviewers were not blinded to the journal or the author’s name. The accuracy of the data abstraction was randomly confirmed in 10% of cases by the initial reviewer, as well as the second reviewer. The data abstraction form included: author’s name, year of publication, investigated parameters, study population, x-ray measurement, statistical methods, outcomes and the QUADAS tool.

Methodological quality assessment

The studies included in this review were independently appraised for quality by two authors using the I4-item QUADAS appraisal...
tool. It was developed to assess the diagnostic accuracy of primary diagnostic studies used in systematic reviews.

Using this tool, two reviewers (MM and SS) independently assessed the methodological quality of each included paper. Any disagreement in respect of study eligibility, data extraction or methodological quality assessment was settled through discussion between the reviewers. If no agreement was reached, a third reviewer (AS) acted as an adjudicator to determine the consensus.

**Study identification**

An appropriate search strategy was constructed to ensure that all relevant trials published during the study period were identified (Table 1). A total of 62 citations were identified through the literature search. All full-text articles were assessed for eligibility. Twelve studies were included in the review after this procedure (Figure 1).

**Investigated parameters**

The vertebral rotation was measured radiographically in nine studies out of the twelve investigated and compared with the rasterstereographic surface rotation respectively. The lateral deviation was the second most frequent parameter mentioned in three out of four studies by Hackenberg et al. with five mentions altogether. Kyphotic angle and lumbar lordosis were investigated triply. Torso overhang, apex height, lumbar lordosis, and thoracic scoliosis were assessed once by Crawford et al. and once by Weiss et al.

Table 2. Parameters investigated in the primary studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Vertebral rotation (surface)</th>
<th>Cobb angle</th>
<th>Torso overhang</th>
<th>Pelvic balance</th>
<th>Lateral deviation of spine</th>
<th>Kyphosis angle</th>
<th>Lumbar lordosis angle</th>
<th>Thoracic scoliosis</th>
<th>Apex height</th>
<th>Lumbar scoliosis</th>
<th>Total</th>
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<tbody>
<tr>
<td>Drerup et al.</td>
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<td>Lijenqvist et al.</td>
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<td>Hackenberg et al.</td>
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<td>Hackenberg et al.</td>
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<td>Hackenberg et al.</td>
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<td>Schulte et al.</td>
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<td>Weiss et al.</td>
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<td>Crawford et al.</td>
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<td>Feric et al.</td>
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<td>Mangone et al.</td>
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<td>Total</td>
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*According to Stagnara; via modified Cobb method; via Raimondi method.
Table 3. Study population, X-ray measurement and statistical methods.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study population</th>
<th>X-ray measurement</th>
<th>Statistical methods</th>
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</thead>
<tbody>
<tr>
<td>Drerup et al.</td>
<td>113 patients with Cobb angles below 52 degrees</td>
<td>Anterior-posterior radiographs</td>
<td>RMS, standard deviation</td>
</tr>
<tr>
<td>Liljenqvist et al.</td>
<td>35 patients with idiopathic scoliosis or scoliotic posture and 18 patients with thoracic hyperkyphosis and Scheuermann's disease</td>
<td>Anterior-posterior radiography in standing posture, vertebral rotation according to Perdriolle 197937</td>
<td>RMS, mean</td>
</tr>
<tr>
<td>Hackenberg et al.</td>
<td>31 patients with thoracic, thoracolumbar and lumbar idiopathic scoliosis</td>
<td>Anterior-posterior radiography in standing posture, sagittal curvature according to Cobb 1948 and vertebral rotation according to Perdriolle 197937</td>
<td>Wilcoxon sign rank test, mean, standard deviation, minimum, maximum</td>
</tr>
<tr>
<td>Hackenberg et al.</td>
<td>25 patients with severe idiopathic scoliosis (Cobb angle of 57° on average)</td>
<td>Standard anterior-posterior radiographs were digitized according to Drerup14,15</td>
<td>RMS</td>
</tr>
<tr>
<td>Hackenberg et al.</td>
<td>52 patients with thoracic, thoracolumbar and lumbar idiopathic scoliosis</td>
<td>Anterior-posterior radiography in standing posture, digitized according to the method of Drerup14,15</td>
<td>RMS</td>
</tr>
<tr>
<td>Hackenberg et al.</td>
<td>25 patients with idiopathic scoliosis</td>
<td>Anterior-posterior radiography in relaxed standing posture, digitized according to the method of Drerup14,15</td>
<td>RMS</td>
</tr>
<tr>
<td>Schulte et al.</td>
<td>43 patients with idiopathic scoliosis</td>
<td>Digital radiometric rotation according to Drerup anterior-posterior radiographs, relaxed standing posture8,6</td>
<td>Wilcoxon sign rank test, mean, median, minimum, maximum, standard deviation</td>
</tr>
<tr>
<td>Schulte et al.</td>
<td>16 patients with idiopathic right convex scoliosis</td>
<td>Radiographs digitized in accordance with Drerup's method14,15</td>
<td>RMS, maximum, correlation coefficient r2</td>
</tr>
<tr>
<td>Weiss et al.</td>
<td>53 patients (26 with Scheuermann's disease, 3 with thoracolumbar kyphosis, 15 with idiopathic kyphosis, 9 with kyphosis other origin)</td>
<td>Lateral X-ray</td>
<td>Mean, standard deviation, Pearson correlation, t-test,</td>
</tr>
<tr>
<td>Crawford et al.</td>
<td>10 patients prepared for lumbar spine surgery</td>
<td>Relaxed clavicle position with hands placed over ipsilateral clavicles, standardized erect X-ray positioning guide, lordotic angle via the modified Cobb-method using the superior endplates of L1 and S1 for reference</td>
<td>Nonparametric correlation coefficient Spearman's rho, mean, standard deviation, coefficient of variations</td>
</tr>
<tr>
<td>Freerich et al.</td>
<td>64 patients with adolescent idiopathic scoliosis (AIS), Cobb angle between 10-50 degrees</td>
<td>Standard anterior-posterior radiograph</td>
<td>Correlation coefficient, average difference, range of difference</td>
</tr>
<tr>
<td>Mangone et al.</td>
<td>25 patients with diagnosis of AIS</td>
<td>Vertebral rotation (Raimondi method regolo)10</td>
<td>Kolmogorov-Smirnov test, one way ANOVA, intra-class-correlation coefficient (ICC), paired t-test, Spearman's correlation coefficient by rank (rs)</td>
</tr>
</tbody>
</table>

Total: 570 patients

SD, Standard deviation; RMS, root mean square.

Discussion

Our systematic review of twelve studies evaluating the validity of an instrument used to measure vertebral rotation accuracy of this method varied. Liljenqvist investigated the highest number of parameters in their study (Table 3).25

Weiss et al. studied four out of 14 possible points (Table 3).282933

Frerich et al. produced differences between papers.30

The studies produced different results. The highest RMS for vertebral rotation was measured at 7.9 degrees. Smaller values were found by Hackenberg et al. and Crawford et al.2224 Crawford et al.2234 illustrated that non-significant association between the two methods was produced and significant differences were found by Hackenberg et al. These two methods were the only ones whose determined vertebral rotation using the Perdriolle method. Table 3.

Study outcomes

The root mean square (RMS) was used for data evaluation in six studies. Mean values were also evaluated for statistical comparison of the parameters (Table 3).2122232425

Comparing the results of our study with the two methods, we found that the highest RMS for vertebral rotation was measured at 7.9 degrees. Smaller values were found by Hackenberg et al. and Crawford et al. These two methods were the only ones whose determined vertebral rotation using the Perdriolle method. Table 3.

X-ray methods

All studies investigated vertebral rotation in standing posture. hackenberg et al.

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Comparing the results of our study with the two methods, we found that the highest RMS for vertebral rotation was measured at 7.9 degrees. Smaller values were found by Hackenberg et al. and Crawford et al. These two methods were the only ones whose determined vertebral rotation using the Perdriolle method. Table 3.
Table 4. Comparison between x-ray measurement and rasterstereography.

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drerup et al.34</td>
<td>RMS deviation of the spinal midline (frontal) 3.6 mm (4.6 mm), RMS deviation of rotation 2,7 degrees (3.1°), SD of lateral curve amplitude 4.0 mm, SD of rotation amplitude 2.5, difference in apex height -1.6 mm (2.1 mm), SD of Cobb angle 7.9°.</td>
</tr>
<tr>
<td>Liljenqvist et al.25</td>
<td>Cobb angle: double-major scoliosis upper curvature 7.1° RMS, lower curvature 8.2°, thoracic scoliosis 7.8° RMS, thoracic and lumbar scoliosis 6.9° RMS. Thoracic cm. Rotation of apical vertebra on average 7.9° RMS (depends on type of scoliosis).</td>
</tr>
<tr>
<td>Radiography</td>
<td>Average RMS difference of the spinal midline (frontal) 3.5° RMS, RMS deviation of rotation 2.7° RMS, Cobb angle 4.8° RMS. Above results without correction of rounding soft tissue and overlying subcutaneous tissue that may affect the evaluation of parameters related to the internal morphology e.g. the surrounding soft tissue rotates less than the spine itself. In contrast, radiographic measures are derived directly from the internal morphology and consider variability of the spine.32,40</td>
</tr>
<tr>
<td>Crawford et al.40</td>
<td>Lumbar lordosis radiography at baseline mean 56.4°, SD 10.7° preoperatively, mean 53.5°, SD 12.1° six week follow-up. Lumbar lordosis rasterstereography baseline mean preoperatively 46.2°, SD 10.2°, follow-up 43.1°, SD 10.1°. Lumbar lordosis average difference 9.40 degrees, range of difference 0-22, r=0.758 Thoracic curve average difference 7.00 degrees, range of difference 0-19, r=0.872, Thoracic kyphosis average difference 10.6 degrees, range of difference 1-24, r=0.799, Lumbar lordosis average difference 8 degrees, range of difference 0-21, r=0.813</td>
</tr>
<tr>
<td>Mangone et al.32</td>
<td>Ventral rotation (VR) by x-ray mean 9.93, SD 5.38, mean by RS 4.99, SD 3.50, t-test significant (t=10.48, P&lt;0.0001). Lumbar VR by x-ray mean ± SD 9.18, SD 3.33, by RS mean 5.52, SD 3.01. Thoracic VR by x-ray mean 10.8, SD 5.90, by RS mean 4.82, SD 3.65. r=0.52 entire spine, r=0.47, Cobb angle &lt;30° (subgroup) r=0.42, Cobb angle &gt;30° (subgroup) r=0.30 lumbar ventral rotation (subgroup)</td>
</tr>
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</table>

SD, Standard deviation; RMS, root mean square.
methods. Useful and suitable methods, in addition to mean values, standard deviation, scattering etc., would be a continuous evaluation of the correlation coefficient (e.g., Pearson) and the RMS. Ideally, in diagnostic studies involving rasterstereography, i.e., during an evaluation if the method appropriately detects spinal disorders according to current standards, a statement about the sensitivity and specificity should be made. Questions about influential factors such as the thickness of skin folds, body weight, body height, scars, etc., should be systematically included in further study designs.

Conclusions

Rasterstereography facilitates clinical practice by examining the spinal column. Further, it is completely radiation free and could help to monitor scoliosis progression. It can be used for screening examinations as well as for follow-ups and a diagnostic method for spinal scoliosis.

References