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REVIEW

of the Doctoral thesis by Carsten KANTELBERG entitled '*Morphometric analysis of the cervical pedicles and conclusions for posterior cervical instrumentations*' prepared under the supervision on Prof. Szymon Dragan, MD, PhD.

The doctoral student complemented and introduced corrections to the reviewed work, taking into account most of the remarks contained in the first review of his doctoral dissertation. The work contains important cognitive aspects, and the introduced changes increase the quality of the doctoral thesis.

I conclude that the doctoral thesis of Carsten Kantelberg, MD entitled '*Morphometric analysis of the cervical pedicles and conclusions for posterior cervical instrumentations*' meets the requirements for a thesis for the degree of Doctor of Medical Sciences specified in Article 13.1 of the Act of 14 March 2003 on Academic Degrees and Title and Degrees and Title in the Arts (Journal of Laws No 65, item 595, as mended).

I recommend that the Medical Faculty Council of the Wrocław Medical University accepts Carsten Kantelberg, MD for later stages of the doctoral process, including public defence of the thesis.



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of the Doctoral thesis by Carsten KANTELBERG entitled '*Morphometric analysis of the cervical pedicles and conclusions for posterior cervical instrumentations*' prepared under the supervision on Prof. Szymon Dragan, MD, PhD.

The spine is a complex, multi-joint system controlled by muscles that supports the head and trunk during the upright posture, allows to perform complex body movements, and encloses and protects the spinal cord, the nerve roots, and, at the cervical level, also the vertebral arteries.

Surgical procedures in diseases of the cervical spine, such as trauma, tumours, and spondylosis, have evolved rapidly. Implants have been widely used for many years as a technical means of treating traumatic cervical injuries. Cervical fixation from a posterior approach is becoming progressively accepted. Despite the use of different surgical techniques to reconstruct a damaged or destabilised spine, there are no clear indications for a procedure from an anterior or posterior approach. Because surgeons are not completely satisfied with the effects of the applied anterior fixation of the cervical spine, pedicle screws have become increasingly popular in the reconstruction of a number of disorders of this spinal segment.

Thanks to its biomechanical advantage, a three-column fixation system using bone screws implanted to secure an unstable cervical spine has proven to be a valuable tool in the toolbox of a spine surgeon. Successful placement of a pedicle screw in the cervical region requires at least minimal understanding of the three-dimensional morphology of the pedicle to be able to choose the correct diameter of a pedicle screw and then identify the trajectory of driving the screw in the vertebra.

The first morphometric analyses of the vertebrae were carried out on post-mortem vertebral specimens and due to the measuring accuracy they gave rise to legitimate concerns as to the suitability of the obtained data for clinical use. The lack of a detailed analysis of important parameters, such as the inner and outer pedicular diameters, did not give surgeons a sufficient tool to select the correct pedicle screw, not to mention its positioning.

The emergence of modern computer-assisted imaging techniques, including computed tomography, creates new opportunities for diagnosis and planning of treatment procedures and can be implemented in the operational protocol to improve the accuracy of insertion of a pedicle screw. In this way, the indications for placement of a pedicle screw in the cervical spine are beginning to evolve, expanding the capabilities of fixing the cervical spine.

Given the enormity of the problems and risks associated with the use of fixation from a posterior approach using pedicle screws, the subject of the study is of great practical value. Clinical use of the results of measurements of cervical vertebrae, in particular cervical pedicle morphometry, can be effectively used in the planning and implanting of pedicle screws.

The reviewed study contains 104 pages and has a structure typical of a thesis for a scientific degree. It is divided into seven chapters: introduction, purpose, materials and methods, results, discussion, conclusion, and lists of figures and references. The list of references consists of 63 items, properly selected and used in the study in way that proves a good knowledge of the topic.

As mentioned above, the thesis has seven chapters. The initial chapter is devoted to the history of the treatment of the spine from antiquity to the present. It contains a description of the development of therapeutic processes from non-invasive methods to the use of technical means of enhancing the treatment of pathological traumatic and degenerative changes of the spine. In a separate subchapter, the author describes the development of operational techniques for the treatment of the cervical spine. I wish this chapter also presented the risks and the pros and cons of fixing the cervical spine from a posterior approach, a method that is currently widely used.

The second chapter contains the general characteristics of the anatomy of the spine, including its bone elements and soft tissues (blood vessels, spine cord, muscles). Bearing in mind the subject of the thesis, the cervical structure was described in detail (including the first two cervical vertebrae: atlas and axis) with particular emphasis on the lower part of the cervical spine (C2-C7). The last part of the second chapter is devoted to the basics of physiology of the cervical spine, mainly the range of motion that is implemented in this segment of the spine. The Doctoral student has overstated the title of the subchapter 'Biomechanics of the cervical spine' because its content is limited only to the description of the motor functions of the cervical spine.

The third chapter presents the aim of the doctoral thesis, namely, to describe the morphometric parameters of the cervical spine in the context of their use during insertion of implants in the case of cervical fixation from a posterior approach. This chapter is short and limited to determining the primary purpose of the study. However, it should be noted that the objective of the study is very topical and fully justified. Considering the wide

applicability of the instruments fixing the cervical spine from a posterior approach and the problems occurring in their use, it is very important to evaluate the geometry of the cervical vertebrae for the correct implementation of pedicular fixation.

In the next chapter, the author describes the materials and methods used in the implementation of the stated purpose of the study. Tests using computed tomography techniques were carried out on 123 patients without pathological changes (such as metastases, fractures, or congenital malformations) of the vertebral bodies and pedicles. The study group comprised people aged 10 ÷ 98 years. The analysis covered the vertebrae C2 to C7, with a total of 706 pedicles on the right side and 705 pedicles on the left side. It should be noted that the study group was very large and, considering measurements of pedicles on both sides of the vertebra, the obtained database is very valuable. The measurements were made on four parameters describing the geometry of the pedicles, i.e. the inner and outer pedicular diameter, pedicular length and vertebral body in the pedicular axis, and transverse pedicular angle. The measurement defined by the Doctoral student as diameter is not entirely clear. Based on the description and the diagram of the measurement method (Fig. 11 and Fig. 12) it can be concluded that only the width of the pedicles was measured (in addition, the lack of units of the measured values makes it difficult to analyse the results). The results are presented in the form of charts and tables, which also take into account basic statistical data such as the mean values and standard deviation. Detailed results of all the measurements are included in an annex to the thesis. A certain weakness of the study is the lack of a broader statistical analysis or an analysis of the impact of age and gender on any changes or variation in the measured morphometric parameters.

In the Discussion, the PhD student presented a comprehensive analysis of the state of knowledge on measurements of morphometric parameters of cervical vertebrae, including, among others, screw entry point, screw angle, screw entry area, and pedicle width and height. On this basis, great anatomical variability has been demonstrated in the structure of human cervical pedicles. In the same chapter, the author also includes an analysis of the risk posed by cervical fixation from a posterior approach. In addition to an analysis of clinical reports providing recommendations for fixation from a posterior approach and identifying many risks and complications resulting from insertion of pedicle screws, the thesis presents the results of biomechanical tests carried on post-mortem material. As demonstrated by the Doctoral student, this research is not limited to morphometric studies but is carried out in order to present the most preferable technique of cervical fixation from a posterior approach. An important element of the discussion is the comparison of cervical pedicle screw fixation and lateral mass screw fixation, especially considering the fact that lateral mass screw fixation is believed to carry a smaller risk of complications in the case of not fully satisfactory fixation of the cervical spine. There is an interesting discussion in the subchapter concerning comparison of the use of CT and X-ray

techniques in the planning of the operating process using pedicular fixation. Here, the author indicates significant differences in the measurement accuracy of both imaging methods, which may lead to an incorrect selection of fixation implants.

The Doctoral student fairly briefly discusses the results, comparing them with data from the literature on the subject.

I would like to express some reservations and criticism that came to my mind after reading the reviewed study. The most important of them are as follows:

1. One of the main observations concerning the study is the lack of analysis of current knowledge from studies of morphometric parameters, in particular the characteristics and description of the geometric parameters of cervical pedicles. Such analysis would identify any deficiencies or gaps in the undertaken subject of study, thus providing a background for presenting the contribution made by the thesis to the subject of cervical fixation from a posterior approach.

Also, considering the purpose of the study, it is not clear to me why an analysis of the risks posed by implant insertion from a posterior approach is not presented until the Discussion. If such an analysis were presented early enough in the text, it would provide great justification for the purpose of the study and a basis for further discussion.

In the third chapter, the author refers to the data from the same chapter.

2. In the second chapter, there are no references to the sources of the figures illustrating the content of the chapter.
3. Why does the author focus on only four basic geometric parameters of the cervical vertebral body and pedicles? What is the rationale for the choice of these geometric parameters among many that are relevant when using pedicular fixation?
4. What units were used in measurements of the geometric parameters and what is the measurement accuracy? In the results of the analysis, the author reports the data to five and six decimal places. What is the practical value of such accuracy? The charts from 6.1 to 6.4 do not describe the y axis and the values on the y axis are given without the units of measurement.
5. The PhD student analysed geometric parameters on a large study group aged between 10 and 98 years. With such a large age distribution, the question arises why the results were not analysed taking into account the age of the patients. Morphometric parameters of the cervical vertebrae of people before completion of bone growth will significantly affect the final results.

The above comments in no way diminish my positive evaluation of the content of the reviewed thesis.

The Doctoral student has showed extensive knowledge, satisfactorily analysed the problem, and presented the results of his study. I conclude that the doctoral thesis of Carsten Kantelberg, MD entitled '*Morphometric analysis of the cervical pedicles and conclusions for posterior cervical instrumentations*' meets the requirements for a thesis for the degree of Doctor of Medical Sciences specified in Article 13.1 of the Act of 14 March 2003 on Academic Degrees and Title and Degrees and Title in the Arts (Journal of Laws No 65, item 595, as mended).

I recommend that the Medical Faculty Council of the Wrocław Medical University accepts Carsten Kantelberg, MD for later stages of the doctoral process, including public defence of the thesis.

A handwritten signature in blue ink, appearing to read 'KANTELBERG', with a long horizontal line extending to the left from the start of the signature.