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OUR FURTHER EXPERIENCE REGARDING THE USE OF RASTERSTEREOGRAPHY IN ANALYZING IDIOPATHIC SCOLIOSES

Adriana ZAHARIA[1], Liliana PĂDURE[1,2], Camelia CIOBOTARU[3,4], Steliana POPESCU[3,4], George VISCOPOLEANU[5], Cristian STOICA[2,5] and Gelu ONOSE[2,6]

[1] "Dr. Nicolae Robănescu" National Clinic Center for Neuropsychomotor Rehabilitation in Children, Bucharest, Romania
[2] "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
[3] "Sfântul Apostol Andrei" Emergency Hospital, Constanta, Romania
[4] "Ovidius" University, Faculty of Medicine, Constanta, Romania
[5] "Foişor" Teaching Hospital for Orthopedics – Traumatology and Osteoarticular Tuberculosis, Bucharest, Romania
[6] "Bagdasar-Arseni" Teaching Emergency Hospital, Bucharest, Romania
Corresponding author: Gelu Onose, E-mail: geluonose@gmail.com

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This paper aims, on one hand, to further, in detail, present the main related parameters assessed by gold standard: radiological *vs.* raster stereographic ones, in children with Idiopathic Scoliosis. The assessed parameters were: lateral deviation of the spine, main apex curvature deviation, vertebral rotation, pelvic obliquity, kyphosis and lordosis, angles and adding for vertebral rotation: the Raimondi scale all in order to establish an as accurate as possible correspondence between the results obtained through the Nash-Moe radiological scale grades, the ordinal values provided by raster stereography and respectively, the primary data obtained by measuring with the Raimondi dedicated slide ruler. This further research endeavor completes our previous, preliminary results [obtained on the study including 11 children, aged between 9–13 years – with the calculated correlation coefficients, for: apical deviation (Pearson r = 0.9; Spearman rho = 0.9), lordosis angle (r = 0.8; rho = 0.6) and kyphosis angle (r = 0.8; rho = 0.8)]; our further results are (considering the measurements on the Raimondi scale: The (Pearson) correlation coefficient between the Raimondi data and the corresponding raster stereographic ones – at the same vertebral level – is 0.552, showing a very weak correlation. So, if raster stereographic data are at hand, it is practically impossible to predict the Raimondi results. But, if Raimondi data are at hand, we can expect only modest correctness. Raster stereography as a non-invasive method may be a complementary and intermittent alternative method for the X-Ray examination – without replacing it, but only making its use contingent more seldom – to monitor the evolution of scoliosis and aesthetic aspect.

Key words: idiopathic scoliosis, radiography, raster stereography, Raimondi scale/"regolo".

INTRODUCTION

This article accomplishes a further –necessary and announced by us – step, towards a more thorough way of trying to establish and explain possible correspondence between the results obtained through the Nash-Moe radiological scale grades and the ordinal values determined with raster stereography – and adding in this respect, for rotation, the use of the Raimondi "regolo"[1,2].

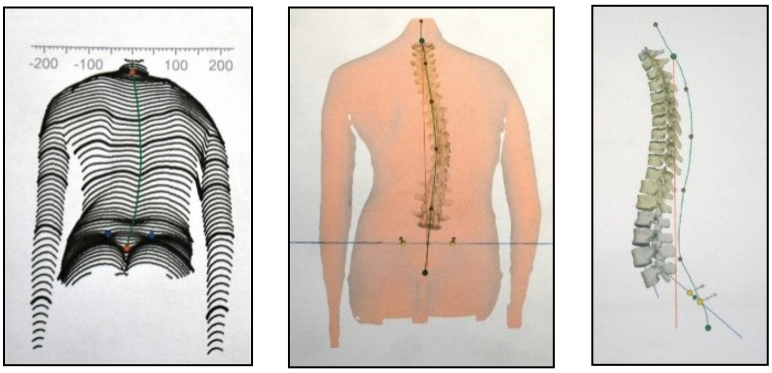
We have started our comparative analysis between data provided by radiology *versus* raster stereography and briefly presented preliminary results and conclusions, elsewhere[3], thus being welcome a detailed presentation of our whole related endeavor, by now, regarding specific assays in children/adolescents with idiopathic scoliosis.

Idiopathic scoliosis is the most common type of spinal deformity, evolutive, characterized by three-dimensional torsional deformation of the spine and trunk[4] affecting 2–3% of the population, predominantly girls[5].

Diagnosis is based on clinical and radiological examination. The spine radiography is the gold-standard[6] for diagnostic and follow-up into Idiopathic Scoliosis, but a worrisome issue from radiation point of view[7], especially as it is about a pathology affecting very young subjects.

Cumulative radiation in this patient population significantly increases the risk of cancer, especially breast cancers[8].

Raster stereography is a radiation free method able to make a three-dimensional reconstruction of the of the back and spine's shape, based on optical measurements of the posterior torso surface processed by the concept of photogrammetric and triangulation method[9].



a b c

Figure 1.13 years old girl from the casuistry of CNCRNC "Dr. N. Robanescu":
a) raster stereography (DIERS Formetric 4D), posterior image,
b) raster stereography (DIERS Formetric 4D), posterior image,
c) raster stereography (DIERS Formetric 4D), lateral image.

Besides the immediate benefit of reducing the exposure to X-ray, raster stereography offers a considerable number of additional advantages: three-dimensional visualization of the trunk – including with the spine profile –, it monitors the effectiveness of treatment for specialists, and the more self-evident aesthetic changes motivate the patient to continue the conservative treatment, otherwise long and even monotonous. These are the main reasons for considering raster stereography as an alternative/ complementary investigation, which's system recognizes the back topography automatically, by calculating the curvatures from the determined coordinates.

Yet, "reliability of raster stereography was proved only for sagittal plane parameters with repeated measures on the same day" – with "lower reproducibility for the frontal plane"[10].

MATERIAL AND METHOD

The study included (with the approval – No. 2563/ 08.04.2016) – of the hospital's Ethics Commission) 11 children (9 girls, 2 boys), in-patients at the CNCRNC Dr. N. Robănescu Bucharest, aged between 9–13 years, diagnosed with idiopathic scoliosis and currently investigated, in this respect, with radiography and raster stereography (performed by DIERS Formetric 4D device) – aiming to objectively compare the assessment capabilities of the latter with those of the radiological gold-standard.

A difficulty and at the same time – we consider – a contributory element of this work, is the attempt (with inevitable limitations in terms of absolute rigorous correspondence between all the afferent objective parameters encompassed in the above mentioned instrumental evaluation tools) to "make compatible" the results obtained by the use of radiological investigations with those provided by raster stereography.

Thus, for idiopathic scoliosis, a semiquantitative measurement tool, well known and widely used, is the Nash-Moe scale for assessment of vertebral rotation (although there is no consensus regarding "the accuracy of vertebral rotation determinations made from roentgenographic pedicle-shadow offset measurements … made from anteroposterior roentgenograms", *i.e.* this being considered, at least, questionable[11]). According to it, the vertebral pedicles' position in anterior-posterior radiographies indicates the degree of vertebral rotation. In "neutral" grade (0 – n.n.), the pedicles – in relation to the edges of the vertebral body – are symmetric, equidistant. The degree may increment up to grade 4 ("++++") of rotation, corresponding to the pedicles passed the center vertebral body[12,]. (For rigor: another radiological related method is the Perdriolle one – also proving "moderate to good overall correlation with the main thoracic curve Cobb angles, apical Perdriolle rotation …, determined by computed tomography (CT), the gold standard for accuracy”[13], and also the Raimondi method. The Perdriolle Method measures vertebral rotation grading in steps of 5 degrees, while the Raimondi Method is more accurate using a 2 degrees step[14]. We have added measurements and consequent resulting data analysis using the Raimondi slide ruler (approved to be availed by its author: Paulo Raimondi).

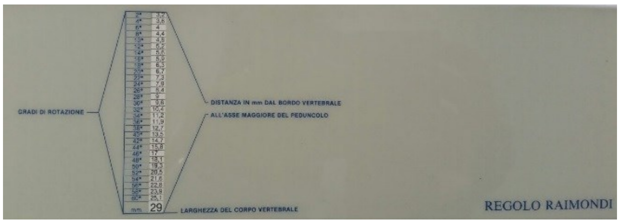
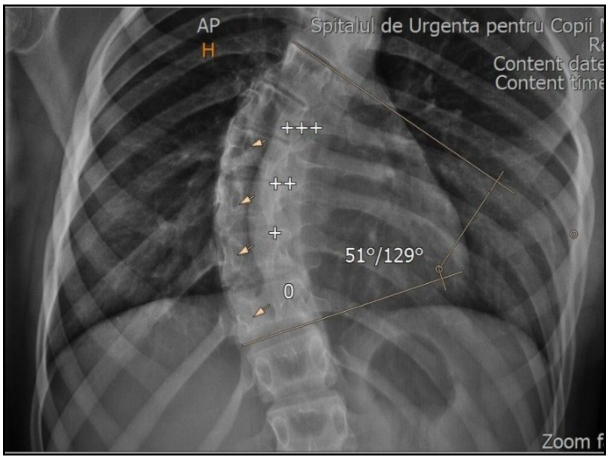


Figure 2. Raimondi slide ruler.



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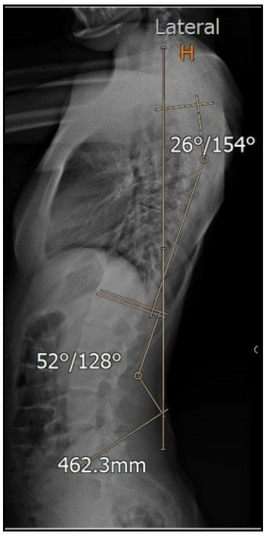

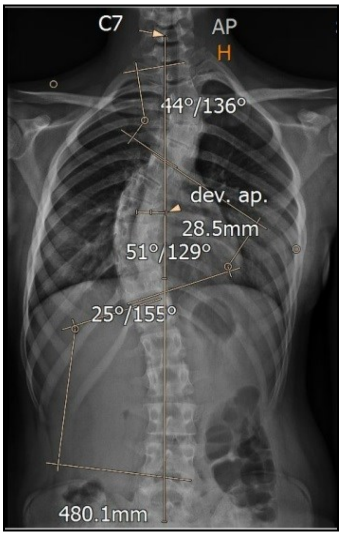

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Figure 3. 13 years old girl from the hospital’s casuistry.

a) Postero-Anterior (PA) X-ray – Cobb angle 51°, vertebral rotation +++ Nash-Moe.

b) Profile X-ray – kyphotic angle 26°, lordotic angle 52°.

c) PA X-ray – apical deviation 2.5 mm.

The target of raster stereography focuses on the changes/deviations of some quasi-similar parameters (that we recorded by radiological assessment): lateral and apical deviation, angle of kyphosis and lordosis and of possibly pelvic obliquity and vertebral rotation. These parameters frequently undergo cumulative changes with the progression of scoliosis; the last mentioned required to be converted, from primary values (expressed in millimeters – or respectively in geometric degrees for rotation into the conventional grades of the Nash-Moe classification, including because the raster stereographically determined “parameters of lateral vertebral deviation and vertebral rotation … are not directly comparable with the Cobb angle”[15]. Accordingly, for spinal rotation, on one hand, lower values – below 10 degrees – may be converted to grade value 0, and on the other, we have assimilated values above 25 degrees to the grade value 3, on the Nash-Moe scale. Unfortunately, one cannot precisely discern between grade value 1 and 2 on the Nash-Moe scale, *i.e.* when raster stereographical evaluation values are between 10 and 25 degrees.

Consequently the assessed possibly compared parameters were: lateral deviation of the spine, main apex curvature deviation, vertebral rotation, pelvic obliquity, kyphosis angle and lordosis angle. Additionally in order to refine the comparted analysis /improve the discern gap between the above mentioned grade values 1 and 2 we have introduced a statistical assay among related primary data provided by raster stereographical and Raimondi ruler.

For statistical processing it was used Pearson linear regression method. Data were monitored in charts and tables, using SPSS v.22 soft completed by a diagram obtained in excel, regression line allowing evaluation of discrepancies that exist between measurements.

RESULTS

The statistical objectivation has been done by comparison of corresponding evaluated pairs of parameters, between the related data provided by radiology and raster stereography, respectively. The correlation coefficients calculated for apical deviation (Pearson r = 0.9; Spearman rho = 0.9), lordosis angle (r = 0.8; rho = 0.6) and kyphosis angle (r = 0.8; rho = 0.8) showed statistical significance between the two respective instrumental assessment methods.

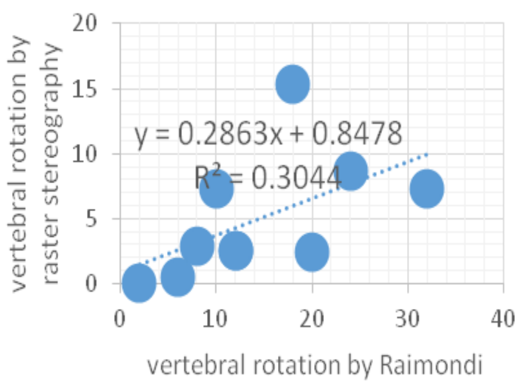
Yet, when refining the quantitative comparative analysis between our measurement outcomes obtained through each investigation tool, on pairs of parallel parameters, raster stereographic values appeared undervalued if compared to the corresponding radiological measurements for apical deviation (0,3 mm) and the lordosis angle (4,2°); understated for ”large” values and overstated for small ones of lateral deviation; overstated for kyphosis angle (7,9°). For pelvic obliquity we found conflicting data (r = 0.7 rho = 0.6, regression slope = = 0.5) the same goes for vertebral rotation.

Comparison of linear and exponential curves appeared to show that exponential function appears to be more close to the values given simultaneously by raster stereography and X-ray data.

Regarding the comparative assesments between data provided by raster streography and radiological ones, obtained through Raimondi scale are presented below.

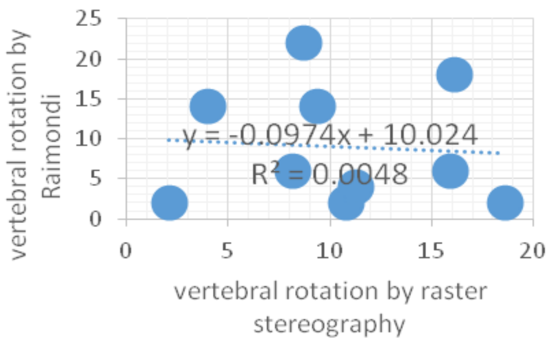
The (Pearson) correlation coefficient between the Raimondi data and the corresponding raster stereographic ones – at the same vertebral level – is 0.552, showing a very weak correlation.

The following diagram shows a large spread of data points – each one corresponding to a patient – around the regression line (R^2 is the square of the correlation coefficient).



The (Pearson) correlation coefficient between the raster stereographic data and the corresponding Raimondi results – at the same vertebral level – is –0.069, showing a statistical independence.

The following diagram shows the spread of data points around the regression line, which has now a negative slope. (Of course, R^2 is the square of the correlation coefficient).



The results above can be interpreted as follows. If raster stereographic data are at hand, then it is practically impossible to predict the Raimondi data. And if Raimondi data (x from the first diagram) are at hand, and we calculate the “predicted” raster stereographic data (y from the first diagram) according to the formula on the diagram, then we can expect only modest correctness.

DISCUSSION

Raster stereography gives a detailed measurement of vertebral rotation. As mentioned above, in order to make (rather) compatible the Nash-Moe grading with the numeric values provided by raster stereography, we made an above specified calculation preliminary convention.

But because the Nash-Moe scale, has a low number of grading, for comparison with vertebral rotation – assessed by raster stereography – it requires greater number of patients in order to establish a putative correlation (including based on a possibly more appropriate calculation convention), this being an objective limitation of our study.

There may be significant differences between the aesthetic aspect and the radiological image, beneficial from the subjective – but nevertheless important – point of view, due to the compensations made by the muscle mass and the subcutaneous tissue which can attenuate the overall deformity.

We compared the values obtained from the radiological examination with those obtained from raster stereography to find out if there are correlations between the compared data strings and furthermore: within our quest for better compatibilization in between radiological and raster stereographical related assessments, we have added comparative calculations *vs.* the data obtained for vertebral rotation on the Raimondi scale.

As opposed to X-Ray, the raster stereography reconstructs the spine based on topographical measurements of the body surface. Sensitive body surface changes reflect modifications – except for rotation – in the skeletal system, giving us the clue for a new X-Ray examination.

CONCLUSION

Raster stereographic measurement highlights important scoliosis parameters' values in strong correlation with some items resulting from radiological classic examinations evaluated, except for situation when compared raster stereography values or 10–25 degrees with grade I or II on the Nash-Moe scale.

Raster stereography as a non-invasive method may be a complementary and intermittent alternative method for the X-Ray examination – without replacing it, but only making its use contingent more seldom – to monitor the evolution of scoliosis and aesthetic aspect, otherwise a priority for the patient.

To increase the validity of the results it is necessary to expand this study to a larger number of patients.

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