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The Journal of Turkish Spinal Surgery is
published 4 times in a year.
(January, April, July and October)

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The Journal of Turkish Spinal Surgery (www.jtss.org), is the official publication of the Turkish Spinal Surgery Society. First journal was printed on January, in 1990. It is a double-blind peer-reviewed multidisciplinary journal for the physicians who deal with spinal diseases and publishes original studies, which offer significant contributions to the development of the spinal knowledge. The journal publishes original scientific research articles, invited reviews and case reports that are accepted by the Editorial Board, in English.

The journal is published once in every three months and a volume consists of four issues.

The Journal of Turkish Spinal Surgery is published four times a year: on January, April, July, and October.

The Turkish Spinal Surgery Society was established in 1989 in Izmir (Turkey) by the pioneering efforts of *Prof. Dr. Emin Alıcı* and other a few members. The objectives of the society were to: - establish a platform for exchange of information/ experience between Orthopedics and Traumatology Specialists and Neurosurgeons who deal with spinal surgery - increase the number of physicians involved in spinal surgery and to establish spinal surgery as a sophisticated medical discipline in Turkey - follow the advances in the field of spinal surgery and to communicate this information to members - organize international and national congresses, symposia and workshops to improve education in the field - establish standardization in training on spinal surgery - encourage scientific research on spinal surgery and publish journals and books on this field - improve the standards of spinal surgery nationally, and therefore make contributions to spinal surgery internationally.

The main objective of the Journal is to improve the level of knowledge and experience among Turkish medical society in general and among those involved with spinal surgery in particular. Also, the Journal aims at communicating the advances in the field, scientific congresses and meetings, new journals and books to its subscribers. The Journal of Turkish Spinal Surgery is as old as the Turkish Spinal Surgery Society.

The first congress organized by the Society took place in Çeşme, Izmir, coincident with the publication of the first four issues. Authors were encouraged by the Society to prepare original articles from the studies presented in international congresses organized by the Society every two years, and these articles were published in the Journal. The Journal publishes clinical or basic research, invited reviews, and case presentations after approval by the Editorial Board. Articles are published after at least two reviewers review them. Editorial Board has the right to accept, to ask for revision, or to refuse manuscripts.

The Journal is issued every three months, and one volume is completed with every four issue. Associate Editors and Editor in Chief are responsible in reviewing and approving material that is published. Responsibility for the problems associated with research ethics or medico-legal issues regarding the content, information and conclusions of the articles lies with the authors, and the editor or the editorial board bears no responsibility. In line with the increasing expectations of scientific communities and the society, improved awareness about research ethics and medico-legal responsibilities forms the basis of our publication policy.

Citations must always be referenced in articles published in our journal. Our journal fully respects to the patient rights, and therefore care is exercised in completion of patient consent forms; no information about the identity of the patient is disclosed; and photographs are published with eye-bands. Ethics committee approval is a prerequisite. Any financial support must clearly be disclosed. Also, our Journal requests from the authors that sponsors do not interfere in the evaluation, selection, or editing of individual articles, and that part or whole of the article cannot be published elsewhere without written permission.

The Journal of Turkish Spinal Surgery is available to the members of the society and subscribers free of charge. Membership fees, congresses, and the advertisements appearing in the journal meet the publication and distribution costs.

The advertisement fees are based on actual pricing. The Editorial Board has the right for signing contracts with one or more financial organizations for sponsorship. However, sponsors cannot interfere in the scientific content and design of the journal, and in selection, publication order, or editing of individual articles.

The Journal of Turkish Spinal Surgery agrees to comply with the "Global Compact" initiative of the UN, and this has been notified to the UN. Therefore, VI our journal has a full respect to human rights in general, and patient rights in particular, in addition to animal rights in experiments; and these principles are an integral part of our publication policy

Recent advances in clinical research necessitate more sophisticated statistical methods, well-designed research plans, and more refined reporting. Scientific articles, as in other types of articles, represent not only an accomplishment, but also a creative process.

The quality of a report depends on the quality of the design and management of the research. Well-designed questions or hypotheses are associated with the design. Well-designed hypotheses reflect the design, and the de-

sign reflects the hypothesis. Two factors that determine the efficiency of a report are focus and shortness. Drawing the attention to limited number of subjects allows the author to focus on critical issues. Avoidance from repetitions (apart from a few exceptions), a simple language, and correct grammar are a key to preparing a concise text. Only few articles need to exceed 3000 words, and longer articles may be accepted when new methods are being reported or literature is being reviewed.

Although authors should avoid complexity, the critical information for effective communication usually means the repetition of questions (or hypotheses or key subjects). Questions must be stated in Abstract, Introduction and Discussion sections, and the answers should be mentioned in Abstract, Results, and Discussion sections. Although many journals issue written instructions for the formatting of articles, the style of the authors shows some variance, mainly due to their writing habits.

The Journal of Turkish Spinal Surgery adopts the AMA style as a general instruction for formatting. However, not many authors have adequate time for learning this style. Thus, our journal is tolerant to personal style within the limitations of correct grammar and plain and efficient communication.

AIMS AND SCOPE

Journal of Turkish Spinal Surgery (JTSS) is the official journal of Turkish Spine Society (TSS). Main purpose of the journal is to publish scientific studies of spine surgeons in Turkey and the whole world, and share knowledge and experience mutually. Likewise, focus of the journal is to deliver innovation and advances in spinal surgery to readers. By this way, we endeavor contributing accumulation of knowledge in spinal surgery. Our main mission is to publish scientific researches and increase scientific quality of the researches. Our vision is to become an upper class journal that is indexed in all scientific indices globally.

ETHICAL RULES

Responsibility for the problems associated with research ethics or medico-legal issues regarding the content, information and conclusions of the articles lies with the authors, and the editor or the editorial board bears no responsibility. In line with the increasing expectations of scientific communities and the society, improved awareness about research ethics and medico-legal responsibilities forms the basis of our publication policy. Citations must always be referenced in articles published in our journal. Our journal fully respects to the patient rights, and therefore care is exercised in completion of patient consent forms; no information about the identity of the patient is disclosed; and photographs are published with eye-bands. Ethics committee approval is a prerequisite. Any financial support must clearly be disclosed. Also, our Journal requests from the authors that sponsors do not interfere in the evaluation, selection, or editing of individual articles, and that part or whole of the article cannot be published elsewhere without written permission.

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PEER REVIEW

Secretaries of the journal review article after it is uploaded to the web site. Article type, presence of the all sections, suitability according to the number of words, name of the authors with their institutions, corresponding address, mail addresses, telephone numbers and ORCID numbers are all evaluated and shortcomings are reported to the editor. Editor request the all defect from the authors and send to vice editors and native English speaker editor after completion of the article. Vice editors edit the blinded article and this blinded copy is sent to two referees. After reviewing of the article by the referees in maximum one month, the review report evaluating all section and his decision is requested, and this blinded report is sent to the author. In fifteen days, revision of the article is requested from the authors with the appreciate explanation. Revised blinded copy is sent to the referees for the new evaluation. Editor if needed may sent the manuscript to a third referee. Editorial Board has the right to accept, revise or reject a manuscript.

APPLICATION LETTER EXAMPLE:

Editor-in-Chief

The Journal of Turkish Spinal Surgery

Dear Editor,

We enclose the manuscript titled '…..' for consideration to publish in The Journal of Turkish Spinal Surgery.

The following authors have designed the study (AU: Parenthetically insert names of the appropriate authors), gathered the data (AU: Parenthetically insert names of the appropriate authors), analyzed the data (AU: Parenthetically insert names of the appropriate authors), wrote the initial drafts (AU: Parenthetically insert initials of the appropriate authors), and ensure the accuracy of the data and analysis (AU: Parenthetically insert names of the appropriate authors).

I confirm that all authors have seen and agree with the contents of the manuscript and agree that the work has not been submitted or published elsewhere in whole or in part.

As the Corresponding Author, I (and any other authors) understand that The Journal of Turkish Spinal Surgery requires all authors to specify any contracts or agreements they might have signed with commercial third parties supporting any portion of the work. I further understand such information will be held in confidence while the paper is under review and will not influence the editorial decision, but that if the article is accepted for publication, a disclosure statement will appear with the article. I have selected the following statement(s) to reflect the relationships of myself and any other author with a commercial third party related to the study:

1) All authors certify that they not have signed any agreement with a commercial third party related to this study which would in any way limit publication of any and all data generated for the study or to delay publication for any reason.

2) One or more of the authors (initials) certifies that he or she has signed agreements with a commercial third party related to this study and that those agreements allow commercial third party to own or control the data generated by this study and review and modify any manuscript but not prevent or delay publication.

3) One or more of the authors (AU: Parenthetically insert initials of the appropriate authors) certifies that he or she has signed agreements with a commercial third party related to this study and that those agreements allow commercial third party to own or control the data and to review and modify any manuscript and to control timing but not prevent publication.

Sincerely,

Date:

Corresponding Author:

Address:

Phone:

Fax-mail:

GSM:

E-mail:

ORCID Numbers of Authors:

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PEER REVIEW

Article is reviewed by secretaries of the journal after it is uploaded to the web site. Article type, presence of the all sections, suitability according to the number of words, name of the authors with their institutions, corresponding address, mail addresses, telephone numbers and ORCID numbers are all evaluated and shortcomings are reported to the editor. Editor request the all defect from the authors and send to vice editors and native English speaker editor after completion of the article. Vice editors edit the blinded article and this blinded copy is sent to two referees. After reviewing of the article by the referees in maximum one month, the review report evaluating all section and his decision is requested, and this blinded report is sent to the author. In fifteen days, revision of the article is requested from the authors with the appreciate explanation. Revised blinded copy is sent to the referees for the new evaluation. Editor if needed may sent the manuscript to a third referee. Editorial Board has the right to accept, revise or reject a manuscript.

- **Following types of manuscripts related to the field of "Spinal Surgery" with English Abstract and Keywords are accepted for publication:**

I- Original clinical and experimental research studies;

II- Case presentations; and

III- Reviews.

AUTHOR'S RESPONSIBILITY

The manuscript submitted to the journal should not be previously published (except as an abstract or a preliminary report) or should not be under consideration for publication elsewhere. Every person listed as an author is expected to have been participated in the study to a significant extent. All authors should confirm that they have read the study and agreed to the submission to the Journal of Turkish Spinal Surgery for publication. This should be notified with a separate document as shown in the "Cover Letter" in the appendix. Although the editors and referees make every effort to ensure the validity of published manuscripts, the final responsibility rests with the authors, not with the Journal, its editors, or the publisher. The source of any financial support for the study should be clearly indicated in the Cover Letter.

lt is the author's responsibility to ensure that a patient's anonymity be carefully protected and to verify that any experimental investigation with human subjects reported in the manuscript was performed upon the informed consent of the patients and in accordance with all guidelines for experimental investigation on human subjects applicable at the institution(s) of all authors.

Authors should mask patients' eyes and remove patients' names from figures unless they obtain written consent to do so from the patients; and this consent should be submitted along with the manuscript.

CONFLICTS OF INTEREST

Authors must state all possible conflicts of interest in the manuscript, including financial, institutional and other relationships that might lead to bias or a conflict of interest. If there is no conflict of interest, this should also be explicitly stated as none declared. All sources of funding should be acknowledged in the manuscript. All relevant conflicts of interest and sources of funding should be included on the title page of the manuscript with the heading "Conflicts of Interest and Source of Funding".

ARTICLE WRITING

Clinically relevant scientific advances during recent years include use of contemporary outcome measures, more sophisticated statistical approaches, and increasing use and reporting of well-formulated research plans (particularly in clinical research).

Scientific writing, no less than any other form of writing, reflects a demanding creative process, not merely an act: the process of writing changes thought. The quality of a report depends on the quality of thought in the design and the rigor of conduct of the research. Well-posed questions or hypotheses interrelate with the design. Well-posed hypotheses imply design and design implies the hypotheses. The effectiveness of a report relates to brevity and focus. Drawing the attention to a few points will allow authors to focus on critical issues. Brevity is achieved in part by avoiding repetition (with a few exceptions to be noted), clear style, and proper grammar. Few original scientific articles need to be longer than 3000 words. Longer articles may be accepted if substantially novel methods are reported, or if the article reflects a comprehensive review of the literature.

Although authors should avoid redundancy, effectively communicating critical information often requires repetition of the questions (or hypotheses/key issues) and answers. The questions should appear in the *Abstract, Introduction, and Discussion*, and the answers should appear in the *Abstract, Results, and Discussion* sections.

Although most journals publish guidelines for formatting a manuscript and many have more or less established writing styles (e.g., the American Medical Association Manual of Style), styles of writing are as numerous as authors. The Journal of Turkish Spinal Surgery traditionally has used the AMA style as a general guideline. However, few scientific and medical authors have the time to learn these styles. Therefore, within the limits of proper grammar and clear, effective communication, we will allow individual styles.

Permissions:

As shown in the example in the appendix (Letter of Copyright Transfer) the authors should declare in a separate statement that the study has not been previously published and is not under consideration for publication elsewhere. Also, the authors should state in the same statement that they transfer copyrights of their manuscript to our Journal. Quoted material and borrowed illustrations: if the authors have used any material that had appeared in a copyrighted publication, they are expected to obtain written permission letter and it should be submitted along with the manuscript.

Review articles:

The format for reviews substantially differs from those reporting original data. However, many of the principles noted above apply. A review still requires an *Abstract*, an *Introduction*, and a *Discussion*. The *Introduction* still requires focused issues and a rationale for the study. Authors should convey to readers the unique aspects of their reviews which distinguish them from other available material (e.g., monographs, book chapters). The main subject should be emphasized in the final paragraph of the *Introduction*. As for an original research article, the *Introduction* section of a review typically need not to be longer than four paragraphs. Longer Introductions tend to lose focus, so that the reader may not be sure what novel information will be presented. The sections after the *Introduction* are almost always unique to the particular review, but need to be organized in a coherent fashion. Headings (and subheadings when appropriate) should follow parallel construction and reflect analogous topics (e.g., diagnostic categories, alternative methods, alternative surgical interventions). If the reader considers only the headings, the logic of the review (as reflected in the Introduction) should be clear. *Discussion* synthesizes the reviewed literature as a whole coherently and within the context of the novel issues stated in the *Introduction*.

The limitations should reflect those of the literature, however, rather than a given study. Those limitations will relate to gaps in the literature which preclude more or less definitive assessment of diagnosis or selection of treatment, for example. Controversies in the literature should be briefly explored. Only by exploring limitations will the reader appropriately place the literature in perspective. Authors should end the *Discussion* by abstract statements similar to those which will appear at the end of the *Abstract* in abbreviated form.

In general, a review requires a more extensive literature review than an original research article, although this will depend on the topic. Some topics (e.g., osteoporosis) could not be comprehensively referenced, even in an entire monograph. However, authors need to ensure that a review is representative of the entire body of literature, and when that body is large, many references are required.

Original Articles:

- Original articles should contain the following sections: *"Title Page", "Abstract", "Keywords", "Introduction", "Materials and Methods", "Results", "Discussion", "Conclusions"*, and *"References"*. "Keywords" sections should also be added if the original article is in English.

- ***Title*** (80 characters, including spaces): Just as the

Abstract is important in capturing a reader's attention, so is the title. Titles rising or answering questions in a few brief words will far more likely do this than titles merely pointing to the topic. Furthermore, such titles as "Bisphosponates reduce bone loss" effectively convey the main message and readers will more likely remember them. Manuscripts that do not follow the protocol described here will be returned to the corresponding author for technical revision before undergoing peer review. All manuscripts in English, should be typed double-spaced on one side of a standard typewriter paper, leaving at least 2.5 cm. margin on all sides. All pages should be numbered beginning from the title page.

- *Title page* should include: a) informative title of the paper, b) complete names of each author with their institutional affiliations, c) name, address, fax and telephone number, e-mail of the corresponding author, d) address for the reprints if different from that of the corresponding author, e) ORCID numbers of the authors. It should also be stated in the title page that informed consent was obtained from patients and that the study was approved by the ethics committee.

The "*Level of Evidence*" should certainly be indicated in the title page (see Table-1 in the appendix). Also, the field of study should be pointed out as outlined in Table-2 (maximum three fields).

- ***Abstract:*** A150 to 250 word abstract should be included at the second page. The abstract should be written in English and for all articles. The main topics to be included in Abstract section are as follows: *Background Data, Purpose, Materials- Methods, Results and Conc*lusion. The *Abstract* should be identical in meaning. Generally, an *Abstract* should be written after the entire manuscript is completed. The reason relates to how the process of writing changes thought and perhaps even purpose. Only after careful consideration of the data and a synthesis of the literature can author(s) write an effective abstract. Many readers now access medical and scientific information via Web-based databases rather than browsing hard copy material. Since the reader's introduction occurs through titles and abstracts, substantive titles and abstracts more effectively capture a reader's attention regardless of the method of access. Whether reader will examine an entire article often will depend on an abstract with compelling information. A compelling *Abstract* contains the questions or purposes, the methods, the results (most often quantitative data), and the conclusions. Each of these may be conveyed in one or two statements. Comments such as "this report describes..." convey little useful information.

-***Key Words :*** Standard wording used in scientific indexes and search engines should be preferred. The minimum number for *keywords* is three and the maximum is five.

- ***Introduction (250 – 750 words):*** It should contain information on historical literature data on the relevant issue; the problem should be defined; and the objective of the study along with the problem solving methods should be mentioned.

The *Introduction*, although typically is the shortest of sections, perhaps the most critical. The Introduction must effectively state the issues and formulate the rationale for those issues or questions. Its organization might differ somewhat for a clinical report, a study of new scientific data, or a description of a new method.

Most studies, however, are published to: (1) report entirely novel findings (frequently case reports, but sometimes substantive basic or clinical studies); (2) confirm previously reported work (eg, case reports, small preliminary series) when such confirmation remains questionable; and (3) introduce or address controversies in the literature when data and/or conclusions conflict. Apart from reviews and other special articles, one of these three purposes generally should be apparent (and often explicit) in the *Introduction*.

The first paragraph should introduce the general topic or problem and emphasized its importance, a second and perhaps a third paragraph should provide the rationale of the study, and a final paragraph should state the questions, hypotheses, or purposes.

One may think of formulating rationale and hypotheses as Aristotelian logic (a modal syllogism) taking the form: If A, B, and C, then D, E, or F. The premises A, B, and C, reflect accepted facts whereas D, E, or F reflect logical outcomes or predictions. The premises best come from published data, but when data are not available, published observations (typically qualitative), logical arguments or consensus of opinion can be used. The strength of these premises is roughly in descending order from data to observations or argument to opinion. D, E, or F reflects logical consequences. For any set of observations, any number of explanations (D, E, or F) logically follows. Therefore, when formulating hypotheses (explanations), researchers designing experiments and reporting results should not rely on a single explanation.

With the rare exception of truly novel material, when establishing rationale authors should generously reference representative (although not necessarily exhaustive) literature. This rationale establishes novelty and validity of the questions and places it within the body of literature. Writers should merely state the premises with relevant citations (superscripted) and

avoid describing cited works and authors` names. The exceptions to this approach include a description of past methods when essential to developing rationale for a new method, or a mention of authors` names when important to establish historic precedent. Amplification of the citations may follow in the Discussion when appropriate. In establishing a rationale, new interventions of any sort are intended to solve certain problems. For example, new implants (unless conceptually novel) typically will be designed according to certain criteria to eliminate problems with previous implants. If the purpose is to report a new treatment, the premises of the study should include those explicitly stated problems (with quantitative frequencies when possible) and they should be referenced generously.

The final paragraph logically flows from the earlier ones, and should explicitly state the questions or hypotheses to be addressed in terms of the study (independent, dependent) variables. Any issue not posed in terms of study variables cannot be addressed meaningfully. Focus of the report relates to focus of these questions, and the report should avoid questions for which answers are well described in the literature (e.g., dislocation rates for an implant designed to minimize stress shielding). Only if there are new and unexpected information should data reported apart from that essential to answer the stated questions.

- Materials - Methods (1000-1500 words): Epidemiological/ demographic data regarding the study subjects; clinical and radiological investigations; surgical technique applied; evaluation methods; and statistical analyses should be described in detail.

In principle, the *Materials and Methods* should contain adequate detail for another investigator to replicate the study. In practice, such detail is neither practical nor desirable because many methods will have been published previously (and in greater detail), and because long descriptions make reading difficult. Nonetheless, the *Materials and Methods* section typically will be the longest section. When reporting clinical studies authors must state approval of the institutional review board or ethics committees according to the laws and regulations of their countries. Informed consent must be stated where appropriate. Such approval should be stated in the first paragraph of *Materials and Methods*. At the outset the reader should grasp the basic study design. Authors should only briefly escribe and reference previously reported methods. When authors modify those methods, the modifications require additional description.

In clinical studies, the patient population and demographics should be outlined at the outset. Clinical reports must state inclusion and exclusion criteria and whether the series is consecutive or selected; if selected, criteria for selection should be stated. The reader should understand from this description all potential sources of bias such as referral, diagnosis, exclusion, recall, or treatment bias. Given the expense and effort for substantial prospective studies, it is not surprising that most published clinical studies are retrospective.

Such studies often are criticized unfairly for being retrospective, but that does not negate the validity or value of a study. Carefully designed retrospective studies provide most of the information available to clinicians. However, authors should describe potential problems such as loss to follow-up, difficulty in matching, missing data, and the various forms of bias more common with retrospective studies.

If authors use statistical analysis, a paragraph should appear at the end of *Materials and Methods* stating all statistical tests used. When multiple tests are used, authors should state which tests are used for which sets of data. All statistical tests are associated with assumptions, and when it is not obvious the data would meet those assumptions, the authors either should provide the supporting data (e.g., data are normally distributed, variances in groups are similar) or use alternative tests. Choice of level of significance should be justified. Although it is common to choose a level of alpha of 0.05 and a beta of 0.80, these levels are somewhat arbitrary and not always appropriate. In the case where the implications of an error are very serious (e.g., missing the diagnosis of a cancer), different alpha and beta levels might be chosen in the study design to assess clinical or biological significance.

- Results (250-750 words): "*Results*" section should be written in an explicit manner, and the details should be described in the tables. The results section can be divided into sub-sections for a more clear understanding.

If the questions or issues are adequately focused in the Introduction section, the *Results* section needs not to be long. Generally, one may need a paragraph or two to persuade the reader of the validity of the methods, one paragraph addressing each explicitly raised question or hypothesis, and finally, any paragraphs to report new and unexpected findings. The first (topic) sentence of each paragraph should state the point or answer the question. When the reader considers only the first sentence in each paragraph in *Results*, the logic of the authors` interpretations should be clear. Parenthetic reference to all figures and tables forces the author to textually state the interpretation of the data; the important material is the authors` interpretation of the data, not the data.

Statistical reporting of data deserves special con-

sideration. Stating some outcome is increased or decreased(or greater or lesser) and parenthetically stating the p (or other statistical) value immediately after the comparative terms more effectively conveys information than stating something is or is not statistically significantly different from something else (different in what way? the readermay ask). Additionally, avoiding the terms 'statistically different' or 'significantly different' lets the reader determine whether they will consider the statistical value biologically or clinically significant, regardless of statistical significance.

Although a matter of philosophy and style, actual p values convey more information than stating a value less than some preset level. Furthermore, as Motulsky notes, "When you read that a result is not significant, don't stop thinking... First, look at the confidence interval... Second, ask about the power of the study to find a significant difference if it were there." This approach will give the reader a much greater sense of biological or clinical significance.

- ***Discussion (750 - 1250 words):*** The *Discussion* section should contain specific elements: a restatement of the problem or question, an exploration of limitations and assumptions, a comparison and/or contrast with information (data, opinion) in the literature, and a synthesis of the comparison and the author's new data to arrive at conclusions. The restatement of the problem or questions should only be a brief emphasis. Exploration of assumptions and limitations are preferred to be next rather than at the end of the manuscript, because interpretation of what will follow depends on these limitations. Failure to explore limitations suggests the author(s) either do not know or choose to ignore them, potentially misleading the reader. Exploration of these limitations should be brief, but all critical issues must be discussed, and the reader should be persuaded they do not jeopardize the conclusions.

Next the authors should compare and/or contrast their data with data reported in the literature. Generally, many of these reports will include those cited as rationale in the Introduction. Because of the peculiarities of a given study the data or observations might not be strictly comparable to that in the literature, it is unusual that the literature (including that cited in the Introduction as rationale) would not contain at least trends. Quantitative comparisons most effectively persuade the reader that the data in the study are "in the ballpark," and tables or figures efficiently convey that information. Discrepancies should be stated and explained when possible; when an explanation of a discrepancy is not clear that also should be stated. Conclusions based solely on data in the paper seldom are warranted because the literature almost always contains previous information.

Finally, the author(s) should interpret their data in the light of the literature. No critical data should be overlooked, because contrary data might effectively refute an argument. That is, the final conclusions must be consistent not only with the new data presented, but also that in the literature.

- ***Conclusion:*** The conclusions and recommendations by the authors should be described briefly. Sentences containing personal opinions or hypotheses that are not based on the scientific data obtained from the study should be avoided.

- ***References:*** Care must be exercised to include references that are available in indexes. Data based on personal communication should not be included in the reference list. References should be arranged in alphabetical order and be cited within the text; references that are not cited should not be included in the reference list. The abstract of the presentations made at Symposia or Congresses should be submitted together with the manuscript. The following listing method should be used.

References should derive primarily from peer-reviewed journals, standard textbooks or monographs, or well-accepted and stable electronic sources. For citations dependent on interpretation of data, authors generally should use only high quality peer-reviewed sources. Abstracts and submitted articles should not be used because many in both categories ultimately do not pass peer review.

They should be listed at the end of the paper in alphabetical order under the first author's last name and numbered accordingly. If needed, the authors may be asked to provide and send full text of any reference. If the authors refer to an unpublished data, they should state the name and institution of the study, Unpublished papers and personal communications must be cited in the text. For the abbreviations of the journal names, the authors can apply to "list of Journals" in Index Medicus or to the address "http:// www.nlm.nih.gov/tsd/serials/lji.html".

In the references, reference must be included all authors, "et al." term dose not used. In all references, DOI numbers must be written in end of the reference.

Please note the following examples of journal, book and other reference styles:

Journal article:

1. Berk H, Akçalı Ö, Kıter E, Alıcı E. Does anterior spinal instrument rotation cause rethrolisthesis of the lower instrumented vertebra? *J Turk Spinal Surg.* 1997; 8 (1): 5-9.

Book chapter:

2. Wedge IH, Kirkaldy-Willis WH, Kinnard P. Lumbar spinal stenosis. Chapter 5. In: Helfet A, Grubel DM (Eds.). *Disorders of the Lumbar Spine*. JB Lippincott, Philadelphia 1978; pp: 61-68.

Entire book:

3. Paul LW, Juhl IH (Eds.). *The Essentials of Roentgen Interpretation*. Second Edition, Harper and Row, New York 1965; pp: 294-311.

Book with volume number:

4. Stauffer ES, Kaufer H, Kling THF. Fractures and dislocations of the spine. In: Rockwood CA, Green DP (Eds.). *Fractures in Adults*. Vol. 2, JB Lippincott, Philadelphia 1984; pp: 987-1092.

Journal article in press:

5. Arslantaş A, Durmaz R, Coşan E, Tel E. Aneurysmal bone cysts of the cervical spine. *J Turk Spinal Surg*. (In press).

Book in press:

6. Condon RH. Modalities in the treatment of acute and chronic low back pain. In: Finnison BE (Ed.). *Low Back Pain*. JB Lippincott (In press).

Symposium:

7. Raycroft IF, Curtis BH. Spinal curvature in myelomeningocele: natural history and etiology. *Proceedings of the American Academy of Orthopaedic Surgeons Symposium on Myelomeningocele*, Hartford, Connecticut, November 1970, CV Mosby, St. Louis 1972; pp: 186-201.

Papers presented at the meeting:

8. Rhoton AL. Microsurgery of the Arnold-Chiari malformation with and without hydromyelia in adults. Presented at the *Annual Meeting of the American Association of Neurological Surgeons*, Miami, Florida, April 7, 1975.

- **Tables:** They should be numbered consecutively in the text with Arabic numbers. Each table with its number and title should be typed on a separate sheet of paper. Each table must be able to stand alone; all necessary information must be contained in the caption and the table itself so that it can be understood independent from the text. Information should be presented explicitly in "*Tables*" so that the reader can obtain a clear idea about its content. Information presented in "*Tables*" should not be repeated within the text. If possible, information in "*Tables*" should contain statistical means, standard deviations, and t and p values for possibility. Abbreviations used in the table should be explained as a footnote.

Tables should complement not duplicate material in the text. They compactly present information, which would be difficult to describe in text form. (Material which may be succinctly described in text should rarely be placed in tables or figures.) Clinical studies for example, often contain complementary tables of demographic data, which although important for interpreting the results, are not critical for the questions raised in the paper. Well focused papers contain only one or two tables or figures for every question or hypothesis explicitly posed in the Introduction section. Additional material may be used for unexpected results. Well-constructed tables are self-explanatory and require only a title. Every column contains a header with units when appropriate.

- ***Figures:*** All *figures* should be numbered consecutively throughout the text. Each *figure* should have a label pasted on its back indicating the number of the *figure*, an arrow to show the top edge of the *figure* and the name of the first author. Black-and-white illustrations should be in the form of glossy prints (9x13 cm). The letter size on the figure should be large enough to be readable after the figure is reduced to its actual printing size. Unprofessional typewritten characters are not accepted. Legends to figures should be written on a separate sheet of paper after the references.

The journal accepts color *figures* for publication if they enhance the article. Authors who submit color figures will receive an estimate of the cost for color reproduction. If they decide not to pay for color reproduction, they can request that the figures be converted to black and white at no charge. For studies submitted by electronic means, the figures should be in jpeg and tiff formats with a resolution greater than 300 dpi. Figures should be numbered and must be cited in the text.

- **Style:** For manuscript style, American Medical Association Manual of Style (9th edition). Stedman's Medical Dictionary (27th edition) and Merriam Webster's Collegiate Dictionary (10th edition) should be used as standard references. The drugs and therapeutic agents must be referred by their accepted generic or chemical names, without abbreviations. Code numbers must be used only when a generic name is not yet available. In that case, the chemical name and a figure giving the chemical structure of the drug should be given. The trade names of drugs should be capitalized and placed in parentheses after the generic names. To comply with trademark law, the name and location (city and state/country) of the manufacturer of any drug, supply, or

equipment mentioned in the manuscript should be included. The metric system must be used to express the units of measure and degrees Celsius to express temperatures, and SI units rather than conventional units should be preferred.

The abbreviations should be defined when they first appear in the text and in each table and figure. If a brand name is cited, the manufacturer's name and address (city and state/country) must be supplied.

The address, "Council of Biology Editors Style Guide" (Council of Science Editors, 9650 Rockville Pike, Bethesda, MD 20814) can be consulted for the standard list of abbreviations.

- ***Acknowledgments:*** Note any non-financial acknowledgments. Begin with, "The Authors wish to thank…" All forms of support, including pharmaceutical industry support should also be stated in Acknowledgments section.

Authors are requested to apply and load including the last version of their manuscript to the manuscript submission in the official web address (*www.jtss.org*). The electronic file must be in Word format (Microsoft Word or Corel Word Perfect). Authors can submit their articles for publication via internet using the guidelines in the following address: www.jtss.org.

- Practical Tips:

1. Read only the first sentence in each paragraph throughout the text to ascertain whether those statements contain all critical material and the logical flow is clear.

2. Avoid in the *Abstract* comments such as, "... this report describes..." Such statements convey no substantive information for the reader.

3. Avoid references and statistical values in the *Abstract*.

4. Avoid using the names of cited authors except to establish historical precedent. Instead, indicate the point in the manuscript by providing citation by superscripting.

5. Avoid in the final paragraph of the *Introduction* purposes such as, "... we report our data..." Such statements fail to focus the reader's (and author's!) attention on the critical issues (and do not mention study variables).

6. Parenthetically refer to *tables and figures* and avoid statements in which a table of figure is either subject or object of a sentence. Parenthetic reference places interpretation of the information in the table or figure, and not the table or figure.

7. Regularly count words from the *Introduction* through *Discussion*.

TABLE-1. LEVELS OF EVIDENCE

LEVEL- I .

1) Randomized, double-blind, controlled trials for which tests of statistical significance have been performed
2) Prospective clinical trials comparing criteria for diagnosis, treatment and prognosis with tests of statistical significance where compliance rate to study exceeds 80%
3) Prospective clinical trials where tests of statistical ignificance for consecutive subjects are based on predefined criteria and a comparison with universal (gold standard) reference is performed
4) Systematic meta-analyses which compare two or more studies with Level I evidence using pre-defined methods and statistical comparisons.
5) Multi-center, randomized, prospective studies

LEVEL –II.

1) Randomized, prospective studies where compliance rate is less than 80%
2) All Level-I studies with no randomization
3) Randomized retrospective clinical studies
4) Meta-analysis of Level-II studies

LEVEL– III.

1) Level-II studies with no randomization (prospective clinical studies etc.)
2) Clinical studies comparing non-consecutive cases (without a consistent reference range)
3) Meta-analysis of Level III studies

LEVEL- IV.

1) Case presentations
2) Case series with weak reference range and with no statistical tests of significance

LEVEL – V.

1) Expert opinion and review articles
2) Anecdotal reports of personal experience regarding a study, with no scientific basis

TABLE-2. CLINICAL AREAS

Anatomy
- Morphometric analysis

Anesthesiology
Animal study
Basic Science
- Biology
- Biochemistry
- Biomaterials
- Bone mechanics
- Bone regeneration
- Bone graft
- Bone graft sustitutes
- Drugs

Disc
- Disc Degeneration
- Herniated Disc
- Disc Pathology
- Disc Replacement
- IDET

Disease/Disorder
- Congenital
- Genetics
- Degenerative disease
- Destructive (Spinal Tumors)
- Metabolic bone disease
- Rheumatologic

Biomechanics
Cervical Spine
- Cervical myelopathy
- Cervical reconstruction
- Cervical disc disease
- Cervical Trauma
- Degenerative disease

Complications
- Early
- Late
- Postoperative

Deformity
- Adolescent idiopathic scoliosis
- Kyphosis
- Congenital spine
- Degenerative spine conditions

Diagnostics
- Radiology
- MRI
- CT scan
- Others

Epidemiology
Etiology
Examination
Experimental study
Fusion
- Anterior
- Posterior
- Combined
- With instrumentation

Infection of the spine
- Postoperative
- Rare infections
- Spondylitis
- Spondylodiscitis
- Tuberculosis

Instrumentation
Meta-Analysis
Osteoporosis
- Bone density
- Fractures
- Kyphoplasty
- Medical Treatment
- Surgical Treatment

Outcomes
- Conservative care
- Patient Care
- Primary care
- Quality of life research
- Surgical

Pain
- Chronic pain
- Discogenic pain
- Injections
- Low back pain
- Management of pain
- Postoperative pain
- Pain measurement

Physical Therapy
- Motion Analysis
- Manipulation
- Non-Operative Treatment

Surgery
- Minimal invasive
- Others
- Reconstructive surgery

Thoracic Spine
Thoracolumbar Spine
Lumbar Spine
Lumbosacral Spine
Psychology
Trauma
- Fractures
- Dislocations

Spinal cord
- Spinal Cord Injury

Spinal stenosis
- Cervical
- Lumbar
- Lumbosacral

Tumors
- Metastatic tumors
- Primary benign tumors
- Primary malign tumors

Dear colleagues,

I feel very pleased to have the privilege of publishing 3rd issue of our journal this year. First, I would like to thank the previous editor Professor Dr. İ. Teoman Benli and editorial board for their years of dedicated service period. Their hard work has enabled our journal to reach the highest level of professionalism. This journal has inspired all of us to hone our technical skills so that we can provide cutting edge service to our patients. Our new board promise to continue to provide necessary parameters to our authors to improve quality of articles and level of citations so that we will be promoted to next level of scientific indexes. This is our primary goal.

We like to congratulate the newly elected President and members of administrative board of Turkish Spine Society who are in charge from 2019 to 2021.

There are 10 clinical research, 1 experimental research articles and one case report in this issue. One of the clinical research is from Azerbaijan which was about new technique to prevent Pedicle screw loosening and demonstration of application results. 2nd study is about radiological, MRI based quantitative analysis of the cervical spine and spinal cord in a series of children. In the 3rd study, anatomic dimensions of the spinal canal at thoracolumbar region in Turkish population were analyzed. In 4th article, authors studied about the anatomy of C7 vertebra in Turkish society. In 5th study, the aim of the study was to do morphometric analysis of the pediatric occipital bones and to provide guidance for pediatric occipitocervical fusion. 6th study was about cervical spine alignment parameters of healthy adult patients. 7th study is a MRI study about relationship between disc pathologies and intervertebral disc heights. 8th article was about the early effects of single lumbar epidural injection on the fasting blood glucose. 9th article evaluated the safety and efficacy of Percutaneous Vertebroplasty in patients with Vertebral Compression Fracture patients. 10th study investigated the spinal arachnoid cysts. 10th article is about a new routing device. This experimental original article's aim to show that the transforaminal route for endoscopic lumbar disc herniations is safely applicable with the aid of this device. In this issue, one case report about migration of cement to the vena cava inferior following Polymethylmetacrylate (PMMA) leakage after the Percutaneous Vertebroplasty operation is reported.

We wish all the all Turkish spinal surgeons and their families a healthy, peaceful and productive summer.

Professor Dr. Metin ÖZALAY

JTSS Editor

EDITORIAL

ORIGINAL ARTICLES

SURGICAL TECHNIQUES

MORPHOMETRIC ANALYSIS

RADIOLOGICAL DIAGNOSIS

LUMBAR DISC HERNIATION

PAIN MANAGEMENT

VERTEBRAL AUGMENTATION (VERTEBROPLASTY)

EPIDEMIOLOGY

EXPERIMENTAL STUDY

CASE REPORT

Volume: 30, Issue: 3, July 2019 pp: 151-155 ORIGINAL ARTICLE

NEW TECHNIQUE FOR ADDITIONAL SUPPORT POINT TO IMPROVE THE STABILITY OF PEDICLE SCREW SYSTEMS

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ABSTRACT

Objective: Pedicle screw (PS) fixation for spine arthrodesis is a useful procedure for the treatment of spinal disorders. However, instrument failure often occurs, and PS loosening is the initial step of a range of complications. In order to prevent PS loosening, the author offers to open a hole in the middle of spinous process of vertebra and pass a cross link which connects rods with each other through that hole. The paper provides explanation of an operating technique, clinical impressions in the early and late postoperative period and any technical problems that may occur. The aim of this study is description of a new technique to prevent PS loosening and demonstration of application results.

Materials and Methods: The technique we propose has been applied for two years to 24 patients with idiopathic scoliosis, 4 patients with vertebral fracture and 4 patients with lumbar stenosis, all aged between 13 and 65.

Results: The modification can be easily conducted and takes no more than 2- 5 minutes. None of the patients had any unusual or pronounced pain in the shaft zone in early postoperative period and no movement restriction or any other clinical symptoms can be observed. None of the patients have had loosening or displacements of screws for two years.

Conclusion: The technique for support of spinous processes is efficient and easy which prevents PS loosening and creates no further complications. It does not thoroughly modify the principles of fixation and require any special instruments, therefore it can widely be used.

Key words: implant failure, loosening, pedicle screw fixation, pedicle screw loosening, spine surgery

Level of evidence: Retrospective clinical study, Level III

INTRODUCTION

In 1959, Boucher was the first to penetrate into the vertebral body through the pedicle, describe the possibility of fixation passage [5]. There have been no significant changes in the design of segmental pedicle systems since 1959 up to now. We should point out screws that pass through the main vertebral body and support spongious bone circular thread blades and rods that connect them with each other. Three factors are required to obtain successful and longstanding fixation: quite hard bone, non-releasable tightening metal elements which keep rods firm and above-construct strong scar if possible. Thus, there are three factors to keep the structure firm:

1. Spongious material of the vertebral body to be the only contact area of vertebrae and metal implant;

2. Tightening elements of regular metal screws and metal screws for fixation;

3. Transverse ties to reduce the rod movements when the patient moves and ensure once again metal - metal contact;

4. Above-construct scar that has a relatively low effect, prevents the construct from coming out of the bone and ensures the second metal — tissue contact.

Generally, the metal and the bone are always in conflict during metal implantation due to their different density, which results in atrophy in the bone because of metal pressure, and local osteoporosis can lead to the loosening and dislocation of pedicle screws in 3 - 6 months postoperatively. Clinically, this state reveals itself by pain, inflammation, purulence and the loss of correction in case of deformity and finally results in the appearance of the construct under the skin.

Pull-out may also occur with patients as a result of osteoporosis. The screws can also be displaced during the operation that may occur in cases when the unbalancing force is applied, the direction of force is parallel to screw, the transverse size of the screw is thinner than the width of the pedicle or when the screw fails to reach the anterior part of the body.

Taking all the above-mentioned into consideration, we offer to create the second contact and support point by forming a contact with another element of vertebra, apart from the contact of pedicle screw into spinal construct with the vertebral body. We propose to refuse to place the component earlier called DDT and later - Cross Link Shaft among the rods instead of the posterior process upon its resection and let it pass through the transverse hole opened in the middle of processus spinosus. Therefore, when fixing the rods by putting the shaft through the hole with a lying patient, the support of the construct on that hole and posterior process can reduce the patient's micro-motions in the sagittal plane and impede or eliminate the occurrence of atrophy, osteoporosis and Looser's zones as a result of pressure relief around the blade during the fixation of the construct and flexion motions while placing the patient vertically.

MATERIALS AND METHODS

The current retrospective study assesses the outcomes of a new technique which was performing as the application of Cross Link through spinous processes. The study was performed in the department of adult orthopedics in Azerbaijan Research Institute of Traumatology and Orthopedics.

Application technique

When seeking for a place to put Cross Link after the implantation of pedicle screws and rods, we have to pay attention to whether the spinous processes are wide and thick. If the lowest instrumented Vertebra is L5, the level of its placement can be L4 or L5. Once the construct is for vertebral fracture and covers the short number of segments, it should be noted that pull-out cases mainly occur in vertebrae with straight, not angle-wise pedicles which covers the thoracolumbar region, namely the vertebrae above L3 [(3)].

When we cause the cross link pass the hole, we should not think of the osteoporotic vertebra, but bring pedicles closer to axial vertebrae where, according to the reference literature, potential screw loosening is higher. The second factor is that the spinous process' size. It is hardly likely that the cross link would break the hole in case of a wider process and such a case has never been observed by us. Upon the selection of the spinous process of the necessary vertebra, the middle and the lower part of the spinous process is perforated by a custom made perforating instrument and a hole is opened. When opening the hole, the base of the spinous process should be selected because it is thicker and stronger than the top. Also, the level of rods must be taken into consideration so that after the cross link has been passed through the opened hole we could reach it out placing on the rods to put it inside the hooks and fix. If the custom made perforating instrument is not available, the hole can be opened by high speed burr.

The perforating end of the instrument must be of a size to let the Cross Link pass the hole. Afterwards, the Cross Link is passed through the hole using regular Luer's forceps and put inside the hooks placing on the rods and the locks clinched. Then we check whether the posterior and anterior wall of the hole of spinous process is broken or not. If broken, the sizes of the broken part have to be considered, the cross link needn't to be removed if its upper part is covered by a big bone mass and the fracture occurs laterally, cross link must be removed and the manipulation is conducted in another process if fracture in the upper part occurs.

Cross Link simply fixes two rods together and bring their rotational movement to zero; here the spinous process is undergone to resection. The proposed technique is shown in Figure-1and here the shaft once again fixes two rods together, it is just placed by passing through the hole opened in the middle of the spinous process, that prevents not only the movement of the rods, but also the displacement of the screws backward (Figure-2).

We re-operated a scoliosis patient to treat pelvic tilt and another scoliosis patient to treat sagittal imbalance one year after postoperatively and examined the Cross Links inside the spinous processes. Cross Link passing through the spinous process is seen; the process is intact and unbroken. The clinches of the hooks are opened and the Cross Link is removed from the hole using Luer's forceps. We put the thread through the hole to prove that it is intact. We show that the hole is intact by passing the Cross link once again through it without hooks (Figure-2-8).

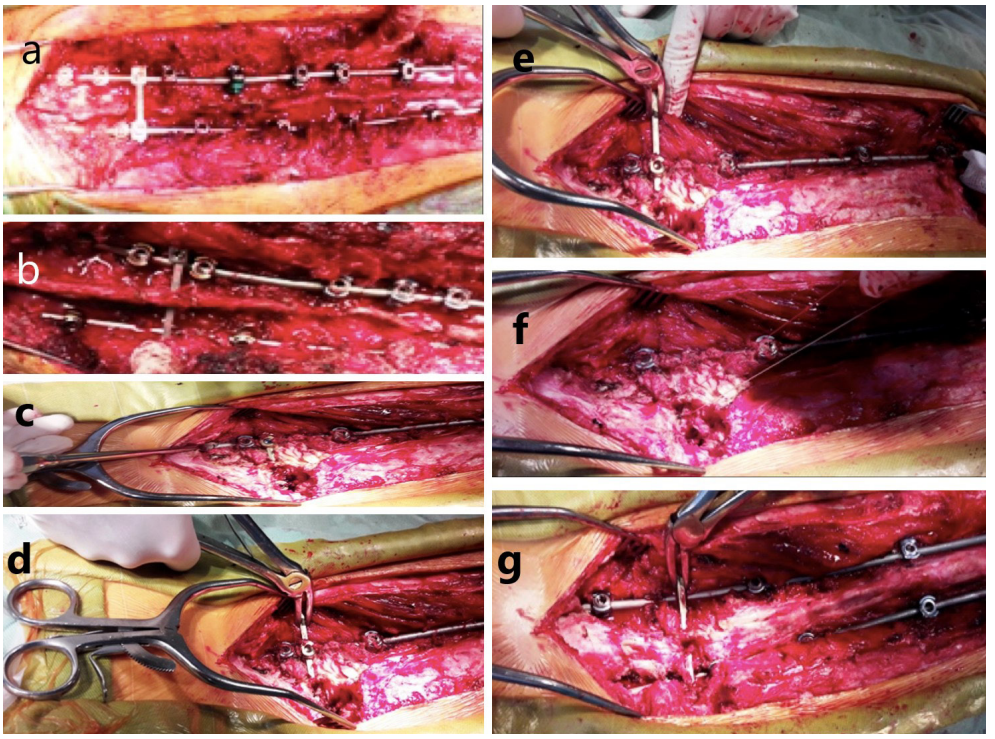

Figure-1. (a) Stabilization of cross-link between the rods, **(b)** cross-link passing through the hole of the spinous process, **(c)** postoperative figure of proposed method, **(d)** hook screws are opened and the cross-link removed, **(e)** removal of the cross-link, **(f)** intact spinous process hole, the thread is pushed through the hole to prove it, **(g)** the shaft is repeatedly pushed through the hole to prove that it is intact.

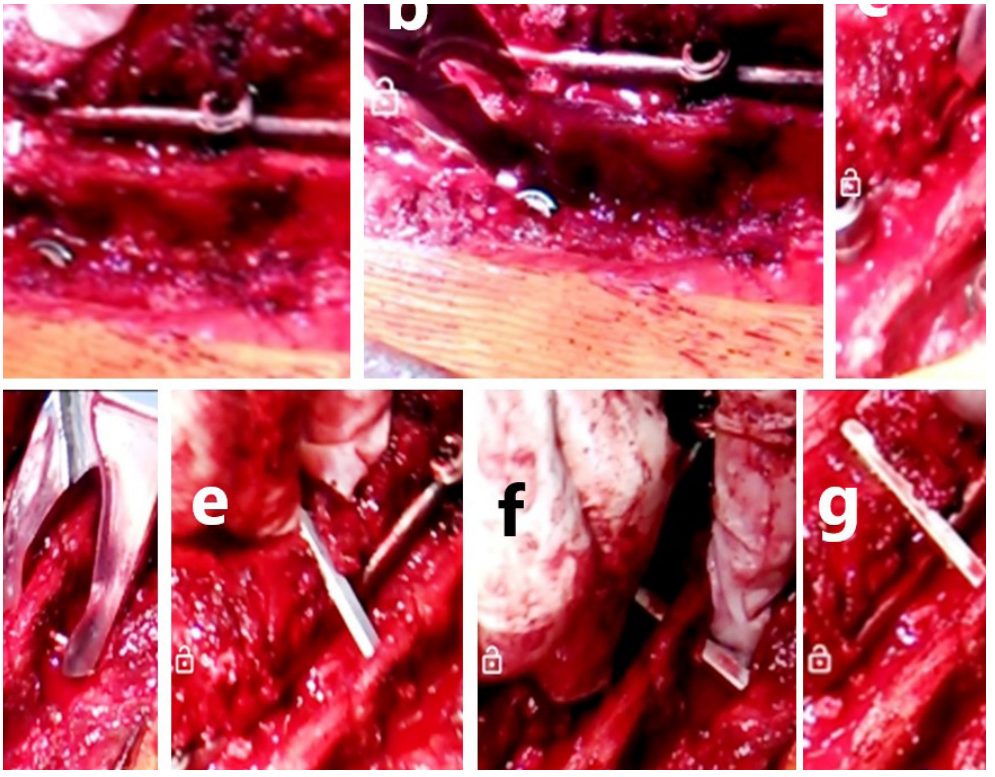

Figure-2. (**a-g**) Technique cross-link rod in to the spinous process with close-up view.

RESULTS

The technique we propose has been applied for 2014-2018 to 24 patients with idiopathic scoliosis, 4 patients with vertebral fracture and 4 patients with lumbar stenosis, all aged 13-65. The modification we propose can be easily conducted technically and takes no more than 2-5 minutes. None of the patients had any unusual pain or pronounced pain in the Cross Link zone in the early postoperative period. No movement restriction was applied. Any complication was not observed postoperatively. None of the patients had loosening or displacements of screws for two years. We think that the technology does not thoroughly modify the principles of fixation and require any special instruments and skills to be applied, so it can widely be used easily.

DISCUSSION

The implant loosening and displacement may occur with patients during the implantation of pedicle screw systems. Thus, in 2014 Abul Kasim and Ohlin examined 1666 pedicle screw displacement with 81 patients suffering from idiopathic scoliosis by low dose CT within two years and published the results. In 26 (32 %) patients there were signs of loosening of one or more screws, a maximum 3 screws. In males there were signs of loosening in 57 % and in females 27 %. One patient with a loosened L-4 screw had neurological deficit. Out of 26 patients with evidence of loosening, 5 patients reported displacement in lumbar region [(2)].

In 2014 Mavrogenis et al considered that loosening occurs due to the stiffness of rods proposed to use rods made from the polyetheretherketone (PEEK) and applied it practically [(12)]. As PEEK is more elastic and tolerant to body tissues it has a wide potential to be used in future. Kang et al also spread an information on the use of Polymethylmethacrylate cement to keep the screws more stable in osteoporotic patients [(8)].

In 2016 Leichtle et al. compared the use of solid pedicle screw, solid pedicle screw augmented with high-viscosity cement and fenestrated screw with cement by special pulling mechanisms in a total of 54 osteoporotic human cadavers. As a result, solid pedicle screws with high-viscosity cement provided comparable screw stability in pull-out testing to that of more expensive fenestrated screws, and the use of 1 mL in the thoracic and 3 mL in the lumbar spine was recommended [(1,4,9)]. Leitner et al attributed pedicle screw loosening to chronic infection [(10)]. Ohe M. et al give information on the use of pedicle screws with a thin hydroxyapatite surface coating in patients with osteoporosis [(11,14)]. Drummond's biomechanical analyses prove that the subspinous region is 117 % thicker and firmer than sublaminar region in the thoracic vertebrae and 73 % in the lumbar vertebrae [(6)]. In 2018 Fu J et al. are reported to apply new-designed high-priced expandable pedicle screws to a total of 27 patients in order to solve the problem in osteoporotic patients and manage to do it partially[(7)].

In 2018, Mizuno T. et al have tested a cross-link model and a cross-rod model for stability and proved the cross-link model to be more stable than the cross-rod one [(13,15)]. Authors says that surgery with pedicle screw instrumentation does not provide sufficient torsional stability. This leads to pseudoarthrosis, loosening of the pedicle screws and ultimately, implant failure. They use 6-axis material testing machine. As the specimen models, they prepared an intact model, a damaged model, a cross-rod model and a crosslink model. They measured the range of motion during the bending and rotation tests. In 2017 Wang Z et al. made a biomechanical study of double level pedicle screw construct with or without crosslink in an unstable model [(16)]. Ten cadaveric lumbar spines [(13-15)] of boars were used and 7 models were prepared by the sequential damage and spinal instrumentation of each specimen. Bending stiffness was measured in flexion, extension, lateral bending and axial rotation for each model using 6 –axis material tester under torgue of 0 to ±3Nm. In conclusion they said that contaminant use of CLs significantly increased axial rotational stiffness, even though stiffness in flexion, extension and lateral bending was not increased. In addition, stiffness in axial rotation significantly improved with the use of 2 crosslinks instead of single CL, and stiffness was unchanged by position and orientation of CL.

CONCLUSION

The cross-link technique we propose creates an additional support point for the pedicle screw system, but the number of cross-links passed through spinous processes can be increased individually, subject to pathology and bone density. Therefore, screw loosening mainly occurs posteriorly and the direction of the pedicle, the thickness and length of the screw, occurrence of chronic infection, osteoporosis, the number and level of instrumented segments are important. Cross-link technique helps to reduce screw movements in every directions and increase the stability of screws, and may prevent pain and greater complications relating to loosening in the early and late postoperative period.

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Volume: 30, Issue: 3, July 2019 pp: 157-161 ORIGINAL ARTICLE

ANALYSIS OF MRI MORPHOMETRIC PARAMETERS OF THE PEDIATRIC CERVICAL SPINE AND SPINAL CORD

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ABSTRACT

Background Data: There have been no standardized morphometric measurements of the pediatric cervical spine. This study provides the first radiological quantitative analysis of the cervical spine and spinal cord in a series of children.

Purpose: This study provides the first radiological, MRI based quantitative analysis of the cervical spine and spinal cord in a series of children

Materials - Methods: We retrospectively reviewed the records of 24 pediatric patients who had undergone spinal MRI's due to various reasons. The morphometric measures of spinal canal to vertebral body ratio (CBR), which is calculated by dividing the antero-posterior diameter of the spinal canal by the antero-posterior diameter the vertebral body, antero-posterior and transverse diameter of the spinal canal and cord, ratio of the antero-posterior diameter to the transverse diameter of the cord (RAPT) and cross-sectional surface area of the dural tube and spinal cord were made.

Results: There were 8 males and 16 females, with a mean age of 11.79±5.25 years (range 2–17 years). The measurements revealed the AP diameter of the spinal canal at the upper cervical spine levels (C1 and C2 levels) as well as the antero-posterior and transverse diameters of the spinal cord were measured slightly wider than lower levels, however there was no statistically significant difference between genders.

Conclusion: The revelation of normative radiographic measurements for the developing pediatric cervical spine is important for treatment decisions. Studies like ours will help to provide the basis for appropriate measurements, therefore adequate instrumentation for the pediatric population.

Keywords: Cervical spine, morphometric analysis, pediatric

Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

The revelation of normative radiographic measurements for the developing pediatric cervical spine is an ongoing process. Few previous studies have provided data on single cervical segments, the craniovertebral junction or surgical anatomy of pedicles and lateral masses [1,6,14]. Each of these studies has defined some normal ranges for the pediatric cervical spine; there have been no reports on correlation of measurements of the entire pediatric cervical spine with age and gender. Understanding the expected normal growth of the cervical spine for each gender and age group is the key to determine the treatment decisions [4,8]. Therefore the purpose of this analysis is to determine the normal range of cervical spinal canal, cervical spinal cord and define age and gender related differences.

MATERIALS AND METHODS

Ethical approval was not sought for this study because of retrospective nature of the study and consent was not obtained as no personal information was revealed.

A retrospective review of children aged between 2 to 17 referred to our institute due to trauma, pain or any other complaint requiring spinal investigation between January 1, 2015, and January 1, 2019 and had undergone a magnetic resonance imaging (MRI) of the cervical

spine was performed in this study. The mean age at referral was 11.79±5.25 years. Measurements were obtained with a 1.5-T MR imager (Magnetom SP, Siemens, Erlangen, Germany). During MRI, the patients were in the neutral supine position. T1-weighted, T2-wighted sagittal and axial images with a slice thickness of 3 mm of Digital Imaging and Communications in Medicine (DICOM) standard were used for analysis using available Picture Archiving and Communications System (PACS) measurement software (Agfa Gevart).

All linear measurements and the axial transverse area measurements were taken at the mid-vertebral levels. For measurements of C1 and C2, the midpoint of C1 ring and C2 mid-body were used as reference points. The cross-sectional surface areas of the spinal canal and spinal cord were measured by tracing the perimeter of the structures with a cursor, a function of PACS. The morphometric information obtained were as follows: spinal canal to vertebral body ratio (CBR), also known as the Torg ratio, which is calculated by dividing the antero-posterior diameter of the spinal canal by the antero-posterior diameter the vertebral body (Figure-1) [9], anterio-posterior (AP) diameter of the spinal canal and cord (Figure-2), the transverse diameter of the spinal cord, ratio of the antero-posterior diameter to the transverse diameter of the cord (RAPT) and cross-sectional surface area of the dural tube and spinal cord (Figure-3). The measurements of the vertebral bodies include both the bony anatomy and soft tissue. All measurements were performed by the same investigator. Statistical analyses were performed using All statistical analyses were performed using SPSS version 22.0 (IBM Inc.). Continuous variables were expressed as mean ± standard deviation (SD). The Student t-test was used to compare parameters between males and females, and statistical significance was accepted with a p-value <0.05.

RESULTS

24 patients (16 females and 8 males) were included in this study. The mean age was 11.79 ± 5.258. The mean age of female patients were 12.25±5.398, and male patients were 10.88±5.194. Spinal canal to vertebral body ratio (CBR) is the radiographic equivalent of Torg ratio on MRI [9] (Figure-1). The mean CBRs are 0.84 for females and 0.78 for males at C2 vertebral level, 0.97 for females and 0.89 for males at C3, 1.04 for females and 0.97 for males at C4, 1.01 for females and 0.98 for males at C5, 1.06 for females and 1.02 for males at C6 and 1.03 for females and 1.08 for males at C7 (Table-1).

C1 does not have a body therefore there is not any CBR for C1. There are not any statistically significant variations between cervical levels of female patients to male patients.

The AP diameters of the cervical spinal canal and the cord are shown in Table-2 and Figure-2. The AP diameter of the spinal canal at the upper cervical spine levels (C1 and C2 levels) were measured wider than lower levels, however no statistically significant difference was found.

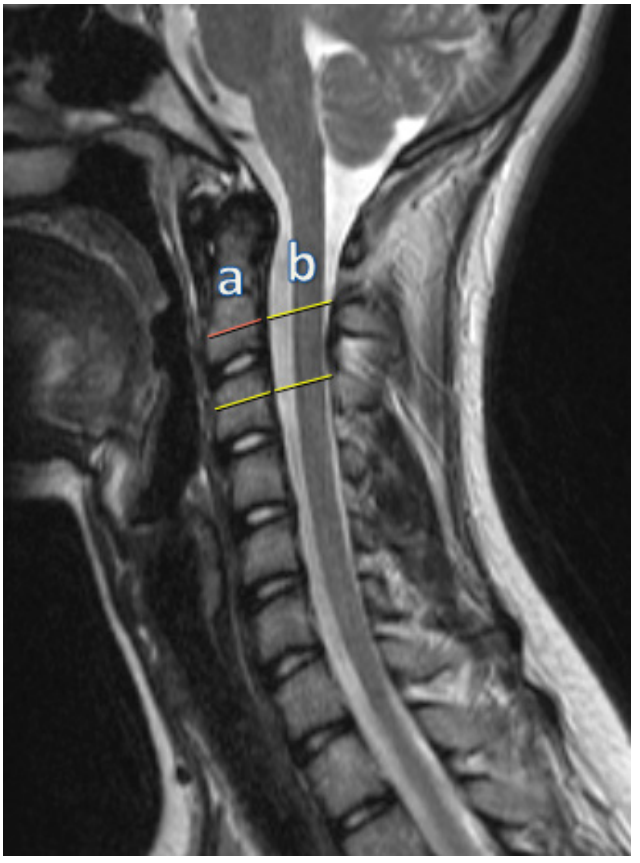

Figure-1. Sagittal section of T2-weighted MRI showing the measurements of the AP diameter of the vertebral bodies **(a)** and spinal canal **(b)**, at the mid-vertebral levels. CBR = b/a

Table-1. The mean values and standart deviations of canal body ratio and cross-sectional area of the cord from C1 to C7 levels for female and male patients.

Level	Canal Body Ratio		Cross-sectional area (mm^2)	
	Female	Male	Female	Male
C1	-	-	0.73±0.19	0.71±0.10
C2	0.84±0.14	0.78±0.13	0.71±0.12	0.72±0.11
C3	0.97±0.31	0.89±0.16	0.76±0.15	0.81±0.15
C4	1.04±0.20	0.97±0.22	0.81±0.08	0.86±0.18
C5	1.01±0.21	0.98±0.23	0.81±0.12	0.87±0.17
C6	1.06±0.27	1.02±0.22	0.73±0.12	0.80±0.13
C7	1.03±0.22	1.08±0.24	0.65±0.19	0.72±019

Table-2. Antero-posterior diameters of spinal canal and spinal cord from C1 to C7 levels at female and male patients (SD: standart deviation)

Level	Antero-posterior Spinal canal diameter (mm) (mean±SD)		Antero-posterior cord diameter (mm) (mean±SD)	
	Female	Male	Female	Male
C1	1.61±0.25	1.71±0.18	0.75±0.10	0.69±0.13
C2	1.41±0.23	1.58±0.13	0.73±0.07	0.75±0.07
C3	1.25±0.16	1.39±0.15	0.71±0.10	0.72±0.08
C4	1.23±0.19	1.31±0.12	0.72±0.07	0.79±0.17
C5	1.22±0.17	1.34±0.13	0.78±0.24	0.75±0.10
C6	1.25±0.17	1.37±0.12	0.67±0.11	0.69±0.07
C7	1.27±0.17	1.35±017	0.68±0.08	0.74±0.12

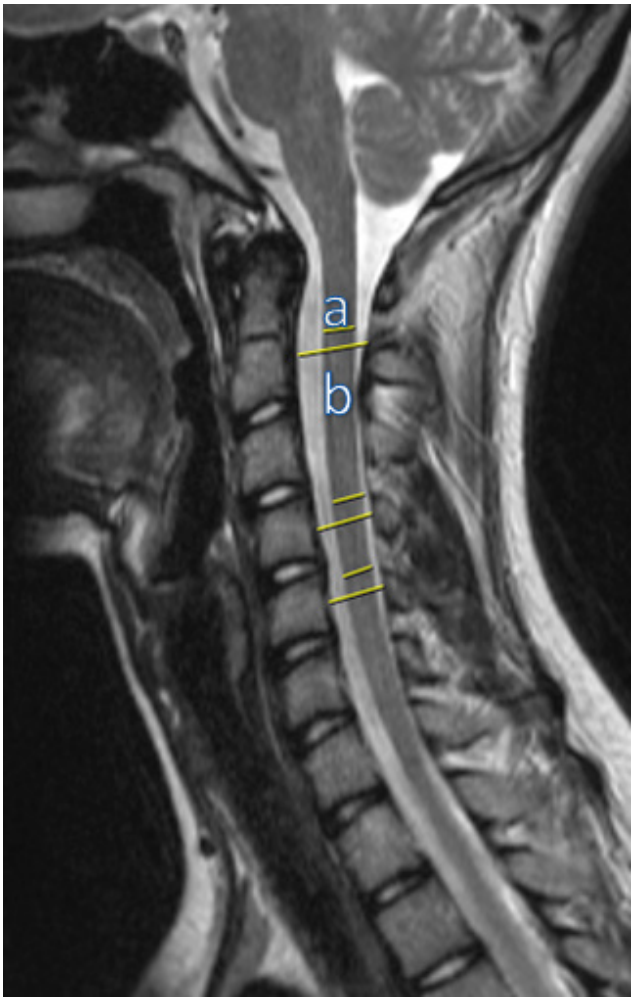

Figure-2. Sagittal section of T2-weighted MRI showing the measurements of the AP diameter of the spinal canal **(a)** and spinal cord **(b)**. All the measurements are taken at the mid-vertebral levels

The cross-sectional surface areas of the spinal canal and cord are summarized in Table-3 and Figure-3. The spinal canal shows a narrowing through C1 to C7 levels, however the variation in spinal canal cross-sectional surface area is not significant. The spinal cord is narrowest at C1and C7 level (73 and 65 mm2 for females, 71 and 72 mm2 for males, respectively), again there is not a significant inter-level variation in area. The ratio of the spinal cord antero-posterior to transvers diameter ratio (RAPT) may be seen in Table-4.

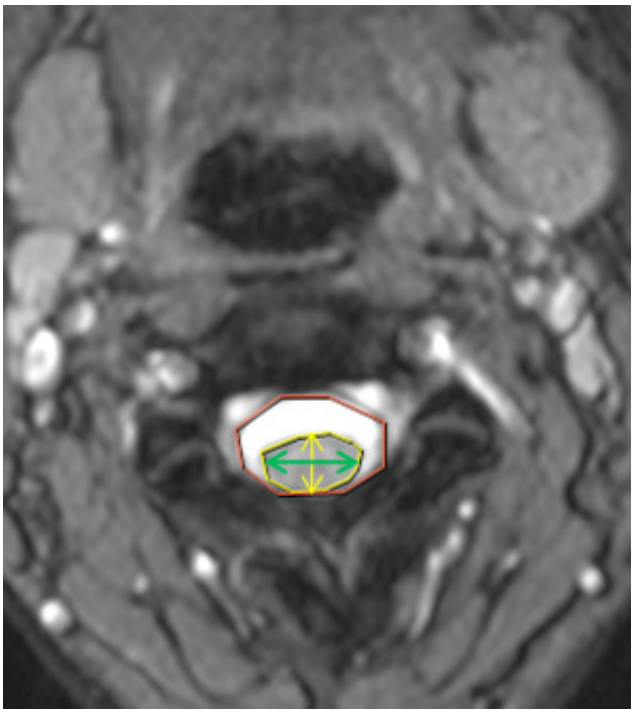

Figure-3. Axial section of T2-weighted MRI showing the measurements of antero-posterior diameter **(yellow arrow)** and transverse diameter **(green arrow)** of the cord, from which RAPT is calculated and cross-sectional area of the spinal canal **(red line)** and spinal cord **(yellow line)**

A displacement at the spinal cord into the potential space of the lateral recesses with a change in shape from round to oval, when compressed in an antero-posterior direction is also observed. While the variations of any parameters are not gender-dependent and the only statistically significant difference was found between gender and age (p-value <0.05).

Table-3. Cross-sectional areas of spinal canal and spinal cord, and canal to cord area ratios from C1 to C7 levels at female and male patients (SD: standart deviation)

Level	Spinal canal cross-sectional area (mm2) (mean±SD)		Spinal cord cross-sectional area (mm2) (mean±SD)		Spinal cord to canal area ratio (mean±SD)	
	Female	Male	Female	Male	Female	Male
C1	2.68±0.59	2.56±0.60	0.73±0.19	0.71±0.10	0.28±0.07	0.31±0.17
C2	2.36±0.71	2.47±0.27	0.71±0.12	0.72±0.11	0.32±0.08	0.29±0.03
C3	2.05±0.38	2.11±0.41	0.76±0.15	0.81±0.15	0.37±0.07	0.39±0.08
C4	2.04±0.44	2.14±0.34	0.81±0.08	0.86±0.18	0.41±0.07	0.41±0.09
C5	2.02±0.38	2.14±0.49	0.81±0.12	0.87±0.17	0.41±0.10	0.42±0.12
C6	1.96±0.40	2.14±0.43	0.73±0.12	0.80±0.13	0.38±0.06	0.33±0.15
C7	1.91±0.42	2.06±0.41	0.65±0.19	0.72±0.19	0.34±0.08	0.35±0.06

Table-4. The mean values and standart deviations of antero-posterior diameter, transverse diameter of the spinal cord and RAPT. *RAPT:* Ratio of the antero-posterior diameter to the transverse diameter (= cord antero-posterior diameter/ cord transverse diameter)

Level	Antero-posterior cord diameter (mm)		Transverse cord diameter (mm)		Cord RAPT	
	Female	Male	Female	Male	Female	Male
C1	0.75±0.10	0.69±0.13	1.11±0.15	1.18±0.06	0.68±0.08	0.58±0.10
C2	0.73±0.07	0.75±0.07	1.14±0.15	1.18±0.05	0.65±0.09	0.63±0.05
C3	0.71±0.10	0.72±0.08	1.17±0.11	1.23±0.07	0.61±0.12	0.58±0.04
C4	0.72±0.07	0.79±0.17	1.26±0.12	1.32±0.05	0.58±0.09	0.60±0.12
C5	0.78±0.24	0.75±0.10	1.27±0.12	1.26±0.11	0.63±0.27	0.60±0.11
C6	0.67±0.11	0.69±0.07	1.21±0.14	1.26±0.08	0.56±0.13	0.55±0.04
C7	0.68±0.08	0.74±0.12	1.09±0.20	1.10±0.14	0.63±0.09	0.68±0.15

DISCUSSION

The expected normal growth for each age and gender group at pediatric patients are important for making treatment decisions like cervical spine instrumentation and fusion [4]. The morphologic anatomy of spinal canal and cord in adult population is however the precise morphometric measures for pediatric cervical spine remains elusive.

Proliferation of radiological imaging options may help to develop single standard defining measurements. With its widespread availability and use in Turkey, operator independence, high resolution, and lack of radiation exposure, MRI is often used in the evaluation of the pediatric cervical spine.

Pavlov et al proposed the ratio of the sagittal diameters of the spinal canal and the vertebral body, which is known as the Torg ratio, in 1987 as a radiographic measure of spinal canal stenosis and showed an increased risk for neurologic injury and significant spinal stenosis when the ratio was less than 0.80 or 0.70 respectively [9]. We used the same ratio to measure the pediatric cervical spine and found the similar results. Studies commonly suggest that the pediatric cervical spine matures and becomes closer to an adult cervical spine at around 9 years of age [2-3]. Robinson et al reported a gender divergence of canal/body ratio which seemed to appear after the age of 15 years. The vertebral canal/body ratio was similar in both genders until the age of 15 year however through to adulthood it became consistently smaller in males than in females at every measured level [11]. In our study we also found no gender predisposition at the vertebral canal/body ratio until the age of 17. The vertebral canal/body ratios of pediatric patients of our study were similar to the data of Ishikawa et al in their study of 229 healthy subjects aging from 11 to 72 years [5].

In their study Johnson et al suggested that growth of the spinal diameter of the canal is nearly complete by age 4, instrumentation and fusion after this age would have minimal effect on halting further growth of the spinal canal that could lead to spinal stenosis [3]. In our study we found spinal canal diameter continued to widen with age however our subject number is not enough to make a statement.

In healthy adults, the spinal canal antero-posterior diameter at C1 level measures 22 mm (ranging 20–26 mm), which decreases to 20 mm at C2, and to 14 and 22 mm between C3–7. The antero-posterior diameters of adult cervical spinal cord at C1 measures 10.4 mm (7–11 mm), which decreases to 9 mm (ranging 7 to 10 mm) at C2, with an average of 8.5 mm (6–9 mm) between C3–7. The transverse cervical cord measures 10–14 mm [12].

Our measurements showed that at C1 and C2 levels, the antero-posterior and transverse diameters of the spinal cord are slightly wider than lower segments also spinal canal antero-posterior diameters are reduced at C7 levels with no female-male difference.

Several studies have previously reported more limited morphometric changes in the developing pediatric cervical spine [7,10,13]. Our study is unique because it comprehensively measures all cervical vertebral bodies, spinal cord anterio-posterior and transverse diameters at each levels, and overall spinal canal and spinal cord areas of the entire cervical spine from C1 to C7 segments. We hope that studies like ours helps to provide the basis for appropriate measurements, therefore adequate instrumentation for the pediatric population.

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Volume: 30, Issue: 3, July 2019 pp: 163-167 ORIGINAL ARTICLE

RADIOGRAPHIC EVALUATION OF THE RELATIONSHIP BETWEEN SPINAL CANAL AREA AND THE ANATOMIC DIMENSIONS OF THE SPINAL CANAL AT THE THORACOLUMBAR JUNCTION IN THE TURKISH POPULATION

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ABSTRACT

Aim: To investigate the relationship between spinal canal area and the anatomic dimensions of the spinal canal at the thoracolumbar junction measured by computed tomography (CT) in the Turkish population.

Materials and Methods: The retrospective study reviewed the CT records of 100 consecutive patients that presented to the emergency services in Koc University Hospital. Measurements were performed for the anatomic dimensions of the spinal canal in both T12 and L1 by the same physician. The anatomic dimensions of the spinal canal including pediculolaminar angle, interlaminar angle, bipedicular base distance, spinal canal anterior-posterior (AP) diameter, spinal canal transverse diameter, and spinal canal area were measured and their relationships with spinal canal area were analyzed.

Results: The 100 patients comprised 62 (62%) women and 38 (38%) men with a mean age of 48 (range, 16-87) years. A significant difference was found between T12 and L1 with regard to bipedicular base distance in women and no significant difference was found between T12 and L1 in both men and women. In both T2 and L1, although spinal canal area had no significant correlation with the pediculolaminar and interlaminar angles, it had a moderate correlation with spinal canal transverse diameter, spinal canal AP diameter, and bipedicular base distance.

Conclusion: The results indicated that no significant relationship was found between spinal canal area and the pediculolaminar and interlaminar angles while a significant relationship was found between spinal canal area and spinal canal transverse diameter, spinal canal AP diameter, and bipedicular base distance in both T12 and L1. Moreover, no significant relationship was found between age and spinal canal area in these vertebrae.

Key words: Spinal canal area, bipedicular base distance, AP diameter.

INTRODUCTION

Morphometric analysis of the spine has been performed in numerous radiographic studies via computed tomography (CT) or magnetic resonance imaging (MRI) [1,6]. Some of these studies focused on selected areas in the spine while the others examined the whole spine [4,9]. Moreover, while some of these studies focused on either children or old-age individuals, the others evaluated both patient groups [7,10].

Spinal disorders resulting from traumatic, degenerative, and inflammatory conditions lead to spinal canal stenosis which has been associated with an increased risk of spinal cord injury. Literature indicates that the thoracolumbar junction (T12-L1) is the most common site for lumbar spine injury [8]. In the present study, we investigated the relationship between spinal canal area and the anatomic dimensions of the spinal canal measured by computed tomography (CT) in T12 and L1 and we also evaluated the effect of age on the changes in spinal canal in the Turkish population. Additionally, we evaluated the measurements for both genders.

MATERIALS AND METHODS

The retrospective study reviewed the CT records of 100 consecutive patients

that presented to the emergency services in Koc University Hospital and underwent thoracolumbar CT for any reason and had no signs of fracture. Patients with prior surgery in the thoracolumbar junction were excluded from the study. The patients were initially evaluated as a whole group and then were evaluated and compared in two groups: men and women. Measurements were performed for the anatomic dimensions of the spinal canal in both T12 and L1. These measurements included pediculolaminar angle (angle between the pedicle and lamina), interlaminar angle (angle between two laminae), bipedicular base distance (distance between two pedicle base), spinal canal anterior-posterior (AP) diameter, spinal canal transverse diameter, and spinal canal area (Figure-1).

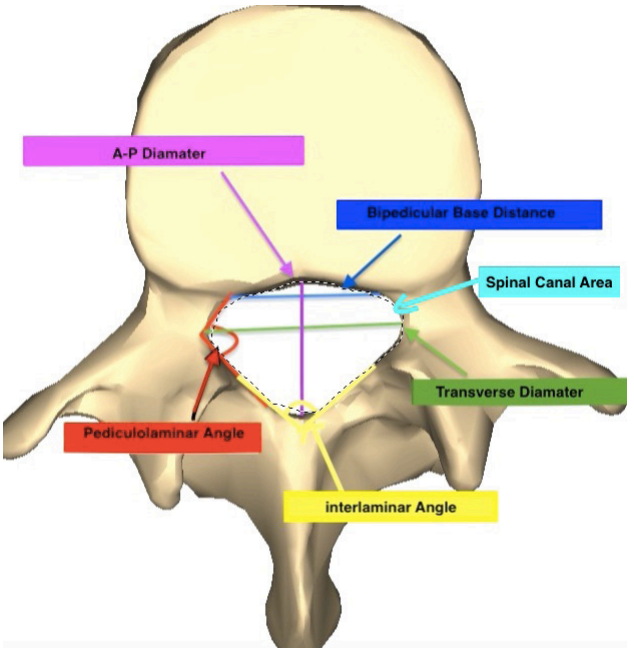

Figure-1. Schematic representation of measurements

Relationships between spinal canal area and the anatomic dimensions of the spinal canal were analyzed. Moreover, correlation between age and spinal canal area was also examined. All the CT scans (Siemens, Munich, Germany) were obtained in an axial plane using a standardized protocol. The images were reviewed on a PACS workstation (General Electric Healthcare, Little Chalfont, United Kingdom). All the measurements were performed by the same physician.

Statistical analysis

Sample size was determined using the following formula: n= t2pq/d2. In this formula;

n: total number of individuals to be included in the sample

t: theoretical value calculated according to the T-distribution table based on a certain significance level

p: probability of occurrence

q: probability of nonoccurrence

d: deviation from prevalence (sampling error)

Correlations between numerical data were analyzed using Pearson's Correlation Coefficient. Means were compared between the two groups using Independent Samples *t*-test.

RESULTS

The 100 patients comprised 62 (62 %) women and 38 (38 %) men with a mean age of 48 (range, 16-87) years. Bipedicular base distance was significantly larger in T12 compared to L1 (p=0.037), although no significant difference was found in the other dimensions (Table-1).

Table-1. Comparison of measurements in T12 and L1

		n	Mean	SD	*p*
A-P diameter (mm)	T12	100	17.92	1.55	0.691
	L1	100	17.82	1.71	
Transverse diameter (mm)	T12	100	24.07	2.30	0.224
	L1	100	24.46	2.18	
Bipedicular base distance (mm)	T12	100	18.18	2.04	**0.037**
	L1	100	18.75	1.78	
Pediculolaminar angle (^{0})	T12	100	96.41	11.23	0.267
	L1	100	98.06	9.59	
Spinal canal area (mm^2)	T12	100	265.44	38.46	0.625
	L1	100	268.14	39.53	
Interlaminar angle (^{0})	T12	100	105.92	12.24	0.089
	L1	100	108.33	6.96	

SD: Standard deviation; $p<0.05$

A significant difference was found between T12 and L1 with regard to bipedicular base distance in women (p=0.035) while no significant difference was found in men (p=0.450). In the remaining dimensions, however, no significant difference was found between T12 and L1 in both men and women ($p>0.05$) (Tables-2, 3).

Table-2. Comparison of measurements in T12 and L1 in women

		n	Mean	SD	*p*
A-P diameter (mm)	T12	62	17.84	1.54	0.905
	L1	62	17.88	1.61	
Transverse diameter (mm)	T12	62	23.77	2.16	0.278
	L1	62	24.22	2.33	
Bipedicular base distance (mm)	T12	62	17.96	1.94	**0.035**
	L1	62	18.68	1.75	
Pediculolaminar angle (^{0})	T12	62	97.70	11.45	0.855
	L1	62	98.06	10.34	
Spinal canal area (mm^2)	T12	62	262.80	39.39	0.527
	L1	62	267.30	38.88	
Interlaminar angle (^{0})	T12	62	104.07	14.54	0.063
	L1	62	108.02	7.65	

SD: Standard deviation; $p<0.05$

Table-3. Comparison of measurements in T12 and L1 in men

		n	Mean	SD	*p*
A-P diameter (mm)	T12	38	18.03	1.56	0.461
	L1	38	17.74	1.87	
Transverse diameter (mm)	T12	38	24.53	2.47	0.549
	L1	38	24.83	1.89	
Bipedicular base distance (mm)	T12	38	18.52	2.17	0.450
	L1	38	18.87	1.83	
Pediculolaminar angle (^{0})	T12	38	94.40	10.81	0.100
	L1	38	98.06	8.41	
Spinal canal area (mm^2)	T12	38	269.55	37.08	0.989
	L1	38	269.43	41.00	
Interlaminar angle (^{0})	T12	38	108.80	6.55	0.993
	L1	38	108.82	5.78	

SD: Standard deviation; $p<0.05$

Correlation analysis

Anatomic dimensions in T12

Spinal canal area had no significant correlation with pediculolaminar angle (r=-0.006; n=100; p=0.949) and interlaminar angle (r=0.109; n=100; p=0.279) for both genders. However, spinal canal area had a moderate correlation with spinal canal transverse diameter (r=0.729; n=100; p=0.000), spinal canal AP diameter (r=0.620; n=100; p=0.000), and bipedicular base distance (r=0.620; n=100; p=0.000). On the other hand, no correlation was found between age and the measurements in T12.

In women, no significant correlation was found between spinal canal area and pediculolaminar angle (r=0.078; n=62; p=0.578) and interlaminar angle (r=0.030; n=62; p=0.818). However, spinal canal area had a moderate correlation with spinal canal transverse diameter (r=0.678; n=62; p=0.000), spinal canal AP diameter (r=0.650; n=62; p=0.000), and bipedicular base distance (r=0.597; n=62; p=0.000).

In men, no significant correlation was found between spinal canal area and pediculolaminar angle (r=-0.132; n=38; p=0.431). However, spinal canal area had a moderate correlation with spinal canal transverse diameter (r=0.806; n=38, p=0.000), spinal canal AP diameter (r=0.562; n=38; p=0.000), and bipedicular base distance (r=0.646; n=38; p=0.000). Additionally, a slight correlation was found between spinal canal area and interlaminar angle (r=0.358, n=38, p=0.027).

Anatomic dimensions in L1

Spinal canal area had no significant correlation with pediculolaminar angle (r=-0.079; n=100; p=0.434) and interlaminar angle (r=0.081; n=100; p=0.423). A moderate correlation was found between spinal canal area and spinal canal transverse diameter (r=0.716; n=100; p=0.000), spinal canal AP diameter (r=0.703; n=100; p=0.000), and bipedicular base distance (r=0.530; n=100; p=0.000). However, no correlation was found between age and the measurements in L1.

In women, no significant correlation was found between spinal canal area and pediculolaminar angle (r=-0.109; n=62; p=0.398) and interlaminar angle (r=0.187; n=62; p=0.146). However, a moderate correlation was found between spinal canal area and spinal canal transverse diameter (r=0.651; n=62; p=0.000), spinal canal AP diameter (r=0.677; n=62; p=0.000), and bipedicular base distance (r=0.516; n=62; p=0.000).

In men, no significant correlation was found between spinal canal area and pediculolaminar angle (r=-0.025; n=38;

p=0.880) and interlaminar angle (r=-0.143; n=38; p=0.391). However, a moderate correlation was found between spinal canal area and spinal canal transverse diameter (r=0.857; n=38, p=0.000), spinal canal AP diameter (r=0.745; n=38; p=0.000), and bipedicular base distance (r=0.548; n=38; p=0.000).

DISCUSSION

Thoracolumbar junction (T12-L1) is the most common site for traumatic spine injury [14]. In the present study, we measured the anatomic dimensions of the spinal canal in T12 and L1 and calculated mean values for each of them. Moreover, we also evaluated the age-related changes in spinal canal area. Previous anatomical and radiographic studies have indicated that spinal canal area can vary based on age, gender, and ethnic differences [2,12]. Depending on this finding, we evaluated spinal canal area in the Turkish population.

Numerous morphometric studies have documented significant relationships between spinal canal area and the anatomic dimensions of the spinal canal [8]. In our study, although no significant relationship was found between spinal canal area and the pediculolaminar and interlaminar angles for both genders, a significant relationship was found between spinal canal area and bipedicular base distance, spinal canal transverse diameter, and spinal canal AP diameter. Similarly, cadaveric studies have also indicated a significant correlation between spinal canal area and spinal canal AP diameter [8].

A study conducted in 2011 evaluated transaxial CT images and found a significant relationship between lateral recess angle and spinal canal area [13]. In our study, however, no significant relationship was found between spinal canal area and the pediculolaminar and interlaminar angles.

The spinal canal AP diameter has been shown to have the strongest correlation with spinal canal area and also to be an indicator of spinal canal diameter [3]. In our study, spinal canal AP diameter as well as bipedicular base distance and spinal canal transverse diameter were also found to have a significant correlation with spinal canal area.

A morphometric study of thoracic vertebrae reported that the mean spinal canal AP diameter was 17.2 mm in both T12 and L1 [1]. Similarly, in our study, mean spinal canal AP diameter was 17.9 mm and 17.8 mm in T12 and L1, respectively. Additionally, spinal canal area was 265.4 mm^2 and 268.1 mm^2 in T12 and L1, respectively.

A morphometric study conducted in the Korean population revealed that the spinal canal AP diameter decreased from L1 to L3 and increased from L3 to L5 and also noted that the mean spinal canal diameter was 15.4 mm in L1, 13.8 mm in L3, and 14.4 mm in L5 [7]. These findings implicate that spinal canal area varies across ethnic groups.

It is commonly known that spinal canal becomes narrower as a person grows older, due to age-related degenerative processes [5]. However, we found no relationship between age and spinal canal stenosis. This finding could be attributed to several notions. First, spinal canal stenosis associated with degenerative processes mostly occurs in the lower lumbar spine and rarely at the thoracolumbar junction. Secondly, the measurement of spinal canal diameters by CT in lieu of MRI and at the pedicular level could have affected the measurement outcomes in our study [11].

CONCLUSION

The results indicated that no significant relationship was found between spinal canal area and the pediculolaminar and interlaminar angles while a significant relationship was found between spinal canal area and spinal canal transverse diameter, spinal canal AP diameter, and bipedicular base distance in both T12 and L1. Moreover, no significant relationship was found between age and spinal canal area in these vertebrae. Further studies are needed to substantiate our findings.

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Volume: 30, Issue: 3, July 2019 pp: 169-173 ORIGINAL ARTICLE

QUANTITATIVE ANATOMICAL EVALUATION OF C7 VERTEBRA IN TURKISH POPULATION IN ORDER TO IMPLANTATION OF LATERAL MASS AND PEDICULE SCREWS

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ABSTRACT

Objective: The purpose of this study is to evaluate the anatomical features of C7 vertebra using some specific measurements in order to select the most appropriate screw for implantation of lateral mass and the pedicle.

Material and Method: We retrospectively enrolled 100 consecutive patients who were admitted to our hospital's emergency Computed Tomography (CT) department suffering from general body trauma in order to evaluate a potential cervical injury with cervical CT. All subjects are Turkish and 18-60 years old. Patients with cervical fractures or malignancies, anatomical variations, cervical deformity, previous cervical surgery were not included in the study. Pedicle width, pedicle screw length and lateral mass screw length were measured in multiplanar reconstructed CT images at workstation. The mean values in Turkish society were determined and these measurements were compared with the previous studies including other societies.

Results: The mean pedicle length, mean pedicle with and mean lateral mass screw length were 29.1 ±1.1, 6.3 ±0.3, 13.5 ±0.6 respectively. Pedicle screw length was higher in men than women and this difference was statistically significant. Additionally, when compared to other studies in the literature, the length of lateral mass screw was higher in Turkish population and this difference was also statistically significant.

Discussion: C7 vertebra is a transitional vertebra with difficulties in fixation due to its close relation with important anatomical structures. This level is also known as the transition between the lordotic cervical vertebral column which is quite mobile and kyphotic thoracic vertebral column which is fixed biomechanically. When planning the fixation of the cervicothoracic region with instrumentation, it has some difficulties for the spine surgeons due to its anatomical features. Compared to other studies in the literature with Magerl technique usage in measurements, the lateral mass screw length in Turkish society is statistically different than other races. Our study is the first study about the anatomy of C7 vertebra in Turkish society.

Key Words: Morphometric analysis, transitional vertebra, lateral mass fixation, pedicule screws

Level of Evidence: Retrospective clinical study, Level III

INTRODUCTION

Although C7 vertebra is a cervical vertebra, it has similar features to the thoracic vertebrae since it is at cervicothoracic transition level. Compared to other cervical vertebrae, it's transverse process is more prominent, and the spinous process is longer and not bifid [12]. In addition to these anatomical differences, this is the level of transition between the biomechanically mobile lordotic cervical spine and fixed kyphotic thoracic spine [4]. Considering that this region is a complex area associated with increased biomechanical stress, difficulty in radiographic imaging and closeness to neurovascular structures, C7 vertebrae instrumentation can be associated with significant morbidity and mortality rates [29].

Sub-axial cervical instability can be caused by the etiologic factors such as trauma, tumor, infection and degenerative diseases [16, 22, 29]. Some spinal instruments are used in order to make the fixation of unstable cervical spine

in these clinical conditions [21, 29]. In the last half-century, spinal reconstruction and fixation has been a major advance in both spinal instrumentation and surgical techniques [29]. Because of the aforementioned biomechanical and anatomic features of C7 vertebra, it is very important to determine the most appropriate instrumentation at this level which creates difficulties for spine surgeons [14]. The lateral mass and pedicle screws are often preferred instruments for posterior stabilization of this region [11, 18]. The C7 lateral mass is smaller and thinner than the other sub axial cervical vertebrae. It has a lesser width in the sagittal plane and a steeper angle than the lateral mass of the other cervical vertebrae. The length of the C7 lateral mass screw is therefore restricted [26]. Also, spinal nerve roots and vertebral arteries are close to the lateral mass and there is a risk of injury during screw insertion [21]. Improper screw placement may result in violation of facet joint (C7-T1) and potentially penetration of C7-T1 neural foramen [1]. However, the short screw reduces the pull-out force [26]. On the other hand, It is difficult to place the pedicle screw through C7 vertebra due to the small size of the C7 pedicles and the variability in the pedicle morphometry, the steep converging angle, the lack of a significant entry point for the screw placement, the difficulty of radiological imaging and the critical structures near the pedicle [11].

Morphology of the cervical spine pedicles and lateral mass structures has been evaluated extensively with both cadaveric and computed tomography studies. The studies in the literature have been conducted in different populations and mean values may vary across societies [1,8,18,23,26].

Since the cervical spine pedicles and lateral mass structure in our population may be different from other populations, preoperative evaluation and understanding of their morphology in a quantitative manner will minimize the risk and improve the successful surgical outcome. According to our knowledge, there is no study in Turkish society in the literature. Our aim in this present study was to evaluate the quantitative anatomical features of C7 vertebra in Turkish population in order to understand and to decide the appropriate lateral mass and pedicle screws for using in cervical vertebral stabilization.

MATERIAL AND METHOD

We retrospectively enrolled 50 consecutive patients who were admitted to our hospital's emergency Computed Tomography (CT) department suffering from general body trauma in order to evaluate a potential cervical injury with cervical CT. All subjects are Turkish and 18-60 years old. Patients with cervical fractures or malignancies, anatomical variations, cervical deformity, previous cervical surgery were not included in the study. Pedicle width, pedicle screw length and lateral mass screw length were measured in multiplanar reconstructed CT images at workstation. Lateral mass and pedicle measurements were done using Margerl's technique [13]. The starting point was 1 mm medial and superior to the center of the posterior lateral mass in the 3D reconstructed image (Fig. 1A). We then obtained a reformatted image superiorly elevated 45 degrees based on the start point, which was tilted 45 degrees with respect to the vertical plane along the posterior border of the C7 lateral mass (Fig. 1B). The screw length was then measured at a trajectory of 25 degrees angulated laterally on the axial plane (Fig. 1C). Pedicle width was measured on a reformatted image. The width was the outer cortical width of the isthmus that was parallel to the pedicle axis and at the mid-point of the pedicle height (Fig. 2). The mean values in Turkish society were determined.

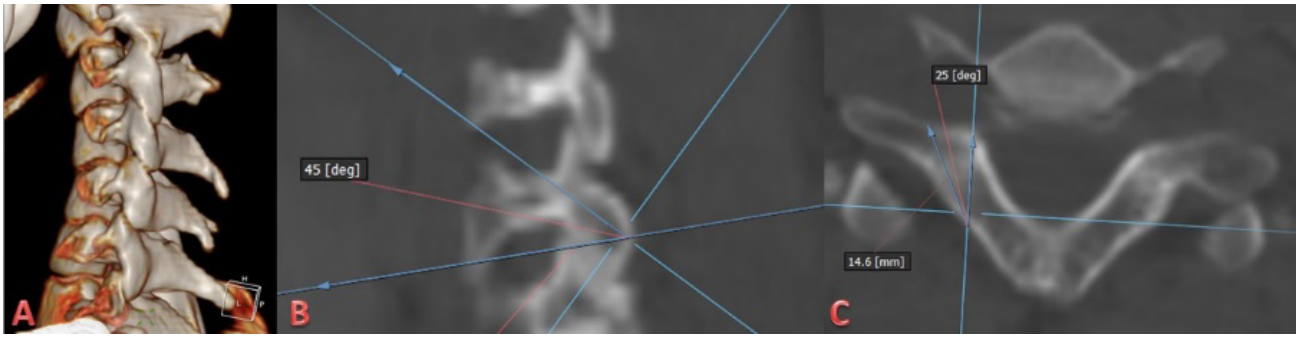

Figure-1.A-C. Measurement of lateral mass screw length in 3D volume-rendering and multiplanar reconstructed CT images.

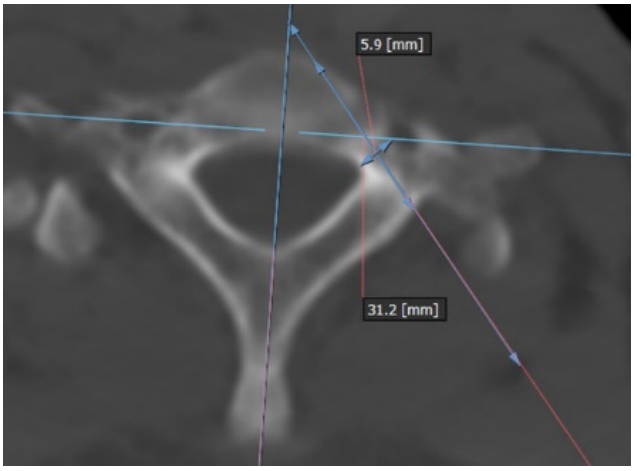

Figure-2. Measurement of pedicle width and pedicle trajectory in axial CT image.

Statistical Analysis

The analyses were performed by using the SPSS software (Statistical Package for the Social Sciences, version 20.0, SPSS Inc, Chicago Illinois, USA). Descriptive statistics; mean, the standard deviation was given for numerical variables. The independent simple t-test was used for the comparisons between the two independent groups when the numerical variables provided the normal distribution condition. Statistical significance was accepted as $p < 0.05$.

RESULTS

Mean age was 39.7 ± 14.6 (18-60) in 50 consecutive patients (25 male and 25 female). Mean pedicle length (PL) was 28.8 ± 1.2 in females and 29.4 ± 0.9 in males. Among these two groups, male's PL was longer and there was a statistically significant difference ($p < 0.05$). Mean pedicle width (PW) was 6.3 ± 0.3 and the lateral mass length (LML) was 13.5 ± 0.6 in all patients (Table-1).

The mean PW and LML values were similar in males and females and there was no statistically significant difference.

Table-1. PWO: pedicle outer cortical width, PL: pedicle length, LMSL: Lateral mass screws length results of patients.

	PWO	PL	LMSL
All patients	6.3±0.3	29.1±1.1	13.5±0.6
Male	6.3±0.3	29.4±0.9	13.6±0.5
Female	6.2±0.2	28.8±1.2	13.5±0.8
P value	*0.091*	*0.048*	*0.984*

DISCUSSION

Since C7 vertebra is a transition level in cervicothoracic spine and the lateral mass is thinner than the others, it is hard to perform the classical bone fixation method. Hereby, the angle of lateral mass screw placement should be changed [27-28]. There are many methods related to mass screw placement technique have been defined in the literature. First, Roy-Camille et al. described lateral mass screw insertion technique [24]. Louis et al. [20], Magerl et al. [13] and Anderson et al. [5] described other alternative techniques to reduce the risks associated with screw misplacement, such as adjacent nerve root lesions, vertebral artery injuries, and adjacent lateral mass damage. However, there are contradictory results in the literature regarding each technique. Because of the lateral mass of C7 vertebra was smaller than that of the other cervical vertebrae, it was stated in some studies that the lateral mass screws for the C7 vertebra were not strong and robust [11,18] and that the pedicle screw should be the first choice for posterior stabilization in C7 [11,17-18]. C7 cervical spine pedicle screw was first proposed as an alternative fixation method of this region by Abumi et al. [2]. However, the different morphological features of C7 also cause difficulty in the placement of pedicle screws [29]. Therefore it is not clear which technique is safer. It is important to quantify the anatomical structure of the C7 vertebra to avoid complications and to select the best surgical technique. The use of preoperative CT imaging in C7 vertebrae implantation is useful for visualizing and understanding the size of the pedicle as it visualizes the relevant bone anatomy. It is also important to know the relationship of pedicle to the vertebral artery in the lateral aspect and the spinal canal in the medial aspect in order to plan a secure and effective fixation. These valuable informations can be evaluated with CT in the preoperative period [4].

Studies comparing the fixation strength between lateral mass screws and pedicle screws have shown that the cervical pedicle screws have significantly higher pull out strength than the lateral mass screws [14-15]. However, the cervical pedicle screw has a risk of breaking the pedicle wall by % 6.7-13 and it is stated that we should consider the decrease in the pull out force when the screw comes out of the pedicle wall [3, 26]. It is reported a 21 % reduction in the average pull-out force when the lateral pedicle wall was broken in a biomechanical study examining the effect on the pull-out force in the thoracic pedicle screws in cases where the pedicle wall was broken [6]. It is therefore important to evaluate the width of the preoperative pedicle and choose the correct screw thickness. As stated in the latest anatomical studies of the cervical spine, pedicle widths increase from C3 to C7 vertebrae. The mean pedicle width in C3 and C7 vertebrae were reported in the literature as 4.76 ± 1.1 mm and 6.56 ± 1.2 mm respectively.

Jang et al reported in their study of Korean population that the width of the pedicle was 6.8 ± 1.2 mm and the length of the transpedicular screw was 33.9 ± 3.1 mm [12]. In this present study; we demonstrated that the mean outer cortical width of pedicle was 6.3 mm (range 5.7-6.9) in Turkish population. Additionally, mean transpedicular screw length was 28.8 ± 1.2 in females and 29.4 ± 0.9 in males and it was significantly longer in males ($p<0.05$). We found that pedicle width and screw length are shorter when compared to the study in Korean population. Assuming we use a 3.5 mm pedicle screw, a minimum pedicle diameter of 4.5 mm is required to allow at least 0.5 mm bone wall, both medially and laterally. Considering the fact that pedicle structure can show differences between different societies, it is clear that this should be taken into consideration when selecting the thickness of the appropriate screw.

It is also reported the length of lateral mass screws in some studies in the literature. These articles pointed out that the screw length in the Magerl technique was a few millimeters longer than the Roy-Camille technique [9,21,25]. However, in a study on cadaver, the biggest difference between these values was found to be only 1 mm. Therefore, there was no significant difference in clinical practice [21]. It is compared the bicortical screws with longer unicortical screws in lateral mass fixation in a biomechanical study of 11 human cadavers for construct stiffness. It was stated in mentioned study that there was no significant difference in construct stiffness between long unicortical screws and bicortical screws if the patient did not undergo laminectomy. Muffoletto et al. reported that the unicortical lateral mass screws had an equal pull-out force compared to bicortical placement and recommended the use of unicortical screws to reduce the risk of neural or arterial injury [19].

Bicortical screws can potentially cause injury to the nerve root and vertebral artery and may damage the facet joints. It is important to understand the anatomical features of the ventral lateral mass which is the exit of the lateral mass screws in order to avoid these complications [21]. The risk of vertebral artery injury by lateral mass screwing is considered to be relatively low compared to the use of pedicle screws. On the other hand, nerve root injury is a more important concern in lateral mass screwing since it is more common than vertebral artery injury [21].

The vertebral artery enters the transverse foramen at the level of C6 vertebra during its normal anatomical course. But the entry point is known to be the C7 vertebral level in 0.8 % of the population [7]. Graham et al. stated in their study that there was a risk of radiculopathy at 1.8 % without any spinal cord or vertebral artery injury in lateral mass screw placement and especially the risk of C8 nerve root injury during bicortical screw insertion [10]. Abumi et al. reported the cases of vertebral artery injury in one patient and radiculopathy in two patients without an incidence of spinal cord injuries in their study with 180 patients who underwent cervical pedicle screw fixation. They also mentioned 6.7 % of the screws breaking the pedicle wall in their series [3]. Preoperative evaluation of the appropriate lateral mass screw length is important to prevent complications. Stemper et al. reported a mean C7 lateral mass length of 9.6 mm in women and 9.8 mm in men with Magerl technique [25]. Jang et al. reported a mean lateral mass length of 10.6 mm [12]. In a recent study in Chinese population, the average lateral mass length was reported as 13.2 mm [26]. A reasonable length of unicortical screw for C7 lateral mass was determined as 13.5 ± 0.6 mm for Turkish population with the Magerl technique in our study. While the average value in Turkish population has higher values than the first two aforementioned studies, we see that it has close characteristics with Chinese population.

The most important limitation of our study is the small number of cases. The other limitation of our study is that we did not make statistical comparisons with studies in other societies.

CONCLUSION

C7 vertebra is an anatomically and biomechanically complex area that complicates the decision of vertebral instrumentations. Since the selection based solely on anatomy of lateral mass or pedicle screw insertion for C-7 vertebrae is not a clear, other factors also should be considered. According to studies conducted in other societies, choosing standard pedicle screw thickness in Turkish society may cause fracture in the medial or lateral pedicle wall and decrease in pullout strength or damage of neurovascular structures. We think that anatomical evaluation with preoperative CT should be taken into account and social differences should be considered in the selection of screws in order to minimize the complications

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Volume: 30, Issue: 3, July 2019 pp: 175-179 ORIGINAL ARTICLE

COMPUTED TOMOGRAPHY MEASUREMENTS OF OCCIPITAL BONE THICKNESS IN CHILDREN

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ABSTRACT

Background Data: The unique anatomy of the craniovertebral junction, the perceived high risk of vascular and neurological complications, and the anatomical variations require the morphological analysis of the occipital bone.

Purpose: The purpose of this study was to present morphometric analysis of the pediatric occipital bones and to provide guidance for pediatric occipitocervical fusion.

Materials - Methods: We retrospectively reviewed the records of pediatric patients who had undergone head CT scanning due to various reasons. Patients with traumatic fractures, congenital abnormality, tumor or other diseases and problematic CT images were excluded. Occipital bone thicknesses were determined at three levels (each level having 5 points) starting from the external occipital protuberance (EOP) (Level 0) and extending inferiorly for 2 cm by 1-cm decrements (Level 1 and Level 2).

Results: Among 300 CT scans, 70 were found to be suitable for the study. There were 50 males and 20 females, with a mean age of 9.9 ± 4.40 years (range 2–17 years). The external occipital protuberance (EOP) had the greatest thickness, with mean values of 10.3 ± 2.99 mm (range, 5.0-18.5 mm) in males and 9.9 ± 2.41 mm (range, 5.1–14.1 mm) in females. At each level, the midline was always thicker than the lateral regions at each age group ($p<0.001$). The midline thickness at Level 0, 1 and 2 were thicker in males compared to females ($p=0.011$, $p=0.045$ and $p=0.032$, respectively). Positive correlation was found between age and occipital bone thickness ($r=0.828$ and $p<0.001$ for EOP, $r=0.770$ and $p<0.001$ for midline at Level 1, $r=0.792$ and $p<0.001$ for midline at Level 2) and the other points showed similar findings.

Conclusion: Safe zones with thicknesses > 8 mm for screw insertion were found only at the midline in children older than 5 years of age and preoperative evaluation of occipital thickness should be performed in every patient considering the individual variability.

Keywords: Occipital bone, occipitocervical fusion, morphometric analysis

Level of evidence: Retrospective clinical study, Level III.

INTRODUCTION

The craniovertebral junction (CVJ) is the most cephalic portion of the spinal axis, and craniovertebral instability in children is a rare disorder with severe neurological and potentially life-threatening consequences. A wide variety of congenital, developmental, and acquired abnormalities can occur at the CVJ, and instability can manifest as disabling neck pain, occipital headaches, cranial nerve dysfunction, paralysis, or even sudden death [(1)]. The same general principles that apply to adults also apply to children regarding the assignment of instability, spinal immobilization and surgical fusion, and the most common intervention for instability at the CVJ is occipitocervical fusion [(2)].

Several types of posterior approaches have been described for occipitocervical fusion and an increasing number of researchers recommend rigid posterior fixation systems utilizing screw-rod or screw-plate constructs that provides superior biomechanical stability and higher rates of fusion [(3-5)]. However, the anatomical complexity of this area

complicates instrumented stabilization and this necessitates detailed morphological anatomical knowledge about the thickness of the occipital bone in terms of both providing adequate bony purchase for screws and avoiding penetration of the dura, which is poorly documented in the literature. Although occipital bone thickness was investigated in a few previous anatomic or computed tomography (CT) studies in the adult population, to the best of our knowledge, there are no studies on pediatric patients in Turkish population [6].

The aim of this study was to perform a morphometric analysis of pediatric occipital bone using CT images of patients from different age groups.

MATERIALS AND METHODS

Ethical approval was not sought for this study because of retrospective nature of the study and consent was not obtained as no personal information was revealed.

We retrospectively reviewed the records of pediatric patients who had undergone head CT scanning (SIEMENS Sensation 64, Siemens Healthineers Headquarters, Erlangen, Germany) due to trauma, headache, or any other complaint requiring cranial investigation at our institution between January 1, 2015, and January 1, 2019. Patients with traumatic fractures, congenital abnormality, tumor or other diseases and problematic CT images were excluded. Among 300 CT scans, 70 were found to be suitable for the study. The children were divided into four groups according to age, Group 1 (2-5 years), Group 2 (6-9 years), Group 3 (10-13 years) and Group 4 (14-17 years).

The CT scan parameters included: 120 kV, 260 MA, DFOV 20 x 20 cm, layer thickness of 1.2 mm, collimation of 200 × 0.600 mm, pitch of 0.8 mm. Bone windows were used for analysis. The external occipital protuberance (EOP) was used as a reference point to measure the thickness of the occipital bone on arbitrary CT slices. When measuring, a McRae line was drawn as the base line on the images, then find the center of EOP (Level 0) and through it make a line with the McRae's line into an angle about 45°. Two parallel lines were drawn by 1-cm decrements extending inferiorly for 2 cm (Level 1 and Level 2). The surface was divided into 1-cm segments extending bilaterally for 2 cm (R2, R1, Midline, L1, L2). Therefore, 3 × 5 sites were created in each patient (Figure-1).

Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (IBM Inc.). Continuous variables were expressed as mean ± standard deviation (SD). The Student t-test was used to compare parameters between males and females, and statistical significance was accepted with a p-value <0.05. The relationship between age and the thickness of the occipital bone were estimated using Spearman's rank correlation.

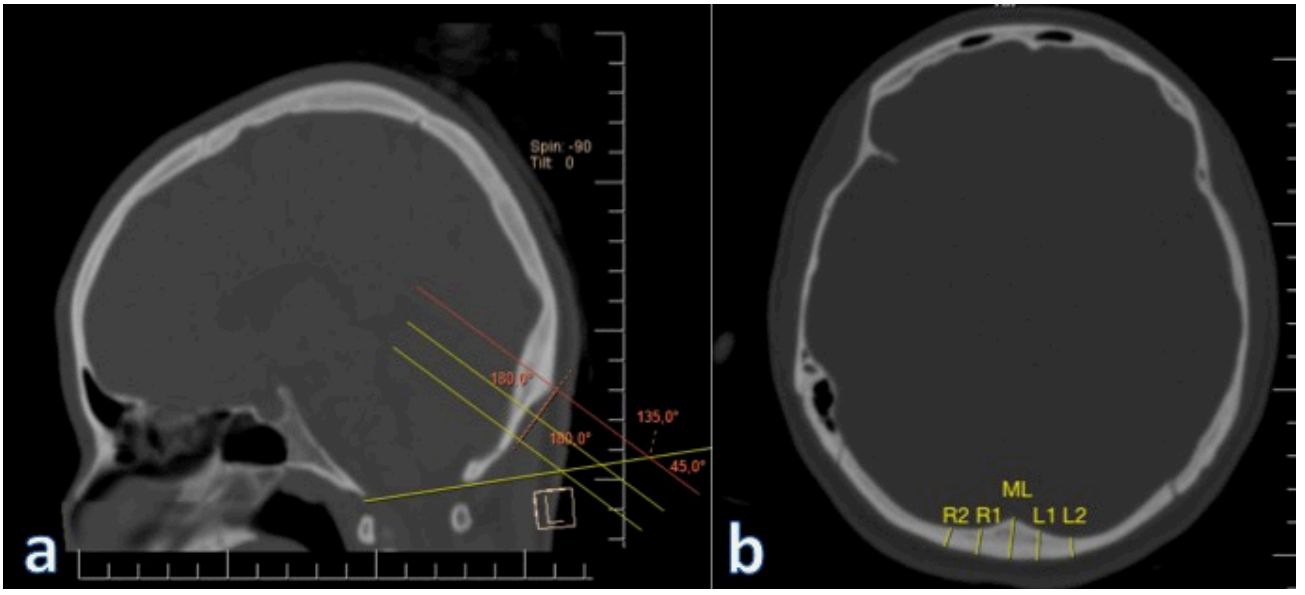

Figure-1. Computed tomography measurements of the occipital bone. a) Sagittal plane showing the lines representing 1-cm segments using the external occipital protuberance as a reference, for a distance up to 2 cm. b) Axial plane showing points created at each level in 1-cm segments laterally in both directions using the external occipital as a reference, for a distance up to 2 cm.

Table-1. Thickness of the occipital bone in the study cohort

		2-5 years group (n=13)			6-9 years group (n=19)			10-13 years group (n=16)			14-17 years group (n=22)		
Mean age, years		3.4 ± 1.12			7.3 ± 1.11			11.4 ± 1.31			14.9 ± 0.83		
Female		4.3 ± 0.96			7.4 ± 1.14			12.3 ± 1.16			14.5 ± 0.76		
Male		3.0 ± 1.0			7.3 ± 1.14			11.2 ± 1.28			15.1 ± 0.83		
Female / Male		4 / 9			5 / 14			3 / 13			8 / 14		
Gender	**Point**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**
Male	**R2**	2.5±0.64	2.0±0.72	1.8±0.74	3.6±0.61	2.7±0.59	2.2±0.66	4.5±0.92	2.9±0.75	2.8±0.71	5.7±1.17	4.2±1.25	3.4±1.06
	R1	3.5±0.72	2.7±0.76	2.2±0.72	4.4±1.40	3.9±1.30	3.3±0.76	5.8±0.99	3.7±1.15	3.4±0.86	7.8±1.43	5.2±1.48	4.1±1.38
	ML	6.4±0.93	5.1±1.28	4.0±1.16	8.9±1.38	7.9±0.82	6.7±0.72	10.7±1.37	9.7±1.46	8.2±1.26	13.7±2.13	10.5±2.11	9.1±1.52
	L1	3.6±0.83	2.8±1.21	1.9±0.49	4.8±1.47	4.1±1.44	3.6±0.93	5.8±1.09	3.9±0.94	3.5±0.94	7.9±1.51	5.3±1.80	4.3±1.72
	L2	2.5±0.61	2.1±0.85	1.8±0.67	3.8±0.97	2.9±0.95	2.1±0.81	4.6±0.89	3.0±0.58	2.7±0.66	5.7±1.18	4.2±1.44	3.5±1.27
Female	**R2**	3.1±1.02	2.2±0.60	2.0±0.59	3.8±0.65	3.0±0.68	2.1±0.75	4.8±0.95	2.7±1.32	2.7±0.76	4.7±1.28	3.4±0.82	3.1±0.41
	R1	4.1±0.85	2.8±0.85	2.6±0.78	3.6±1.16	3.5±1.0	3.0±0.52	6.1±2.13	2.9±0.91	3.1±0.98	6.3±1.75	4.0±1.07	3.4±0.69
	ML	6.7±1.23	5.7±1.02	4.4±1.32	9.0±0.71	7.5±0.69	6.1±0.6	12.1±1.78	9.7±0.45	9.3±1.60	11.3±1.76	9.0±1.20	7.7±1.28
	L1	3.8±1.34	2.7±0.96	2.8±0.69	3.7±0.87	3.1±0.49	3.0±0.87	5.7±1.62	3.0±0.35	2.8±0.83	6.0±1.58	4.4±1.23	3.8±1.0
	L2	2.8±0.93	2.1±0.68	2.0±0.55	3.1±0.71	2.7±0.43	2.2±0.42	4.6±0.68	3.3±1.23	2.4±0.99	4.5±1.50	3.3±1.11	2.9±0.54
All	**R2**	2.7±0.79	2.1±0.67	1.9±0.68	3.6±0.62	2.8±0.61	2.2±0.66	4.5±0.90	2.8±0.82	2.8±0.7	5.3±1.29	3.9±1.16	3.3±0.88
	R1	3.7±0.77	2.7±0.75	2.3±0.73	4.2±1.36	3.8±1.21	3.2±0.71	5.9±1.18	3.6±1.13	3.4±0.86	7.3±1.69	4.8±1.46	3.8±1.21
	ML	6.5±0.98	5.3±1.19	4.1±1.17	9.0±1.22	7.8±0.79	6.5±0.72	11.0±1.49	9.7±1.32	8.4±1.34	12.8±2.29	10.0±1.94	8.6±1.57
	L1	3.6±0.96	2.8±1.10	2.1±0.68	4.5±1.40	3.8±1.32	3.4±0.93	5.8±1.14	3.7±0.91	3.4±0.93	7.2±1.78	5.0±1.65	4.1±1.49
	L2	2.6±0.70	2.1±0.78	1.8±0.62	3.6±0.94	2.8±0.84	2.2±0.72	4.6±0.83	3.0±0.71	2.7±0.70	5.2±1.39	3.9±1.36	3.3±1.08

RESULTS

Seventy patients, composed of 50 males and 20 females, with a mean age of 9.9 ± 4.40 years (range 2–17 years), were the subjects of this analysis. The mean thickness ± SD of the pediatric occipital bones in different age groups is presented in Table 1.

The external occipital protuberance had the greatest thickness, with mean values of 10.3 ± 2.99 mm (range, 5.0-18.5 mm) in males and 9.9 ± 2.41 mm (range, 5.1–14.1 mm) in females. At each level, the midline was always thicker than the lateral regions at each age group ($p<0.001$). Occipital bone thickness showed no significant difference between males and females in all age groups, except for 14-17 year group. The midline thickness at Level 0, 1 and 2 were thicker in males compared to females ($p=0.011$, $p=0.045$ and $p=0.032$, respectively).

Positive correlation was found between age and occipital bone thickness ($r=0.828$ and $p<0.001$ for EOP, $r=0.770$ and $p<0.001$ for midline at Level 1, $r=0.792$ and $p<0.001$ for midline at Level 2) and the other points showed similar findings.

DISCUSSION

Occipitocervical fusion is an effective surgical method to treat various CVJ pathologies. While semi-rigid fixation using a rod and wire construct was the preferred method, the fusion techniques have shifted to the more rigid modern fixation modalities over the past several decades [7]. Occipital plate and rod constructs eliminated the need for prolonged postoperative immobilization and the high incidence of dural laceration during sublaminar passage of wires, and also provided lesser number of spinal segments to be fixed more stiffness to the implant assembly by three-column purchase of the cervical screws, thus offering a minimal disturbance to the motion of the cervical spine [8,9].

However, besides these advantages, occipitocervical fusion using screw-rod or screw-plate constructs are challenging due to the slope of the occipital bone and the angle it makes with the cervical spine [10, 11] and these may lead to poor occipital screw purchase, screw loosening, pullout, breakage, dural laceration, cerebrospinal fluid leakage, or dural venous sinus injury. Therefore, choosing the appropriate screw length and fixation points is of great importance.

Stable fixation of the occipital bone requires screws 8 mm or more in length [12, 13]. A few authors have measured occipital bone thickness using CT or morphologic studies in cadavers [6, 13-17]. The thickness of the occiput was reported to be maximum at the median of the occipital bone in these studies. Similar to these studies, the thickest points in the occiputs were mostly at the EOP in our study, namely 6.5 mm in 2-5 years group, 9.0 mm in 6-9 years group, 11.0 mm in 10-13 years group and 12.8 mm in 14-17 years. Although occipital screws in the midline have greater pull-out strength and midline screw placement has been recommended in the literature, the plates with only midline screw options have weaker torsional strength and most of the recent occipital plates also incorporate holes for lateral screw insertion. Paramedian safe zones with thicknesses > 8 mm were reported as follows: up to 2 cm lateral from the midline at the level of the EOP, 1 cm from the median crest at a level 1 cm inferior to the protuberance, and 0.5 cm from the crest at a level 2 cm inferior to the protuberance by Ebraheim et al. [17], up to 1 cm lateral to the EOP at the level of the superior nuchal line and 2 cm inferior to the EOP by Hertel and Hirschfelder [15] and Naderi et al [6]. However, in our study, safe zones with thicknesses > 8 mm remained only at the midline in children older than 5 years of age.

CONCLUSION

Although rare, occipitocervical fusion in children is challenging and preoperative evaluation of occipital thickness should be performed in every patient considering the individual variability.

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Volume: 30, Issue: 3, July 2019 pp: 181-186 ORIGINAL ARTICLE

CERVICAL SPINAL ALIGNMENT PARAMETERS

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ABSTRACT

Aim: The management of complex cervical pathologies could be handled with understanding of cervical biomechanics as well as the baseline data of cervical alignment parameters. The aim of our paper is to support nominative baseline data of the cervical spine alignment parameters to provide guidance for proper surgical treatment.

Material and Methods: We evaluated the lateral cervical radiographs of 347 healthy adult patients between the ages of 18 and 60. We measured cervical lordosis with Cobb angle C0-2 and C2-7, Jackson physiological stress lines, Harrison tangent lines and also sagittal vertical axis with C2-C7 plumb line, cervical tilt and cranial tilt. We analysed measurements according to mean values and genders.

Results: Two hundred and twenty eight patients (65.7%) were female, and 119 patients (34.3%) were males. Mean age was 44.12±16.03 years. Cobb C0-C2 (p=0.307), Jackson (p=0.106), and Harrison (p=0.688) measurements were similar between males and females. But Cobb C2-C7 was significantly different between genders (p=0.017). The comparisons of methods revealed that Cobb C0-C2 had highest values, and Cobb C2-C7 and Jackson was lower than Harrison (CobbC0-C2>Harrison>Cobb C2-C7~Jackson) (p<0.001). SVA (p=0.690) and cervical tilt angle (p=0.538) measurements were similar between males and females but cranial tilt angle was significantly different between genders (p=0.046).

Conclusion: All of these techniques and the standard data must be well understood along with the biomechanical features so that surgeons can choose the best technique for the management of deformities.

Keywords: Cervical spine alignment, cervical lordosis, sagittal vertical axis

Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

The cervical spine not only supports the mass of the head, but also undergoes the widest range of motion of the entire spine. It also plays a key role in influencing the subjacent global spinal alignment and pelvic tilt as compensatory changes occur to maintain the horizontal gaze [12].

The major parameters used to define cervical spinal alignment are the Cobb angles, Jackson stress lines, and Harrisons posterior tangent lines for the sagittal curvature, and the gravity line or C2 plumb line for the sagittal vertical axis (SVA) [19]. However, there is no standardized data about the correction limitations of the cervical alignment parameters in the recent literature, and the cervical deformity treatment modalities have yet to be completely published [16].

The management of complex cervical pathologies could be handled by understanding the cervical biomechanics as well as the normative cervical alignment data. However, few studies have defined the baseline values for the cervical spine alignment parameters [4,5]. Therefore, the aim of our paper was to support the nominative baseline data of the cervical spine alignment parameters in order to provide guidance for proper surgical treatment.

MATERIAL AND METHODS

We evaluated the lateral cervical radiographs of 347 healthy adult patients between the ages of 18 and 60. The exclusion criteria were any radiographic pathologies. The cervical radiographs were taken in the standing lateral neutral position, and all of the data was collected and measured by authors. The radiographs were searched using a radiology picture archiving and communication system (PACS) program and the parameter measurements were evaluated with the techniques explained below:

Cobb angle

The Cobb angle is measured from C2 to C7 using a 4-line technique to draw a parallel line to the inferior endplate of C2, to the posterior border of the spinous process, and to the inferior endplate of C7. Two perpendicular lines are then drawn from these lines to measure the angle between them (Figure-1) [4].

The C0–C2 angle, an angle between the McRae line and the C2 lower end plate, was measured using the Cobb method (Figure-2) [4].

Jackson physiological stress lines

Two lines are drawn parallel to the posterior margins of the C7 and C2 bodies, and the angle between them is then measured (Figure-3) [11].

Harrison posterior tangent method

Lines are drawn parallel to the posterior margins of C2–C7, and all of the angles are added to obtain the cervical curvature results (Figure-4) [10].

Sagittal vertical axis

A plumb line is drawn from the center of C2, and the distance from this line to the posterior corner of the upper endplate of C7 is obtained (Figure-5) [17].

Cervical tilt

A line is drawn from the center point of the upper endplate of the T1 vertebra to the tip of dens, and another line is drawn perpendicular to the same center. The angle between them is then measured (Figure-6) [14].

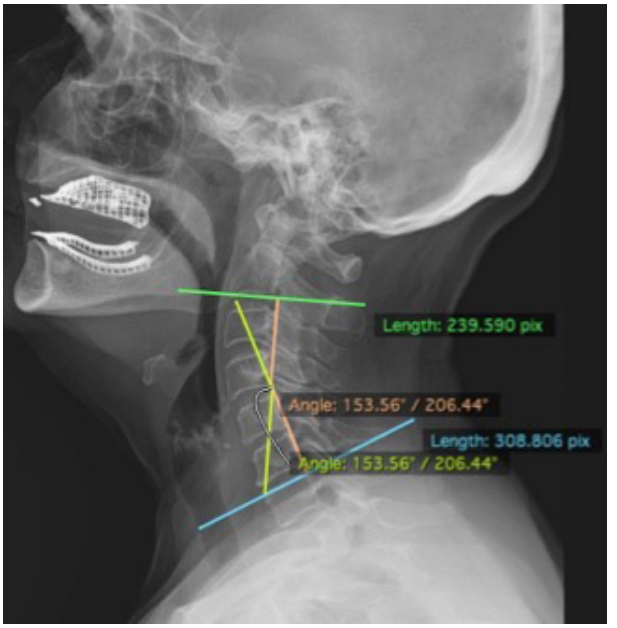

Figure-1. C2-7 4-line Cobb angle measurement technique with lateral X-ray graphy

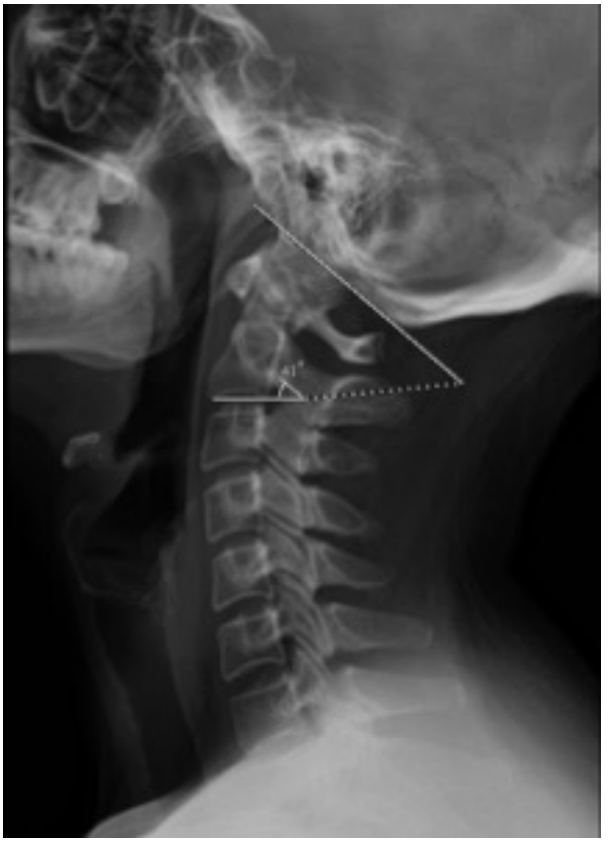

Figure-2. C0-2 Cobb angle measurement technique with lateral X-ray graphy

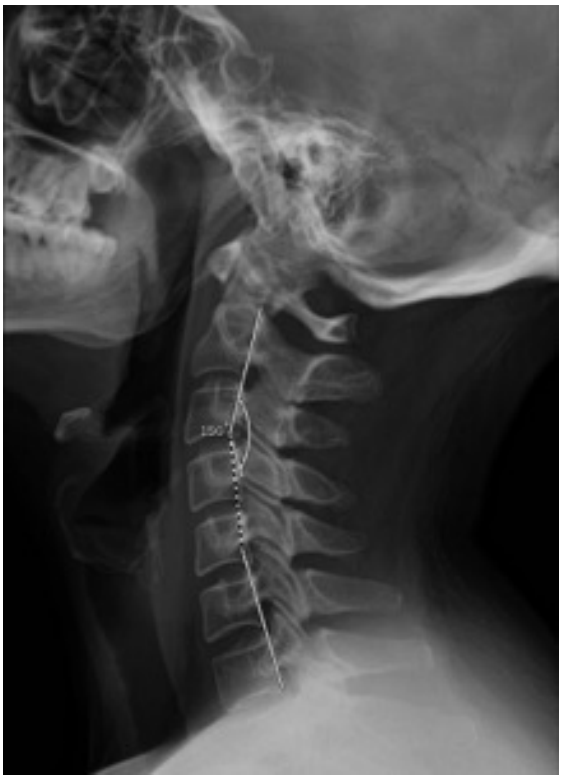

Figure-3. Jackson stress line technique with lateral X-ray graphy

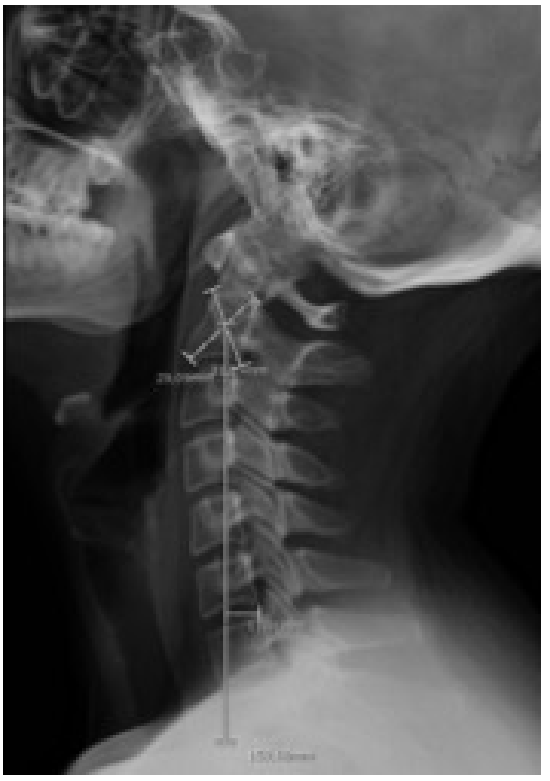

Figure-5. SVA measurement C2-7 plumb line technique with lateral X-ray graphy

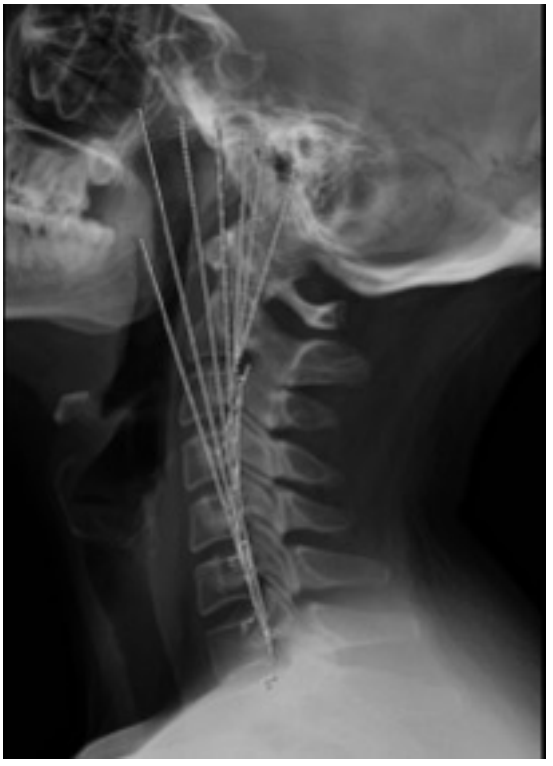

Figure-4. Harrison tangent technique with lateral X-ray graphy

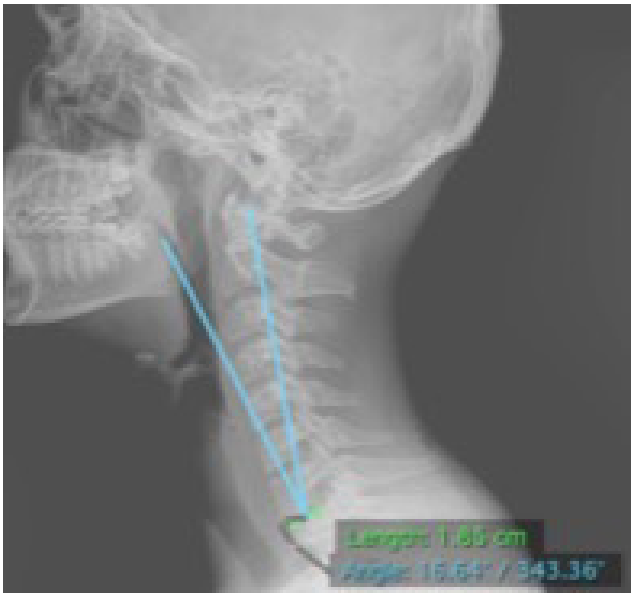

Figure-6. Cervical tilt angle measurement technique with lateral X-ray graphy

Cranial tilt

A line is drawn from the center of the T1 upper endplate to the tip of dens, and then a vertical line is drawn to the same center (Figure-7) [3].

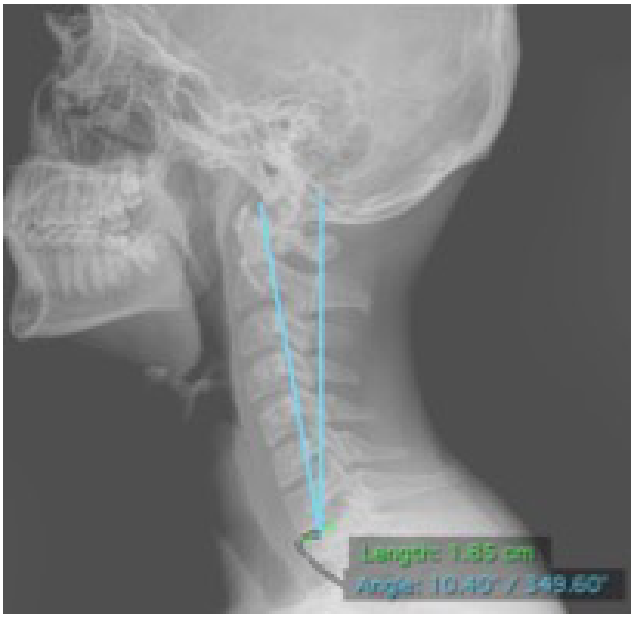

Figure-7. Cranial angle measurement technique with lateral X-ray graphy

Statistical Analysis

The descriptive data were presented as the means and standard deviations for the numerical variables, and the frequencies and percentages for the categorical variables. The independent group comparisons were conducted using the Mann-Whitney U test between the genders. A type I error level of 5% was considered to be statistically significant in the analyses. SPSS Statistics version 18 (IBM Inc., Armonk, NY, USA) was used for the statistical assessments.

RESULTS

Table-1 shows the patients' demographics; 228 patients (65.7 %) were female, 119 patients (34.3 %) were male, and the mean age was 44.12±16.03 years old (Table-1).

Table-1. Patient demographics

		Count	%
GENDER	Female	228	65.7%
	Male	119	34.3%
		Mean	SD
AGE (year)		44.12	16.03

The measurements according to gender are presented in Table-2. The Cobb C0–C2 (p=0.307), Jackson (p=0.106), and Harrison (p=0.688) measurements were similar between the males and females. However, the Cobb C2–C7 measurement was significantly different between the genders (p=0.017), with the males having significantly higher Cobb C2–C7 values. In addition, the C2–C7 plumb line (p=0.690) and cervical tilt angle (p=0.538) measurements were similar between the males and females. However, the cranial tilt angle was significantly different between the genders (p=0.046), with the males having significantly higher cranial tilt angle values.

The method comparisons (Table-3) revealed that the Cobb C0–C2 measurement exhibited the highest values, while the Cobb C2–C7 and Jackson measurements were lower than the Harrison measurement (Cobb C0–C2 > Harrison > Cobb C2–C7 ~ Jackson) (p<0.001).

Table-2. Measurement comparison between genders

	Female		Male		p
	Mean	SD	Mean	SD	
Cobb C0-C2 angle	31,43	7,12	29,57	8,72	0,307
Cobb C2-C7 angle	16,30	9,18	21,73	9,01	0,017
Jackson angle	17,43	11,02	21,33	10,66	0,106
Harrison angle	22,43	9,48	23,69	8,14	0,688
C2-C7 plumb line (mm)	3.81	2.75	3.58	1.89	0.690
Cervical tilt angle	17.69	5.46	18.68	5.89	0.538
Cranial tilt angle	8.62	2.54	9.52	2.18	0.046

Table-3. Comparison of cervical lordosis measurement methods

	Mean	SD	p
COBB_C0_C2	30,72	7,76	p<0.001
COBB_C2_C7	18,37	9,44	
JACKSON	18,92	10,98	
HARRISON	22,91	8,96	

DISCUSSION

The cervical spine carries the load of the head and neck using a 3-column model unlike the 3-column model in the thoracolumbar spine, which consists of an anterior and 2 posterior columns [5]. The major parameters used to assess the cervical spine alignment include the Cobb angles, Jackson stress lines, and Harrison posterior tangent lines for the sagittal curvature, and the gravity line or C2 plumb line for the SVA [11]. In asymptomatic normal volunteers, cervical lordosis (CL) is settled in C1–C2 at a ratio of 75 %–80 % [9,11]. Lippman reported a procedure consisting of drawing lines to measure the scoliosis curves on anterio-posterior radiographs in 1945, which was later developed by Cobb in 1948 [4,18]. The Cobb angles were drawn to measure the sagittal spinal curves of the cervical, thoracic, and lumbar regions on lateral radiographs [4]. In 1957, Jackson reported the physiological stress lines [11]; while in 1986, Gore et al. used Jackson's stress lines and Harrison began to use the posterior tangents technique [7,10].

Beier et al. reported that CL is localized to C1–C2, with only 15 % of lordosis cases being measured below in the rest of the region [2]. Most often, hyperlordosis is the result of occiput–C2 fusion surgery, as reported in the literature [20,21]. Hardacker et al. reported a mean CL of 40.0° ± 9.7° that exhibited a significant correlation with thoracic kyphosis [9]. In addition, Lee et al. reported that the mean value of the C0–C2 angle was 22.4±8.5° and that of the C2–C7 angle was 9.9±12.5° [14]. The ratios of the C0–C2 angle and the C2–C7 angle were 77 % and 23 % of the total CL, respectively [14]. Gore et al. reported C2–C7 CL angles of 16° for males and 15° for females [7].

Harrison et al. conducted a comparison of the 4-line Cobb method and Harrison tangents to measure CL, and they found that the Cobb technique overestimated the cervical curvature at C1–C7 and underestimated the cervical curve at C2–C7 [10]. They also suggested that the posterior tangent method could calculate the cervical curvature better than the Cobb method [10]. We found that the mean values of the C0–C2 and C2–C7 Jackson stress lines and Harrison tangents were 30.72° ± 7.76°, 18.37° ± 9.44°, 18.92° ± 10.98°, and 22.91° ± 8.96°, respectively. Our results are similar to those of Harrison. Overall, the Harrison tangent technique is difficult to measure, but we thought its results were better for determining the values because the tangents can also measure the internal curve.

Lee et al. reported the widest range of nominative data for cervical spine alignment, with mean values of 18° ± 6.6° for cervical tilting and 7.7° ± 5° for cranial tilting [14]. In their study, Hardacker et al. reported a C7 SVA mean value of 15.6 mm [9]. Gore et al. reported a mean SVA of 16.8 mm, and also suggested that CL increased with age, but did not address the adjacent spinal alignment measurements or segmental cervical values [7].

The sagittal balance of the cervical spine may affect the clinical outcomes of the fusion or deformity corrections of cervical degenerative disc diseases [8,15]. In recent studies, the criteria for the physiological reconstruction of CL remains unclear [1,13,22]. However, only a few studies have defined the nominative alignment parameter data [3,6].

CONCLUSION

All of these techniques and the standard data must be well understood along with the biomechanical features so that surgeons can choose the best technique for the management of deformities. However, further investigations with an increased amount of cervical spine nominative data are needed.

In addition, these data must be used to define the relationships between the cervical, thoracic, and lumbar spine alignment parameters for more standardized indications for the surgical correction of deformities.

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Volume: 30, Issue: 3, July 2019 pp: 187-192 ORIGINAL ARTICLE

IS THERE ANY RELATIONSHIP BETWEEN LUMBAR INTERVERTEBRAL DISC SPACE HEIGHT AND LUMBAR DISC HERNIATIONS? A STUDY OF RADIOGRAPHIC EVALUATION

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ABSTRACT

Purpose: The main objective of this study was to evaluate the relationship between intervertebral disc space heights and disc pathologies at L4–L5 and L5–S1 levels via lateral lumbar spine radiographies.

Materials and Methods: The 73 patients included in this study were all examined by lateral lumbar spine radiography and lumbar magnetic resonance imaging (MRI). Two specialists re-assessed the MR images and classified the intervertebral discs as normal, bulging, protrusion or extrusion. The researchers also measured the anterior, middle and posterior intervertebral disc space heights at the L4–L5 and L5–S1 levels. The anterior, middle and posterior intervertebral disc heights were statistically compared between normal and herniated discs.

Results: Degenerated discs had significantly lower anterior and posterior intervertebral disc measurements than non-degenerated discs at the L4–L5 level. Herniated discs had significantly lower anterior, middle and posterior height measurements than non-herniated discs at the L4–L5 level. None of these measurements were significantly different for degeneration or herniation when compared with normal discs at the L5–S1 level.

Conclusion: Disc space heights were significantly lower for herniated discs and anterior and posterior disc space heights were significantly lower for degenerated discs at the L4–L5 level. There was no relationship between disc pathologies and intervertebral disc heights at the L5–S1 level.

Key Words: Intervertebral disc degeneration, intervertebral disc displacement, X-rays, magnetic resonance imaging, lumbar vertebrae

Level of Evidence: Retrospective cross-sectional study, Level III

INTRODUCTION

Back pain is a major public health problem[11] with a high prevalence in the adult population. Back pain also imposes a heavy socioeconomic burden [9-10]. Past studies have cited lumbar disc herniation (LDH) as the most common cause of back pain [6].

Magnetic resonance imaging (MRI) is a non-invasive imaging method used in the diagnosis of radiculopathies, disc herniation, and spinal stenosis, in addition to acquiring useful information regarding soft tissues of the lumbar area[7,12,15]. However, compared to lumbar spine radiographies, MRI is an expensive imaging modality with limited accessibility.

The main purpose of this study is to determine the relationship between lower lumbar disc pathologies and intervertebral disc space heights at the L4–L5 and L5–S1 levels. Here, the relationship between disc space height and LDH has been analyzed using lateral lumbar spine radiographies, which are relatively inexpensive and easily accessible, as an initial evaluation method for LDH in patients with back pain.

MATERIALS AND METHODS

Patients

This study was approved by the ethics committee and informed consent was

waived by the committee due to retrospective nature of the study. This investigation was planned as a cross sectional study. Data from patients who were admitted to our hospital between March 2018 and 2019 and had been examined using both lumbar MR imaging and lateral lumbar radiography were retrospectively evaluated (n = 79). Time interval between lateral lumbar radiography and lumbar MR examination was ≤ 15 days for all patients included in the study. Patients classified as grade 3 or grade 4 on the Kellgren-Lawrence classification system for osteoarthritis, were excluded from the study to avoid incorrect measurements of intervertebral disc heights due to difficulties in visualizing the intervertebral disc space on radiographies (n = 4). Patients who were inappropriately positioned for lateral lumbar radiographies were also excluded (n = 2). Exclusion criteria also included scoliosis with a Cobb angle ≥ 20° and other significant vertebral deformities (e.g. vertebral fracture or neoplasms); however, there were no patients with any of these pathologies in the study group. After exclusions, a total of 73 patients were included in this investigation. The mean age of the patients included in the study was 48.34 ± 2.03. The MRI and lateral lumber spine radiographies of 30 male and 43 female patients were evaluated in this study. MRI results were accepted as the "gold standard" against which lateral lumbar spine radiographies were compared.

Lateral Lumbar Spine Radiographies

Lateral lumbar radiographies were obtained by *Silhouette VR* X-ray System, *GE Healthcare*, *USA*. The radiographies were acquired in the standing position for all patients included in the study. All lateral lumbar radiographies were handled by an automatic exposure device with a film focus distance of 100 cm. A tube voltage of 86 kV and current of 25 mA were average values for capturing radiographic images. The mean time interval between initial symptoms and acquisition of lateral lumbar radiography was 9.7 days (range: 1–21 days).

MRI Interpretation

Disc degeneration was evaluated on T2-weighted images using the Pfirmann grading [14] If there was no clear border between nucleus pulposus and annulus fibrosus (from grade 3 to grade 5), the disc was accepted as a "degenerated disc". Bulging of the disc was defined as the displacement of the outer edges of the intervertebral disc beyond the margins of the adjacent vertebral bodies. More than one-quarter of the circumference of an intervertebral disc should be displaced to accept the disc as "bulging". An intervertebral disc was said to have a "protrusion" if the edges of the herniated part of the disc were less than the measured distance at the base of the herniation. A disc "extrusion" was determined if the distance measured between the edge of the herniated part of the disc and the edge of the non-herniated part of the disc was greater than the length at the base of the herniation in at least one plane of the MR image.5 If no continuity existed between the herniated disc material and the disc itself (a "sequestration"), it was also accepted as an "extrusion" in this study. Bulging was not accepted as a disc herniation in the current study.

Measurements

Three measurements were made for the L4–L5 and L5–S1 intervertebral disc spaces. At each of these levels, the height of the intervertebral disc was measured as the distance between the most anterior parts of the vertebral articular plateau, the distance between the most posterior edges of the articular plateau and the distance between two consecutive vertebral bodies at the midpoint of the anterior and posterior measurements (Figure-1).

The intervertebral disc space height was determined by the consensus of two reviewers (one radiology specialist with 14 years of experience and one orthopedist with 24 years of experience). The measurements were recorded to two digits after the decimal.

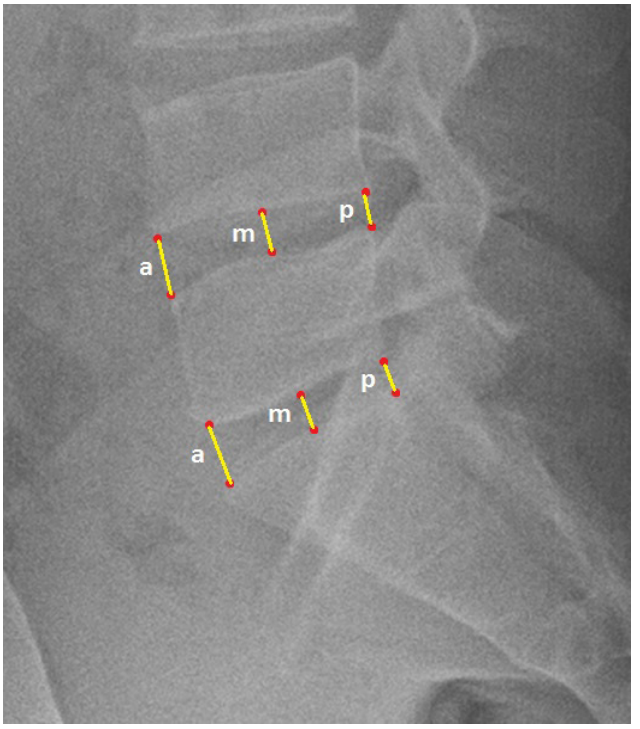

Figure-1. The anterior (a), middle (m), and posterior (p) measurements of intervertebral disc space heights on lateral lumbar spine radiographies

Statistical Analysis

All statistical analyses were performed using IBM SPSS statistics for Windows V.20 (IBM Corp). The homogeneity of data distribution was determined by performing the Kolmogorov–Smirnov test. Receiver operating characteristics (ROCs) were used to specify a cutoff value of intervertebral disc space to determine the presence of disc herniation. Mann Whitney-U test was used to determine the relationship between intervertebral disc space measurements and disc degeneration or herniation. In all statistical calculations, *p*-values < 0.05 represented a significant difference.

RESULTS

The number of herniated discs for each herniation type is presented in Table-1. According to this classification, the anterior and posterior L4–L5 intervertebral disc space height measurements showed a significant difference between degenerated and non-degenerated discs (p = 0.002 and p = 0.011 for anterior and posterior height measurements, respectively). Although the middle height measurements were not statistically significant, there was a trend towards significance (p = 0.051) between degenerated and non-degenerated discs at the L4–L5 level. Significant statistical differences were observed for the anterior, middle and posterior height measurements of intervertebral disc spaces between herniated and non-herniated discs at the L4–L5 level (Table-2).

Table-1. Results of MRI examinations

Disc level	*MRI result*	*n*	*Herniation*	*n*
L4–L5	**Normal disc**	34	Herniation (-)	49
	Bulging	15		
	Protrusion	21	Herniation (+)	24
	Extrusion	3		
L5–S1	**Normal disc**	37	Herniation (-)	58
	Bulging	21		
	Protrusion	11	Herniation (+)	15
	Extrusion	4		

There was no significant difference in anterior, middle and posterior disc space height between degenerated and non-degenerated discs or between herniated and non-herniated discs at the L5–S1 level (Table-3).

Table-2. Height measurements of intervertebral disc space at L4–L5

	Disc degeneration (-) (n = 22)	Disc degeneration (+) (n = 51)	Disc herniation (-) (n = 49)	Disc herniation (+) (n = 24)
Anterior height (mm) (med-max-min)	13.26-18.34-8.75	11.66-16.62-3.71	12.39-18.34-3.71	10.29-15.27-4.61
Middle height (mm) (med-max-min)	11.20-15.62-8.78	10.93-14.15-3.71	11.75-15.62-5.30	9.91-13.44-3.71
Posterior height (mm) (med-max-min)	8.44-11.70-5.15	7.29-13.55-2.18	8.02-11.70-3.71	6.34-13.55-2.18
p value (anterior-middle-posterior height)	0.002-0.051-0.011		0.001-0.001-0.004	

med: median value, max: maximum value, min: minimum value

Table-3. The height measurements of intervertebral disc space at L5–S1

	Disc degeneration (-) (n = 17)	Disc degeneration (+) (n = 56)	Disc herniation (-) (n = 58)	Disc herniation (+) (n = 15)
Anterior height (mm) (med-max-min)	12.46-17.33-7.21	12.47-17.06-4.25	12.46-17.33-4.25	12.90-16.64-10.29
Middle height (mm) (med-max-min)	9.50-16.49-5.25	9.93-14.76-3.64	9.85-16.49-3.64	9.94-13.40-7.21
Posterior height (mm) (med-max-min)	5.89-10.15-3.97	6.45-11.56-3.62	6.06-11.56-3.62	6.89-10.08-3.71
p value (anterior-middle-posterior height)	0.943-0.700-0.583		0.417-0.571-0.530	

med: median value, max: maximum value, min: minimum value

At the L4–L5 level, 11.81mm of anterior intervertebral disc space height showed 54.9% sensitivity and 54.5 % specificity; 8.01 mm of posterior intervertebral disc space height indicated 41.7 % sensitivity and 63.6 % specificity as a cutoff value based on ROC analysis with AUC value of 0.558 and 0.550, respectively for disc degeneration (Figure-2).

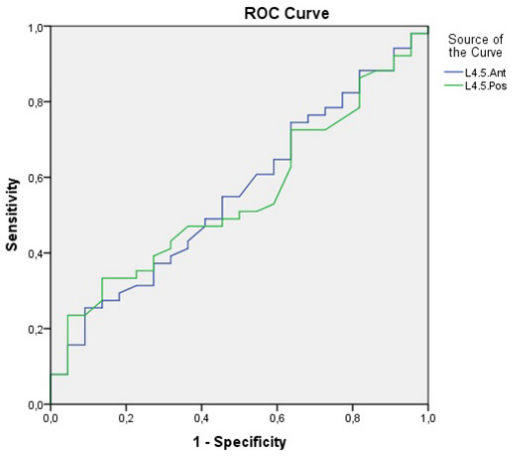

Figure-2. The receiver operating characteristics (ROC) analysis for anterior and posterior intervertebral disc space heights at the L4–L5 level in disc degeneration

For the same intervertebral disc level, 11.67 mm of anterior intervertebral disc height showed 62.5 % sensitivity and 42.9 % specificity; 10.16 mm of middle intervertebral disc height depicted 62.5 % sensitivity and 28.6 % specificity; 8.005 mm of posterior intervertebral disc height showed 37.5 % sensitivity and 53.1 % specificity as a cutoff value with AUC value of 0.493, 0.358 and 0.418, respectively for disc herniation (**Figure-3**).

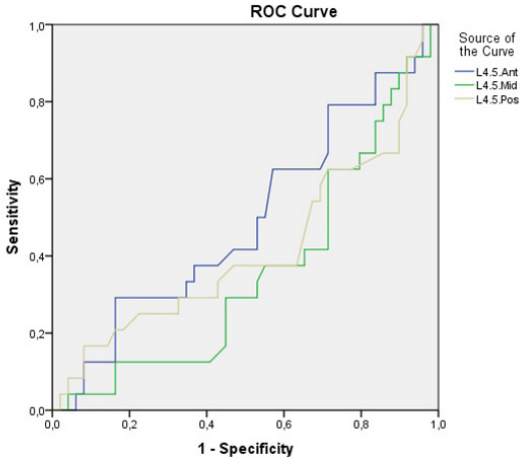

Figure-3. The receiver operating characteristics (ROC) analysis for anterior, middle, and posterior intervertebral disc space heights at L4–L5 level in disc herniation

DISCUSSION

Heights with disc degeneration and disc herniation using lateral lumbar spine radiographies. Our results showed that anterior and posterior intervertebral disc space heights were associated with lumbar disc degeneration, whereas anterior, middle, and posterior intervertebral disc space heights were associated with disc herniation at the L4–L5 level.

The lumbosacral part of the spine is known to be prone to disc herniation because of the mobility of this spinal segment. Previous studies in the literature have shown that the major portion (75 %) of lumbar flexion occurs at the lumbosacral joint and 15-20 % of flexion occurs at the L4–L5 level.[1] In this study, we have analyzed the relationship between L4–L5 and L5–S1 intervertebral disc space heights with disc pathologies since a majority (90-95 %) of clinically significant compressive radiculopathies are known to occur at these levels [4].

Previously, the sum of the disc heights was generally estimated to be a quarter of the total height of the vertebral column [2], leading to the assumption that "disc height was affected by height" [10].

However, some researchers have used converted measurements and ratios based on disc height instead of measuring individual intervertebral disc spaces [8]. Other studies have investigated the shape of end plates and disc heights to determine their relationship with disc pathologies. There are authors in the literature suggested that for degenerated and herniated intervertebral discs, spinal levels with concave-shaped end plates may have significantly higher discs than flat-shaped levels. Flat-shaped levels had significantly higher average disc height than levels with irregular-shaped end plates for degenerated discs but were not significantly higher in herniated discs [13]. In our current research, we were not focused on the specific shapes of end plates; instead, we measured the intervertebral disc space at three positions and analyzed the association between height at each position with disc pathologies.

In a study by Mirab *et al.*, the authors investigated normal intervertebral disc dimensions and found that mean anterior, middle and posterior disc heights were 18.14, 13.82 and 10.14 mm, respectively at the L4–L5 level and 18.71, 12.99 and 8.51 mm, respectively at the L5–S1 level [11]. Hong *et al.* studied the intervertebral disc space in the Korean population and found the anterior, middle and posterior heights to be 10.83, 10.05, and 7.20 mm, respectively at the L4–L5 level and 10.40, 9.58, and 6.02 mm, respectively at the L5–S1 level [8]. Both these studies were performed on MRI. The age range of the Hong *et al.* study population was 15 to 25 years. Our research using lateral lumbar spine radiographies found the anterior, middle and posterior disc heights to be 13.26, 11.20, and 8.44

mm, respectively at the L4–L5 level and 12.46, 9.50, and 5.89 mm, respectively at the L5–S1 level for non-degenerated discs. Besides technical variations, the difference in height measurements may also reflect genetic differences between the various study populations.

In the year 2017, Lee *et al.* published a study in a Korean population of 20 to 25-year-olds (n = 389). The results of this study showed that the anterior and middle height of intervertebral disc spaces were significantly lower for both degenerated and herniated discs, in comparison with normal intervertebral discs at the L4–L5 level [10]. In our research, anterior and posterior heights were significantly lower for disc degeneration. Moreover, anterior, middle and posterior heights were significantly lower for disc herniation at the same level. The difference of middle height of intervertebral disc space was not significant between degenerated and non-degenerated discs at this level in our research; however, the *p* value was remarkably close to statistical significance ($p = 0.051$).

Another aspect of this study showed that intervertebral disc space heights were not related to disc herniation or degeneration at the L5–S1 level. This may be because, at this level, biomechanical factors may play a more dominant role in affecting disc pathologies rather than disc space narrowing. More studies with larger populations may expand our understanding of the exact role of morphological alterations in disc space on disc pathologies at the L5–S1 level.

There are a few limitations of this study. Firstly, a wide range of age groups were included in this study. These measurements should be performed for each age group classified as young adults, adults and elderly, to understand the exact relationship between disc space narrowing and disc pathologies. The peak frequency of intervertebral disc herniation at L4–L5 and L5–S1 levels is known to occur between the ages of 44-50 years [15]. The mean age of our study population was approximately 48 years. This situation should also be considered for the results of this study. Secondly, this study only included a small sample size of the local population. More studies need to be performed on different populations given the possible effects of genetic differences. Thirdly, MRI is accepted as the gold standard in the diagnosis of disc pathologies in this study. However, surgical outcomes of patients may provide more accurate information about the relationship between disc space heights and disc pathologies. Lastly, the data distribution and sample size of our study population did not allow for performance of parametric tests. Much more patients are needed to understand the possible relationship between disc space heights and disc pathologies before the results of this study can be generalized to the entire population.

CONCLUSION

In conclusion, anterior and posterior disc space heights were associated with both disc degeneration and disc herniation, while middle disc space height was associated with disc herniation at the L4–L5 level. In addition, no satisfying cutoff disc space height values were obtained from the results of this study that can reliably be used to indicate disc pathologies on lateral lumbar spine radiographies.

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Volume: 30, Issue: 3, July 2019 pp: 193-197 ORIGINAL ARTICLE

THE EARLY EFFECTS OF THE SINGLE LUMBAR EPIDURAL STEROID INJECTION ON FASTING BLOOD GLUCOSE

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ABSTRACT

Background: Epidural steroid injection is one of the safest and most effective ways to treat acute and chronic lumbar back pain syndromes. The aim of this study is to determine the early effects of single lumbar epidural injection on the fasting blood glucose.

Patients and Methods: In this study, thirty-nine patients with chronic back pain and sciatica nerve pain who did not benefit from conventional therapies, such as anti-inflammatory medications and physiotherapy during last 6 months, were investigated. Each patient was given 80 mg triamcinolone acetonide via epidural route. Ten of the selected patients had type II diabetes mellitus and were treated with oral anti-diabetics. The fasting blood glucose were tested at baseline and at each post-treatment day during the first five days after the single epidural steroid injection.

Results: The mean fasting blood glucose levels increased significantly between baseline (106.38± 26.10 mg/dl) and the first two post-treatment day (day 1, 125± 55.52 mg/dl with p= 0.002; day 2, 113.41± 35.19 mg/dl with p= 0.01) but returned to baseline values by the fourth treatment day (day 4, 106.67± 27.96 mg/dl with p= 0.9) in all patients. The mean fasting blood glucose level on the third post-treatment day was also higher than the baseline but the difference was not statistically significant. When patients with and without diabetes mellitus were evaluated as separate groups, the mean fasting blood glucose levels returned to baseline values on the third day of the treatment in non-diabetic patients, whereas on the fourth post-treatment day in diabetic patients.

Conclusion: Epidural steroid injection may increase fasting blood glucose for a longer period in diabetic patients than those without diabetes mellitus. The patients should be informed about the influence of the epidural steroid injection on the blood glucose levels before the treatment procedure, but diabetic patients should also be offered regular blood glucose monitoring in the early period after the treatment.

Key Words: Lumbar epidural steroid injection, low back pain, diabetes mellitus, fasting blood glucose.

Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

Nowadays the use of minimally invasive procedures constitutes the basic principle for pain management therapies. Thanks to their anti-inflammatory effects, glucocorticoids have been the drug of choice for various types of pain management therapies. Because of their versatility, glucocorticoids' popularity among clinicians has been increasing. Especially for the treatment of chronic low back pain, epidural administration of glucocorticoids (via interlaminar, transforaminal or caudal) has found wide usage as a minimally invasive intervention, in addition or alternative to other conservative types of treatments, such as oral medication therapy, physiotherapy, weight loss, and exercise [30].

Epidural steroid injections have been used for the treatment of spinal originated acute and chronic low back pain for over 40 years. The first use of the epidural hydrocortisone for the treatment of the low back pain and sciatica nerve pain

was reported by Lievre in 1957 [6]. The first evidence of the presence of inflammation in patients who have radiculopathy has emerged in 1981 [25]. In 1986, Benzon concluded that patients with mechanic low back pain with radiculopathy symptoms may respond to epidural steroid injection therapy [3]. This led to the investigation of the use of epidural steroids in pain management with special focus on the strong anti-inflammatory effects of the corticosteroids. Since then, safety and efficacy of the epidural steroid injection have been established for the treatment of acute and chronic lumbar back pain [4,7,17,24,27,28,31].

The most commonly used corticosteroids for epidural injections are methylprednisolone acetate, triamcinolone acetonide, and dexamethasone acetate [2,5,13,16,21-22]. It has been shown that the fosfolipase activity of the herniation disc is more that of a normal disc (20 to 10.000 times) [26] and the benefits of the epidural steroid injections are due to the anti-inflammatory mechanism, which is secondary to inhibition of fosfolipase A_2 resulting with the blockage of the synthesis of prostaglandins and leukotrienes [1,9,10,15]. Even in pharmacologic doses, both oral or parenteral route type of administration of the corticosteroids have systemic effects (rapid decline in cortisol levels due to suppression of the hypothalamic-pituitary-adrenal axis and decrease in the cortisol levels that may continue for weeks) [19]. Several studies showed that after discontinuation of exogenous steroids, the recovery of HPA axis takes approximately one year [18].

Unfortunately, corticosteroids have adverse effects on the insulin metabolism. The main effect of corticosteroids on the blood glucose is hyperglicemia due to increasing insulin resistance and stimulation of gluconeogenesis in the liver. Several studies suggest that there is a relationship between an excess of cortisol and insulin resistance [32]. Reducing the response of the peripheral tissues to insulin would decrease the glucose uptake and the stimulation of gluconeogenesis in the liver would cause elevation of the blood glucose levels.

While the systemic effects of oral or parenterally administrated glucocorticoids have been studied widely, the effects of local steroid therapy have not been adequately studied. The aim of this study, therefore, is to determine the early effects of a single lumbar injection on the fasting blood glucose.

PATIENTS AND METHODS

For determining the early effects of the single lumbar epidural injection on the fasting blood, we designed our study to include patients who had low back pain and leg pain for at least 6 months. The study included 39 patients (29 women and 10 men) with a mean age 48.56 (age range between 27-70). We excluded any patients who had a history of using local or system steroids in the past 6 months. We also excluded patients who had absolute contraindications (such as local infections) to epidural steroid injections and patients who did not accept to participate in the study. We did not use a control group, since performing the epidural injection with local anesthetic alone would not be an ethical procedure for treating the patients who have low back pain and sciatica.

10 of the 39 patients included in our study suffered from previously diagnosed Type II Diabetes Mellitus. These 10 patients were all using oral anti-diabetics for the treatment of diabetes. These patients continued their usual diet and anti-diabetic therapy during the study. We also adviced all patients to continue their daily physical activities during the study period.

We performed low back pain therapy to all patients in the form of a single lumbar interlaminar epidural steroid injection. During the study, these patients did not use any additional steroids.

All epidural injections were administered through the interlaminar approach to the epidural space. The sitting position is a convenient method for both the patient and the operator in helping determine the midline. In our study, our team performed the interlaminar epidural steroid injections to patients in the sitting position. During the procedure, the loss of resistance technique was preferred, in aseptic conditions as is commonly used by experienced pain physicians. For the injection, we used 80 mg of triamcinolone acetonide and local anesthetics (10mg 0.5 % bupivicaine) diluated to 10 cc with 0.9 % NaCl.

We recorded the patient's baseline fasting blood glucose level before the first epidural steroid injection, and to help determine the early effects of the steroid, we measured the fasting blood glucose values for 5 days after the injection. For evaluating the effects of the epidural steroid injections, we scheduled a post-treatment visit on the tenth day which included a physical examination. We recorded the results of this examination, along with the degree of improvement in pain, improvement in physical activities, and any complications.

In our study, the data were evaluated using mean and standard deviations. "Paired t test" was used for parametric data and " chi-square test" was used for non-parametric data the P values < 0.05 were considered statistically significant.

RESULTS

We first considered all patients, and compared the baseline fasting blood values (106.38 ± 26.10 mg/di) which were recorded before the injection with the first day values (125 ±

55.22). The results showed that there was a large increase (18 %) in the fasting blood glucose values and we found that this increase was statistically significant, with a P value of 0.002. During the following days, especially on 2nd and 3rd days, the increase in the fasting blood glucose persisted (113.41 ± 35.19 and 109.59 ± 44.33 respectively). But, these values were lower than the first day (only 6.60 % and 3.01 % increase in days 2 and 3, respectively). In fact while, the 2nd day values are statistically significantly larger than the baseline, with a P value of 0.01, the 3rd day results showed that an increase that was not statistically-significant (P=0.419) (Figure-1).

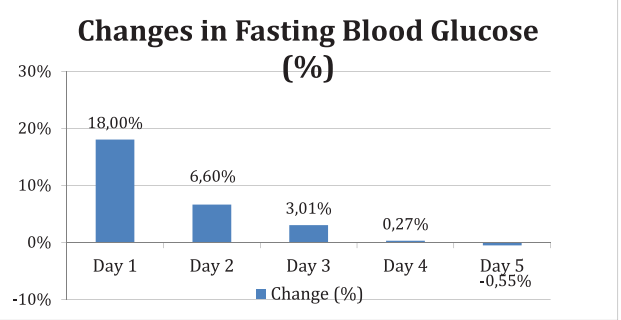

Figure-1. Post-procedure changes in percentage of mean fasting blood glucose according to days after injection

We next considered the non-diabetic and the diabetic patients separately. The results showed that both groups had statistically significant increases (P=0.001 and 0.037, respectively) in fasting blood values on the first day after the injection.

For non-diabetic patients, the fasting blood glucose values showed an increase of 12.70 % (109.24 ± 19.64 mg/dl) on the first day compared with the baseline values recorded before the injection (96.93 ± 7.43 mg/dl). The increase was significant with a P value of 0.001. Second day fasting blood glucose values for this group were 101.37 ± 16.11 with an increase of 4.59 % (P=0.114). In this group, the mean fasting blood glucose values returned close to base values during the last three days of the study.

In the group of diabetic patients, the fasting blood glucose values showed an increase of 23.49 % (165.1 ± 69.11 mg/dl) on the first day compared with the baseline values recorded before the injection (133 ± 39.86 mg/dl). The increase was significant with a P value of 0.037. For these patients, the increase in the blood glucose levels was also statistically significant on the 2nd day (148.2 ± 51.06 mg/dl and P value=0.04). Moreover, unlike the non-diabetic patients, the fasting blood glucose values remained 10.40 % high er also on the 3rd day, but this increase, was not statistically significant (P-value of 0.23). The mean fasting blood glucose values approached the baseline values on the 4th day, also for these diabetic patients.

DISCUSSION

Epidural steroid injection is the preferred treatment method for chronic low back pain. Clinicians prefer this procedure because of its effectiveness and lower rate of side effects: local application of corticosteroid to the epidural area tends to lead to lesser and shorter-time side effects because of its limited systemic distribution. Another advantage of the application of corticosteroid directly to the epidural space is the need to use lower doses of steroids to achieve the desired effects.

General effects of the glucocorticoids include decreasing tissue response to the insulin pathway and inducement of the glucagon pathway. In this study, we investigated the potential effects of single lumbar epidural steroid injection on the average fasting blood glucose in the chronic low back pain and sciatica nerve pain patients. The study results showed that there is a statistically significant change in fasting blood glucose levels for the first and second days after the injection in all patients with or without diabetes mellitus. Previous studies have shown that local injections of the corticosteroids to the intra-articular or epidural area may cause suppression of the hypothalamic-pituitary-adrenal axis [14,29]. A decrease in the cortisol levels is expected via this suppression, but not as much as the systemic routes. The results of our study point to a similar conclusion regarding the local corticosteroids effects on the regulation of the blood glucose. According to the results reported here, this effect is especially significant in the early stages of the treatment.

The application of oral or systemic corticosteroids may impaired the insulin sensitivity in diabetic patients and, for these patients, local glucocorticoids may lead to changes in glucose control. Gottlieb *et al.* reported that, since blood glucose control may change after the application of local glucocorticoids, stricter follow-up is needed for diabetic patients after the treatment [12]. Our study also points to a similar observation: as seen in Figures-2 and 3, after epidural steroid injection, changes in the fasting blood glucose levels are more pronounced in patients with diabetes and the changes last longer than the patients without diabetes mellitus.

In a study done in 2009, Gonzalez [11] has shown that, for diabetic patients, lumbosacral transforaminal and caudal epidural betamethasone injections are associated with statistically significant elevations that lasted for 2 days. Similar results were observed in a 2012 study by Even and colleagues [8] who evaluated the effects of epidural steroid injections on blood glucose levels in patients with diabetes mellitus. Their study reported that increases in blood glucose

levels were seen in approximately 85 % of the patients with diabetes. This increase was transient and blood glucose levels returned back to the baseline within 48 hours after epidural injection. While we also observed similar transient elevations in the blood glucose levels after interlaminar epidural steroid injections on patients with diabetes, blood glucose returned to the baseline levels only approximately four days after the injection.

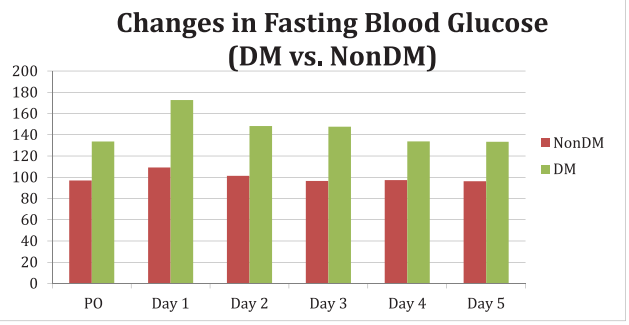

Figure-2. Comparison of the fasting blood glucose in patients with or without diabetes mellitus according to days after injection.

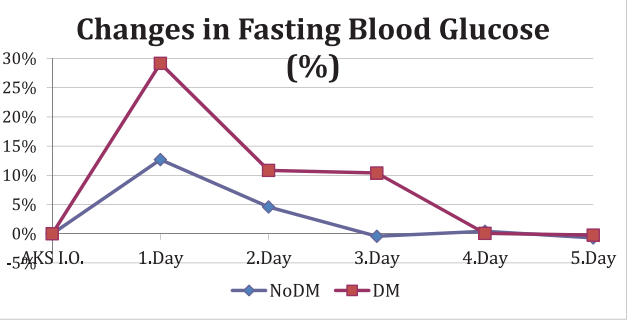

Figure-3. Comparison of the percentage of changes in fasting blood glucose in patients with or without diabetes mellitus according to days after injection.

Moon and colleagues [23] investigated blood glucose and cortisol levels after epidural and shoulder intra-articular glucocorticoid injections in both diabetic and non-diabetic patients. Their study included 29 patients with sciatic or shoulder pain. After glucocorticoid injections, fasting blood glucose and cortisol levels were measured on 1st, 7th, and 21st days and compared with the baseline levels. In all subgroups, fasting blood glucose levels were significantly higher on the first day after the injection. Levels returned to the baseline by the second control on the seventh day. In contrast to Moon's study, to observe how the fasting blood glucose levels vary during the first few days, we measured blood glucose levels every day after the injection; this enabled us to observed that glucose levels returned to the baseline on third day for the non-diabetic patients and fourth day for patients with diabetes.

In a 2007 study, Younes et al. [33] applied local glucocorticoid on 29 patients (epidural injection on 18 patients and intraarticular injection on 11 patients) with or without diabetes mellitus. The results showed a significant postprandial blood glucose elevation for all patients on the first day after the injection. On the seventh day control, high levels of postprandial glucose were seen only on patients with diabetes mellitus. Younes' results differ slightly from the results in our study, where even with diabetic patients blood glucose levels returned to the baseline on the fourth day after the injections. The reason for this difference is likely to be the types and doses of the steroids used in the two studies. In our study, we administered 80 mg triamcinolone acetonide in a single injection, whereas Younes had used 5,625 mg kortivazol per injection and applied three consecutive injections in a row.

Note that in an earlier study with 9 patients, Maillefert and colleagues [20] applied a single epidural injection of 15 mg dexametasone acetate, but they did not observe any change in fasting blood glucose after the epidural steroid injection. In a 2011 study of systemic effects in diabetic patients of single epidural steroid injection, Zufferey [34] administered 80 mg depot methylprednisolone. Also in that study, no effects on the glycemic control were observed. We believe that in these two studies injections failed to produce any effects on the blood glucose control due to the specific pharmacodinamic effects and the different dosing of the preferred drug.

Considering the results of our study and the prior findings, we believe that more comprehensive studies are needed to identify the right medication and dosage, especially for situations in which blood sugar regulation has high priority.

CONCLUSION

Our study has shown that, in all patients, epidural steroid injections may increase fasting blood glucose during the first few days after the procedure. For the patients with the diabetes mellitus, the elevations in the levels of fasting blood glucose may be higher and it may take longer for the glucose levels to return to the baseline levels. Considering these findings, it is important that the patients are informed before the application of epidural steroid injections about the potential impact of the injection on their blood glucose levels. Moreover, diabetic patients should be recommended regular blood glucose monitoring during the first few days after the treatment.

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Volume: 30, Issue: 3, July 2019 pp: 199-205 ORIGINAL ARTICLE

CLINICAL RESULTS OF PERCUTANEOUS VERTEBROPLASTY IN THORACOLUMBAR (T6-L5) VERTEBRAL COMPRESSION FRACTURES: RETROSPECTIVE STUDY OF 111 PATIENTS WITH 140 FRACTURED SEGMENTS

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ABSTRACT

Object: Vertebroplasty was first applied by Harve Deramond to a patient with vertebral hemangioma in 1984. In recent years, the increase in the number of osteoporosis, trauma and tumor cases has increased the incidence of vertebral compression fractures (VCFs). Nowadays, percutaneous vertebroplasty (PVP) has been a widely used treatment for painful acute VCFs. It is a minimally invasive technique. In this procedure, polymethylmethacrylate (PMMA) is injected into the vertebral corpus. There are PMMA's ability to increase stability at fracture site, thermal necrosis effect and chemotoxic effect on intra-osseous pain receptors. In this study, the safety and efficacy of PVP in patients with VCF were evaluated.

Methods: The patients who underwent PVP under sedoanalgesia or general anesthesia for single or multi-level thoracolumbar vertebrae fracture were reviewed retrospectively between January 2012 and March 2018. The study included 111 patients with VCF. 140 vertebral levels were treated with PVP. These VCFs were evaluated in 3 groups as osteoporotic, traumatic and pathological. We used the Oswestry Disability Index (ODI) for functional disability and the Visual Analog Scale (VAS) for pain severity. Our patients were followed up for 12 month after PVP.

Results: Patients mean age was 73,04 ± 7,17 years (91-56 years) and 18 (16,22 %) were male and 93 (83,78 %) were female. The most commonly affected vertebrae were T12 and L1 vertebrae corpus. Following PVP, VAS and ODI values decreased significantly in the last 12 months compared to preoperative levels ($p<.001$). Cement leakage was occurred in six patients (5.40 %).

Conclusions: PVP is an advantageous method. Because the procedure is fast and easy, a biopsy can be taken during the procedure, patients can soon stand up and be discharged; its complications are much less than open surgery. In addition to general anesthesia, it can be performed with sedoanalgesia. It is a reliable and effective technique for the treatment of pain due to osteoporotic and traumatic VCFs or metastatic lesions.

Keywords: Percutaneous vertebroplasty, Polymethylmethacrylate, Vertebral compression fractures

Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

PVP was administered by Galibert and Deramond in patients with vertebral hemangiomas in 1984 [8]. It is a minimally invasive procedure involving injection of bone cement (mostly PMMA) to the vertebral corpus fracture to improve pain and stability of the fracture [13]. Minimally invasive PVP provides significant relief of pain and provides early postoperative ambulation. Therefore, it has been widely preferred as treatment in elderly patients with osteoporotic VCF [23]. Most PVP procedures are performed to relieve pain in patients with severe osteoporosis and those with stable fractures attached to one or more vertebral bodies. In addition, vertebroplasty is recommended for patients suffering from posttraumatic symptoms associated with vertebral fractures, patients with large angioma located within the vertebral body, increased risk of compression fractures, and patients with pain associated with

vertebral body metastatic disease [4]. Osteoporotic fractures have become the main indication for vertebroplasty in many centers [10]. We aim to analyse the clinical results following PVP for single or multi-level segment thoracolumbar VCFs.

MATERIAL AND METHODS

Ethics approval and patient consents

Our study was a retrospective clinical study performed according to the principles of the World Medical Association Declaration of Helsinki, 'Ethical Principles for Medical Research Involving Human Subjects' (revised in 2013). Informed consent form was obtained from all patients.

Patients studied

We retrospectively analyzed the files of 111 patients (93 females, 18 males) who were hospitalized for VCFs at the Neurosurgery Clinic between May 2015 - December 2018 and who had undergone PVP.

Study design

Patients had to have one or more vertebral compression fractures, severe pain in the lumbar or thoracic region, limited activity, and resistance to medical treatment. A thoracolumbar brace was provided to all patients before and after surgery.

Acute (first 2 weeks) or sub-acute (2-8 weeks) VCFs were included in our study. Patients with anterior vertebral compression ratio greater than 85 %, motor and sensory loss, incontinence and unstable vertebral fractures were excluded from the study.

Imaging, VAS and ODI values

Preoperative and postoperative VAS measurements were used to evaluate the severity of the pain. Patients were scored between 0 and 10 points according to VAS requirements The most painless score was 0 points and the most painful score was 10 points.

The functional disability of patients were assessed using the ODI scale. There were 10 questions in the ODI survey. 6 stylish, scored from 0 to 5. The best score was 0 points and the worst score was 5 points. The total score was multiplied by two and calculated as a percentage. The maximum and minimum scores were 100 and 0, respectively. As the total score increases, the level of disability increases.

The patients were followed up in outpatient clinics and by phone interviews for 12 months after the surgery. VAS and ODI evaluations of the patients were done preoperatively, and again at 1. month, 6. month, and 12. month. Vertebral MRI, X-ray or computed tomography (CT) was taken to patients.

Surgical technique: Percutaneous vertebroplasty

These procedures were performed in the operating room under sedo anesthesia (95 patients, 85,59%) or general anesthesia (16 patients, 14,41%). All patients were placed in the prone position and C-Arm scopy (X ray) was positioned appropriately. An antibioprophylaxis (intravenous 1 gm cephazolin sodium) was performed systemically before the procedure. Fractured vertebra was identified in both anteroposterior and lateral view images. C- Arm was positioned for an anteroposterior view to visualize the pedicles of the affected vertebra. 11-gauge Jamshidi biopsy needles were inserted through the upper external edge of the pedicle ring in AP imaging and the transpedicular approach was inserted percutaneously into the fracture vertebral body. Kirschner wires were used to place a cannula into the posterior half of the vertebral body. Bone biopsies were taken from the vertebral corpus from some of these patients. PMMA was injected through the pedicle into the vertebrae. Post-PVP PMMA leakage was evaluated by postoperative vertebrae radiography or vertebral CT. Figure 1a shows preoperative T12 compression fracture in the sagittal MRI sections. Figure 1b shows post-operative 1st month PMMA in the vertebra CT. Figure 1c shows post-operative 12th month T12 compression fracture in the sagittal MRI sections. These images belong to a 72-year-old female patient.

Data of analysis

In this study, VAS and ODI values were examined measured before PVP and at the first, sixth, twelfth months after PVP. Statistical and visual analysis was used to analyze the data. Prior to the analysis of the data, the kurtosis and skewness values were examined to see if the data set met the assumption of normality. In all data the kurtosis values are in the range of -8686 and .092 and the skewness values are in the range of -.294 to .133. These findings show that the data show normal distribution. Since the data met the normality assumption, one of the parametric tests, Variance Analysis for Repeated Measurements (Repeated Measures ANOVA), was used to compare the change observed in pre- and post-intervention measurements. SPSS Statistic 22 package program was used to analyze the data and the significance value was analyzed as $p < .05$.

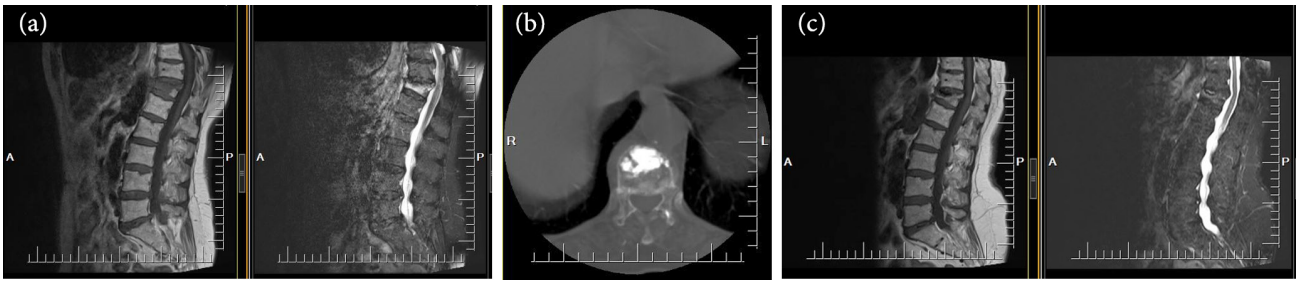

Figure-1. (a) T1-weighted and fat suppression sagittal magnetic resonance images reveal a fresh compression fracture at the T12 level (preoperative), **(b)** PMMA appearance in the T12 vertebral body in the thoracic CT axial section (post-operative 1st month), **(c)** T1-weighted and fat suppression sagittal magnetic resonance images reveal a fresh compression fracture at the T12 level (post-operative 12th month).

RESULTS

A total of 111 patients with traumatic, osteoporotic and pathological VCF and 140 vertebral levels were included in the study. The mean age was 73,04 ± 7,17 years (91-56 years), 18 (16,22%) were male and 93 (83,78 %) were female. The mean age of the males was 72.33 ± 8.43 (87-56) years, and the mean age of the females was 73.18 ± 6.95 (91-56) years. 68.47 % (n = 76) of the patients were treated for osteoporotic, 30.63 % (n = 34) traumatic and 0.90 % (n = 1) due to pathological compression fracture. 79.28 % (n = 88) had single level, 17.12 % (n = 19) had two levels, 3.60 % (n = 4) had three levels of VCF.

Most of the VCF was 59,29 % (n = 83) at the lumbar level. 40,71 % (n = 57) were at the thoracic level. The most affected level was T12 vertebra (n = 27, 19.29 %) and L1 vertebra (n = 27, 19.29 %). The mean preoperative anterior vertebral height loss rate was calculated as 26,61±14,57 %. The mean volume of PMMA injected to one vertebral level was 4.11±0.73 ml. In 6 patients (5,40 %) there was cement leakage. No neurological complications were associated with cement leakage. Postoperative hospital stay was calculated as 15.08 ± 9.50 hours (0.63 ± 0.40 days). Pathology was obtained from 61 patients. Only one patient (1.6 %) had multiple myeloma. All patients were mobilized in the first 4 hours postoperatively (Table-1,2).

Table-1. Demographic and clinical characteristics of study population

Study Population	Patients (n=111)
Age (years, mean ±SD)	73,04±7,17
Gender (n,%)	Male 18 (16,22%) Female 93 (83,78%)
Polymethyl methacrylate (PMMA) volume (ml, mean ±SD)	4.11 ± 0.73
Incidental metastatic tumours (n,%) Note: Bone biopsy samples were taken from 61 patients	
Multiple myeloma	1 (%1,6)
Postoperative hospital stay (hours, mean ± SD)	15.08 ± 9.50
Etiology of the VCF (n (%))	
Osteoporotic	76 (68.47%)
Neoplastic	1 (0.90%)
Post-traumatic	34 (30.63%)

SD – standard deviation.

Table-2. The numbers (n) and percentages (%) of T6-L5 VCFs.

Vertebra (n (%))	Total 140 segments
T6	3 (2.14%)
T7	4 (2.86%)
T8	3 (2.14%)
T9	4 (2.86%)
T10	3 (2.14%)
T11	13 (9.80%)
T12	27 (19.29%)
L1	27 (19.29%)
L2	22 (15.71%)
L3	15 (10.71%)
L4	10 (7.14%)
L5	9 (6.43%)

Table-3 shows the pre-test and post-test mean and standard deviation (SD) values for VAS and ODI, while Figure 2 shows the graph of these values.

The mean VAS of the patients before the intervention was 8.12 ± 1.11 and after the intervention was 2.19 ± 1.20 at the 1st month , 1.81 ± .98 at the 6th month, 1.41 ± .89 at the 12th month. After the surgery in the VAS values of the patients, a decrease was observed in all three measurements. According to the results of repeated measures analysis of variance, this decrease in VAS values are statistically significant, F = 1634.425, p <.001 (Table 4). According to post-hoc tests to determine the difference between the measurements, the difference observed between all measurements is statistically significant.

The mean ODI of the patients before the intervention was 73.72±10.93 and after the intervention was 21.15±12.11 at the 1st month , 18.00±10.58 at the 6th month, 14.52±8.97 at the 12th month. After the surgery in the ODI values of the patients, a decrease was observed in all three measurements. According to the results of repeated measures analysis of variance, this decrease in ODI values are statistically significant, F=1391.971, p<.001 (Table 5). According to post-hoc tests to determine the difference between the measurements, the difference observed between all measurements is statistically significant.

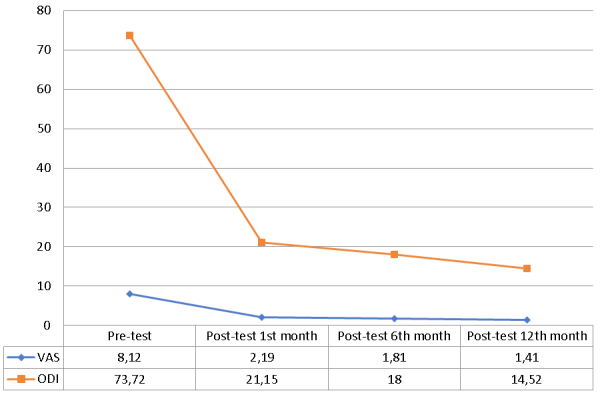

Figure-2. Pre-test and post-test (1st, 6th, 12th month) mean of VAS and ODI values

Table-3. Pre-test and post-test mean and standard deviation values of VAS and ODI values

	n	Pre-test		Post-test 1st month		Post-test 6th month		Post-test 12th month	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
VAS	111	8.12	1.11	2.19	1.20	1.81	.98	1.41	.89
ODI	111	73.72	10.93	21.15	12.11	18.00	10.58	14.52	8.97

Table 4. ANOVA results of pre-test and post-test scores of VAS values

Source of variance	Sum of Squares (SS)	Sd	Mean Squares (MS)	F	p
Subjects within	3583.500	333			
Measurement	3357.532	3	1119.177	1634.425	.000
Error	225.968	330	.968		

Table-5. ANOVA results for the pre-test and post-test scores of the ODI values

Source of variance	Sum of Squares (SS)	Sd	Mean Squares (MS)	F	p
Subjects within	282709.000	333			
Measurement	262004.207	3	87334.736	1391.971	.000
Error	20704.793	330	62.742		

DISCUSSION

PVP is an accepted treatment modality for osteoporotic, malignant, and traumatic spinal fractures. The effectiveness of this technique has been demonstrated in numerous studies [7,9,11-12]. These fractures cause severe disability and reduce the quality of life [19]. Hence, bringing the patient back to functional status at the earliest is very important to prevent further osteoporosis. To achieve that, pain needs to be managed at the earliest. Vertebroplasty is one of the minimally invasive procedures to achieve such pain relief and stability where less viscous bone cement is injected into the vertebral body [1,3,6].

In 2016, Leali, Paolo Tranquilli et al. reported that the pain and disability caused by acute osteoporotic VCF appear to be treated with more efficacy through the PVP than with the conservative therapy alone [14].

The advantage of vertebroplasty in malignant spine disease is the less invasive nature compared to open spinal surgery and the apparent rapid pain relief compared to radiotherapy and other conventional treatment options. In the present study, the patients with painful spine metastasis were successfully treated without serious complications. One of the proposed mechanisms is the balancing of fractures. Other factors are vascular, chemical and thermal. Pain decreases with exothermic reaction of bone cement and compression of small nerve endings [5].

The absolute contraindications of vertebroplasty are irreversible coagulopathy, allergy to PMMA and the presence of infection in the body. PVP should not be applied to asymptomatic VCFs which may heal with conservative treatment. Disruption of the posterior vertebral corpus wall, tumor invasion to the spinal canal and collapse to less than one third of the vertebral body is a relative contraindication. These VCFs are difficult to treat. The risk of complications is higher during the surgical procedure [10]. Complications of PVP include pulmonary embolism, cardiac perforation, fractures of adjacent vertebrae and infections. In addition to these complications, there may be bone cement extravasation into the spinal canal, paravertebral and intervertebral areas or venous systems [2]. No significant complication was observed in our study. Only 6 patients had cement leakage. These results show that PVP is usually a safe surgery for patients with VCF.

PVP and PKP (percutaneous kyphoplasty) have been compared in literature many times. In a recent study, PVP was found to be more advantageous than PKP in terms of operative time. However, PKP is more advantageous in terms of correcting kyphotic angle and restoration of vertebral height. There is no significant change in VAS and ODI values between PVP and PKP. Similarly, there is no difference in cement leakage rates [22]. However, in a meta-analysis study published in 2016, it was reported that PVP caused more cement leakage than PKP. The cost of PKP was also higher. In terms of cost, PVP is more advantageous. In this meta-analysis study, there was no difference between PKP and PVP groups in terms the rate of adjacent and new vertebral fractures [15]. In our study, VAS and ODI values were found to be quite significant at 1-year follow-up. Values in our study many kyphoplasty in the literature were not worse than VAS and ODI values.

As in the study of Takahara et al., The most common vertebral fractures is T12 or L1 (thoracolumbar junction) levels [20]. In our series, T12 and L1 were the most commonly affected with 54 levels (38.57 %).

In a study conducted by Morsi et al., the mean duration of hospital stay for PVP and PKP was 22.4 hours and 24.5 hours respectively[16]. In our study, this rate was approximately 15 hours. This shows us that after the PVP, the duration of hospital stay and cost decreases as the experience increased.

Xu et al., calculated the average injected PMMA volume 4.3 ml In their study [21]. Saracen A and Kotwica Z, injected maximum 0.5 ml PMMA even into the vertebral plane [18]. In our case series, a mean volume of 4.11ml PMMA was injected per vertebra.

In an article published in 2010, 75 patients underwent routine bone biopsy during the PKP procedure. A high rate (11 patients) had pathology. These pathologies were metastatic lesions (7 patients), myeloma (3 patients) and leukemia (1 patient) [17]. However, only one patient had multiple myeloma in our patient series (61 patients).

CONCLUSION

PVP provides stability in patients with osteoporotic, traumatic and pathological vertebral compression fractures. It is a safe surgical option with minimal complications and it prevents spinal deformity by reducing the collapse of the vertebral corpus. PVP can be performed quickly and should be preferred especially in elderly patients with secondary diseases. Routine bone biopsy during the surgical procedure may be significant in terms of incidental tumor detection. The low complication rate in our study may be related to the volume of injected PMMA (approximately 4ml). More work is needed in the future for the proof of all these claims. We consider PVP as a reliable and effective technique for the treatment of pain associated with osteoporotic, traumatic and pathological VCFs.

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Volume: 30, Issue: 3, July 2019 pp: 207-210 ORIGINAL ARTICLE

SPINAL ARACHNOID CYSTS

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ABSTRACT

Aim: Spinal arachnoid cysts are rare seen and uncommon lesions in the spinal canal. The aim of this study is to investigate the spinal arachnoid cysts in our series.

Material and Methods: We inspected 322 patients who were admitted to outpatient clinic from patient file system retrospectively. The patients that admitted for cranial pathologies were excluded. We found only 10 spinal arachnoid cyst lesions and only one of them had been operated. Neurological examinations, symptoms, type of SAC and demographic characteristics of patients were evaluated.

Results: A total of 322 patients were evaluated. 172 patients (53.5 %) were female and 150 patients (46.5 %) were male and the mean age was 53.11 ± 14.03 years old. We found 10 patients (3.1 %) with SAC. Female ratio was 60 % and male was 40 % patients with SAC. Extradural type SAC rate was 70 %.

Conclusion: Spinal arachnoid cysts are rare entities that present with symptoms and signs as a result of focal spinal cord compression. Surgical fenestration or excision could improve mostly in motor, gait and sensory components of the patient's clinical presentation.

Keywords: Spinal arachnoid cysts, meningeal cysts, spinal cystic lesions

Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

Arachnoid cysts are entrapment of cerebro-spinal fluid (CSF) or CSF-like fluid presenting adjacent to normal CSF spaces. Spinal arachnoid cysts (SAC) are relatively uncommon but a well-described entity [(2)]. Spinal arachnoid cysts (SACs) are rare lesions that account for 1 %-3 % of all mass lesions in the spinal canal [(3)]. The cause of these cysts has not been definitively determined and many theories have been postulated to explain their origin and expansion [(6)]. These cysts are usually extradural, but they can be intradural, perineural and intramedullary also [(11)].

First classification about SAC was made by Nabors et al. as spinal meningeal cysts on the basis of their anatomical location and tissue of origin following histological assessment [(12)]. The classification classified lesions as Type-1 are extradural being anterior or lateral meningocoeles, Type-2 are extradural meningeal cysts containing nerve root fibres and Type-3 representing the true intra-dural arachnoid cysts which are the subjective of this study. A more recent classification was made by Klekamp for the pathologies of the spinal meninges concurs that SAC are fundamentally intra-dural lesions that are either primary in origin or secondary to inflammatory reactions as a result of hemorrhage, trauma, surgical procedure or infection [(8)].

Magnetic resonance imaging (MRI) is the gold standard radiodiagnostic tool to expose location and the resultant spinal cord compression, however computed tomography (CT) myelography is better in displaying the dural defect through which an extradural cyst communicates with the subarachnoid space. Thoracic region is most commonly seen spinal

region for SAC. Only a small percentage of these patients may be asymptomatic. Mostly they present with symptoms due to spinal cord compression affecting motor, sensory and bladder functions [6]. Good outcomes have been reported following surgery in symptomatic patients [5].

MATERIAL AND METHODS

We inspected 322 patients who were admitted to outpatient clinic from patient file system retrospectively. The patients that admitted for cranial pathologies were excluded. We found only 10 spinal arachnoid cyst lesions. Neurological examinations, symptoms, type of SAC and demographic characteristics of patients were evaluated. Only one of the patients with SAC was operated. She had been operated for a thoracic mass lesion. Her motor weakness began after one year of surgery. SAC was seen when MRI displayed. After she had been operated motor deficit decrease and walking ability improve (Figure-1-4).

RESULTS

A total of 322 patients were evaluated. 172 patients (53.5 %) were female and 150 patients (46.5 %) were male and the mean age was 53.11 ± 14.03 years old. We found 10 patients (3.1 %) with SAC. Female ratio was 60 % and male was 40 % patients with SAC. Extradural type SAC rate was 70 %. The characteristics of patients with SAC are presented. (Table-1).

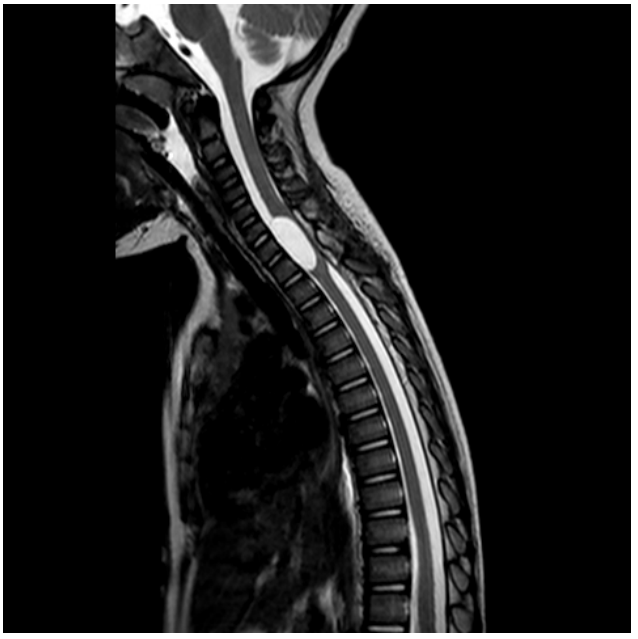

Figure-1. Preoperative sagittal MRI image of SCA

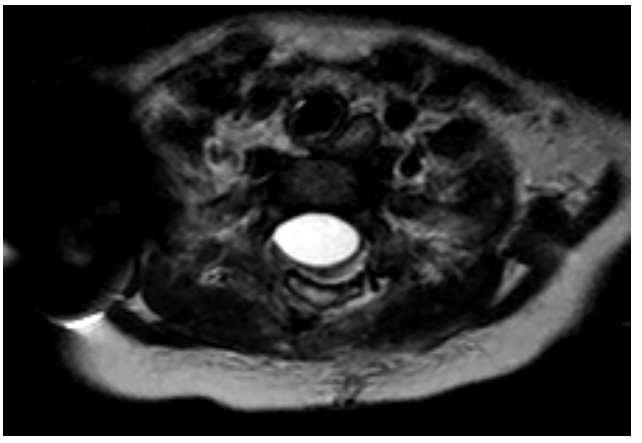

Figure-2. Preoperative axial MRI image of SCA

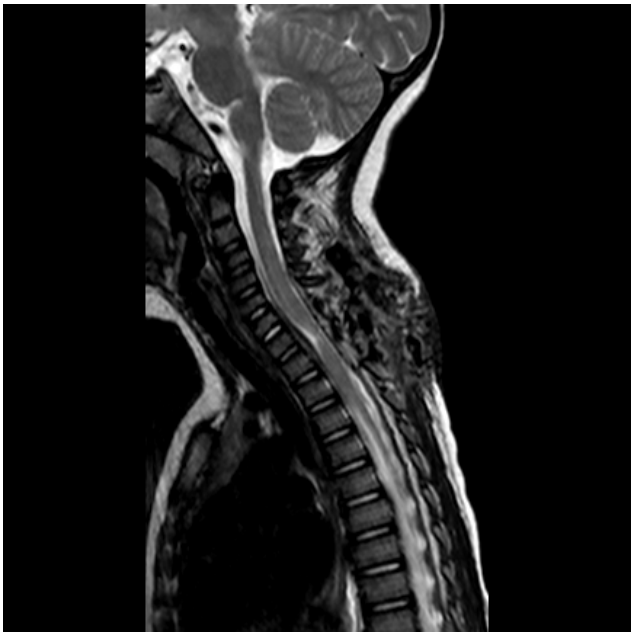

Figure-3. Postoperative sagittal MRI image of SCA

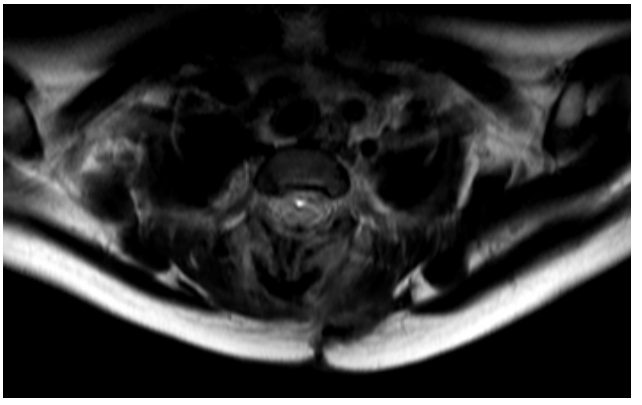

Figure-4. Postoperative axial MRI image of SCA

Table-1. Characteristics of patients with SAC

AGE	GENDER	LOCATION	TYPE	SYMPTOMS
30	Female	Thoracic	Extradural	Back pain
56	Male	Thoracic	Intradural	Back pain
41	Male	Lumbar	Intradural	Lower extremity numbness
29	Female	Thoracic	Extradural	Back pain
3	Female	Cervical+Thoracic	Extradural	Motor deficit
49	Female	Thoracic	Extradural	Back pain
59	Male	Lumbar	Extradural	Low back pain
33	Female	Thoracic+Lumbar	Intradural	Back pain
60	Female	Thoracic	Extradural	Back pain
36	Male	Thoracic	Extradural	Back pain

DISCUSSION

The origin of primary idiopathic SAC is ill-defined with several theories proposed explaining their origin[4]. The leading theory is that SAC arise from the septum posticum; a thin midline arachnoid membrane spanning the subarachnoid space from the pial surface to the arachnoid mater and was first described by Magendie [1,13]. SAC may be extradural or intradural. Most reports show that extradural are more common than intradural arachnoid cysts [7,9]. Extradural was mostly seen in our series too.

Arachnoid cysts are classified into primary or secondary. The etiology for the cause of cyst formation remains uncertain. An inflammatory process as a result of trauma, infection, surgery, or hemorrhage is the cause of process. SAC probably cause patients to develop neural symptoms due to pressure on the spinal cord or nerve root [10]. Patients with SAC usually present with back pain, numbness, paresthesia, motor weakness, gait disturbance and neuropathic pain. The gold standart radiodiagnostic tool do diagnose sac is MRI because of its high sensitivity and specificity and SAC appear as homogeneous low-intensity-signals on T1-weighted sequences and high-intensity signals on T2-weighted sequences, consistent with CSF characteristics [14].

Sadek et al reported 17 patients with thoracic arachnoid cysts that observed with complaints of motor weakness (47 %), paresthesia (76 %), unsteadiness (53 %) and neuropathic pain (76 %) [13]. They inspected that all patients experienced improvement in at least of one their presenting symptoms and or clinical signs six months following surgery and they conluded with that weakness, gait and paresthesia were most likely to improve following surgery.

Eroglu et al. inspected 13 patients that operated for SAC and they found that the majority of cases were located in the thoracic spine (54 %) and all but one case was located dorsally or dorsolateral [3]. They also reported 38% SAC were located extradural and 54 % were located intradural. Pain (80 %) was the most common presenting symptom and most patients had improvement or complete resolution of their symptoms after intervention in their series.

Garg et al. evaluated 11 patients were operated for SAC during the study period, the mean age at surgery was 32.9 ± 20.8 years and male to female ratio was 2.7:1 [6]. They reported that common presenting complaints were lower limb weakness and pain; the median duration of symptoms before surgery was nine months. Ten patients had extradural cysts while one had intradural cyst. Their rates were similar to our study.

CONCLUSION

Spinal arachnoid cysts are rare entities that present with symptoms and signs as a result of focal spinal cord compression. Surgical fenestration or excision could improve mostly in motor, gait and sensory components of the patients clinical presentation.

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Volume: 30, Issue: 3, July 2019 pp: 211-221 ORIGINAL ARTICLE

SPECIAL DESIGNED ROUTING DEVICE TO EASE ENDOSCOPİC TRANSFORAMINAL LUMBAR DISC SURGERY: A CADAVERIC STUDY

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***Ethics committee approval was obtained for the study.**
***Level of Evidence:** Level IV
*** Field of the study:** Minimal Invasive Surgery

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ABSTRACT

Background Data: Fully endoscopic lumbar disc (FELD) surgery via transforaminal (TF) approach may be more demanding to adopt for surgeons experienced with conventional microdiscectomy, due to the necessity of a new anatomic orientation and understanding. We designed a routing device to facilitate access to safe anatomic triangle defined by Kambin at the level of foramen in cadavers.

Purpose: To show that the transforaminal route for endoscopic lumbar disc herniations is safely applicable with the aid of a new routing device.

Materials and Methods: Ten cadavers between the ages 18-75, with no history of lumbar spinal surgery or trauma, with previous abdominal computed tomography (CT) scans included in our study. Postmortem abdominal CT scans were performed. Images were examined and transforaminal entrance angles without causing damage to retroperitoneal structures for each lumbar disc space and anatomical differences were recorded. TF approach was performed in cadavers using the angles measured from abdominal CTs and the entry point determined with the help of routing device.

Results: L1-L2, L2-L3, L3-L4, L4-L5 disc spaces were operated in ten cadavers. Kambin's triangle was successfully reached with help of routing device using data obtained from CT (X', α) and C-arm fluoroscopy (X, Y, Y'). Y' marker with protractor on routing device, and the metal rod on this Y' marker with an opening through which only the punction needle could pass were very important in reaching the target. The metal bar horizontal movement and fixation to this mechanism contributed to operation of device. Entrance points and angles calculated with the help of CT scans were found to be compatible with the images obtained from fluoroscopy and endoscopy during operation.

Conclusions: In this study, it has been showed that TF approach can be safely performed with help of the new designed routing device.

Key Words: Spinal endoscopy; transforaminal, minimal invasive spine surgery; exiting root, traversing root; endoscopic anatomy

INTRODUCTION

Surgery for lumbar disc herniation can be classified into two categories: conventional versus minimally invasive surgery [(10)]. Currently, conventional microdiscectomy (MD) is widespreadly used [(13)]. However, minimally invasive techniques have been increasingly applied all around the world [(3)]. Fully endoscopic lumbar disc surgery (FELD) via TF approach is a minimally invasive technique with advantages of small incision, rapid recovery, short operation time, and low cost [(2)]. For neurosurgeons who are experienced in conventional MD, the interlaminar approach is easier to adopt because of similarities in the anatomic orientation. However, the lateral TF approach may be more demanding. The initial stage of spinal cannula insertion under fluoroscopy is of the utmost importance, as it leads the surgeon to the optimal target point. Failures at that stage may result in improper placement of the endoscope, creating a risk of nerve root injury and inability to remove the herniated disc. TF approach requires multiple punctures under fluoroscopy as in other minimally invasive spinal surgeries [(9)].

Transforaminal steroid injection is a common method used in the management of radicular pain. Inexperienced surgeons may perform transforaminal steroid injections to improve foraminal puncture for endoscope placement. However, this may lead to increased exposure to radiation, prolonged operation time, and damage to soft tissue [3]. Therefore, we designed a routing device to reduce the number of punctures even in inexperienced hands. In this study, we aimed to evaluate the effectiveness of this routing device which facilitates access to safe anatomic triangle defined by Kambin at the level of foramen in cadavers.

MATERIALS AND METHODS

The study was approved by the local Institutional Review Board of Istanbul University and Republic of Turkey, Forensic Medicine, Ministry of Justice. This study was conducted in autopsy training hall of Forensic Medicine Institution Morgue Department, Ministry of Justice, Republic of Turkey. Postmortem abdominal CT scans were performed one each cadaver. CT images were examined and TF entrance angles without causing damage to retroperitoneal structures for each lumbar disc space and anatomical differences were recorded.

After the examination of forensic experts and the completion of the autopsy, fresh cadavers were taken to the autopsy training hall. The cadavers were placed in prone position on a radiolucent table. Roller cushions were located bilaterally between shoulder and anterior superior iliac wing. Endoscopic unit and monitor were positioned on the head side, C-arm and surgical instruments were located on foot site, and the surgeon was positioned on the left side of the cadaver.

Routing Device:

A routing device was designed to facilitate access to the secure anatomic triangle defined by Kambin without damaging retroperitoneal structures. This device consisted of following parts (**Figure 1, 2, 3**);

1. 25x25-cm stainless steel table welded with M8x36 mm stainless steel bolt in the center.

2. U-channel joint (10 cm long, 1.2 cm in diameter; 4.5 cm long, 0.8 cm in diameter in the middle) threaded to the M8x36 mm stainless steel bolt.

3. A 1.2 cm diameter, 85 cm long stainless steel bar passed through the U-joint to form the Y axis of the device (The 8mm flat end side of this bar which was inserted into the channel joint was fixed with a M6x28 mm stainless steel bolt. One side of the bar was flattened to fix the markers on the Y-axis of the routing device at 90°, and a strip ruler was fixed on it with M6x9 mm setscrew bolt and Plexiglas holder (polymethylmethacrylate based, radiolucent, thermoplastic material. Y axis could stay at 90° as well as it could be moved forward or backward from the open ends (Z axis) of U-joint).

4. A metal rod of 1.2 cm in diameter, 30 cm in length, which could be moved in the Y-axis and used as the X-axis, placed perpendicularly to the Y-axis, and 90° angled, 20x20x40 mm stainless steel axis fixing piece to fix it in the Y-axis 90° with holes 1.2 cm in diameter and M6 teeth to secure both axes (The metal bar forming the X-axis had s trip ruler on it, fixed with M6x9 mm setscrew bolt and Plexiglas holder.

5. 2.4 cm wide, 1.46 cm thick, 12 cm long Plexiglas with a '+' shaped stainless steel marker fixed to the end, attached perpendicularly to the X axis in the Z axis, and secured with stainless steel wing bolt. This Plexiglas was used as an X marker.

6. Markers moving on the Y axis, and perpendicular to this axis, markers mounted on the Z axis, which were secured with M6 stainless steel wing bolt;

a. 2.4 cm wide, 1.46 cm thick, 12 cm long Plexiglas with '+' shaped stainless steel marker placed on the tip of it (This Plexiglas was used as '0' zero point or Y marker).

b. A 12 cm long Plexiglas that could move in the Y-Axis and could be attached to the Z-axis with a stainless steel wing bolt, with a goniometer in the end (A goniometer parallel to the X-axis was fixed perpendicular to the lower edge of the free end of this Plexiglas, which was used as the Y' marker. A second Plexiglas of 1.6 cm in length which had a space in it to allow the passage of the metal bar through, was secured by a bolt to allow movement to the backward Plexiglas on the lower edge of goniometer. A metal rod of 0.6 cm in diameter and 20 cm in length was inserted in second Plexiglas, and secured with stainless steel bolt. This metal rod could measure angles, and move back and forth in the second Plexiglas. There was an opening of 1.2 mm diameter, 25 cm long in the middle of metal rod. 18-gauge needle could pass from this opening. So, it is ensured that the target of the needle sent through the metal bar was not deviated.)

The sizes of the Plexiglases used for the X, Y, Y' markers in the routing device were the same and the sign of each intersected at a point on the Z axis, which formed our target point.

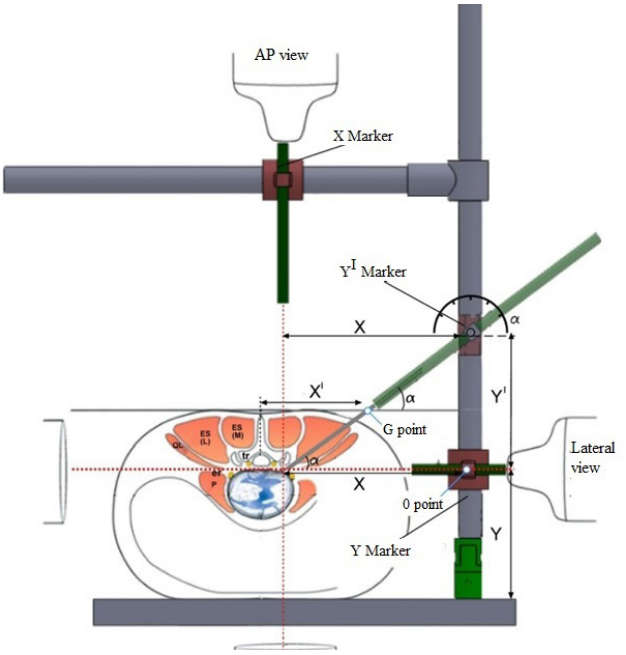

Figure-1. This is the demonstrative view of the patient and routing device. X value is distance between midpedicular line and Y axes of the routing device. Y value is distance between Y marker and metal base of the routing device. It will change according to age, gender, weight and height Y′ value is obtained by multiplying tangent α and X value. As tangent α is a constant value, with increase and decrease of X values, Y′ also will increase and decrease. X′ value is distance from the entry point to the midline.

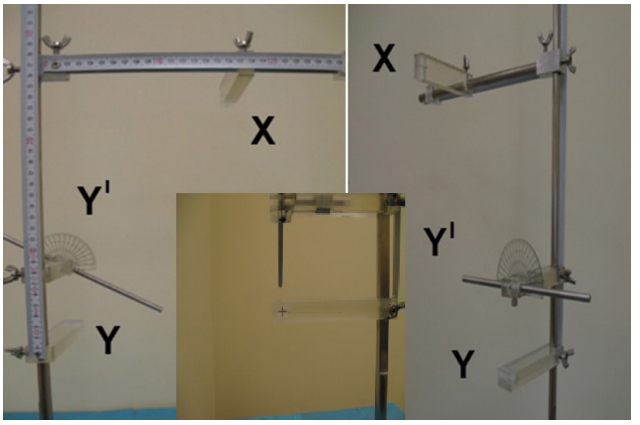

Figure-3. The metal rod acting on Y-axis and placing perpendicularly to the Y- axis and is going to be used as X-axis (left). The X marker is located at the X axis and placed perpendicularly to the Z axis (right). The X and Y markers are composed of plexyglass at which plus shaped stainless steel is placed to the distal parts (middle).

Figure-2. Picture showing the routing device, that is designed according to basic principles of endoscopic transforaminal lumbar disc surgery (AP and antrolateral view: Left and middle respectively). The routing device includes stainless steel bolt at the mid-point of the stainless steel table. U-channel joint is placed in this bolt. The stainless steel rod forms Y axis and passes through the U-channel joints. One side of the Y axis rod is flat in order to have markers stabilized on the rod at 90°. On the other side of the rod, a ruler is placed to make measurements (right).

Foraminal puncture with the use of the routing device:

The routing device was placed under the roller cushions after the positioning of cadaver. Before X and Y axes were determined, the device was moved in the Z axis in the lateral view of C-arm to position it parallel to vertebral end plates. A longitudinal line connecting the spinous processes in the AP image was drawn with the help of a metal rod and the midline was identified. The distances of entrance points from the midline were measured with ruler in cm (**Figure 4**).

The X marker on the X axis was brought on midpedicular line of target disc space in AP image. The distance of midpedicular line to Y-axis of routing device was recorded as an X value (**Figure 4**).

In the lateral view, target foraminal level was identified with the Y marker. The distance from this point to the device's plane was recorded as the Y value, and the Y marker was fixed on the Y axis. Also, this point was taken as the Y-axis zero-point (0) for each cadaver (**Figure 4**).

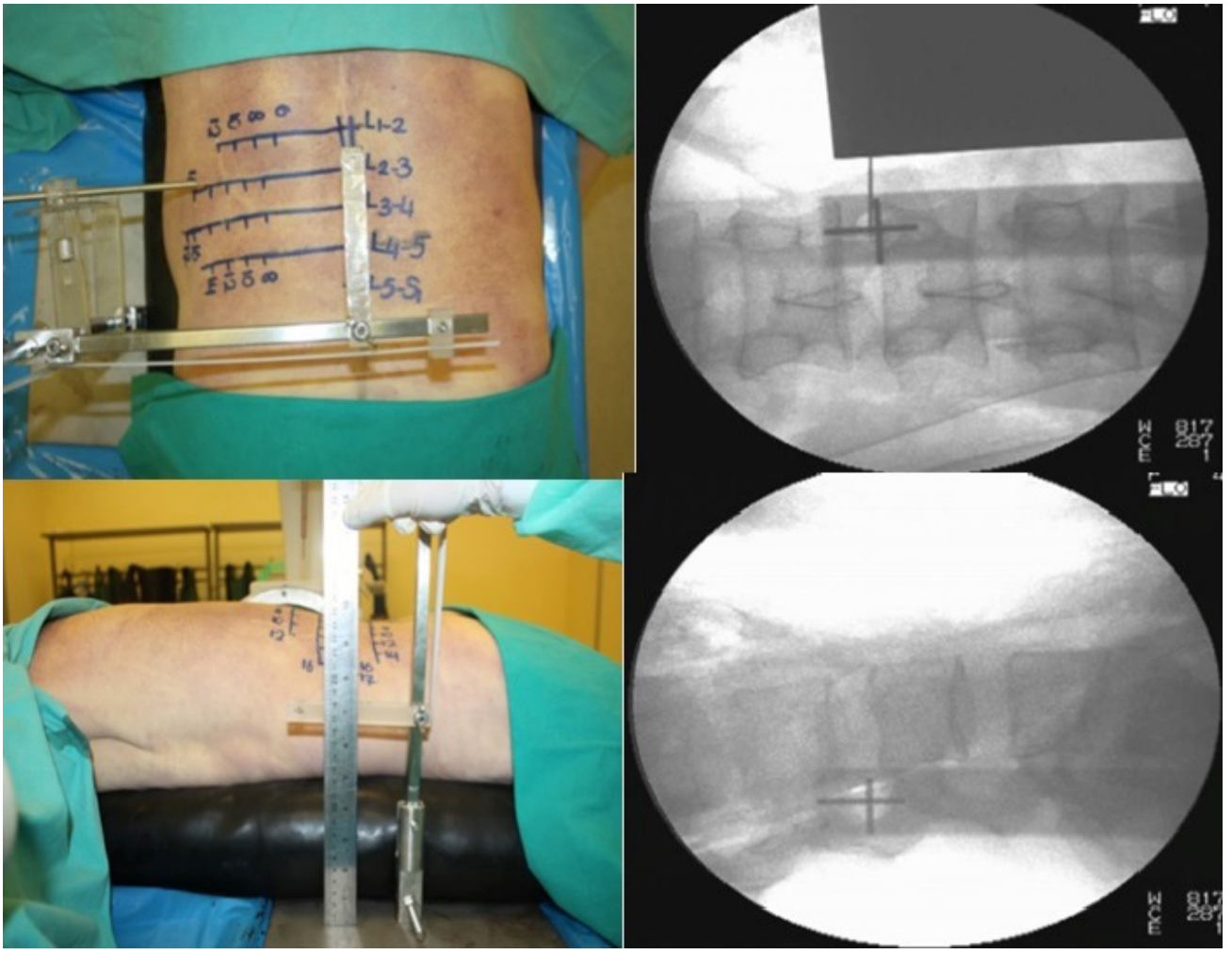

Figure-4. Determining the X value at the L2-L3 level X= 23 cm. X marker is placed on to the midpedicular line at the target disc level in AP projection. Distance between midpedicular line and Y axis of the routing device is determined as X value (above row left and right). In the lateral projection Y marker is fastened at the target foramen L2-L3, Y=17.3 cm. Target foraminal levels determined by Y marker at the lateral projection . Distance between Y marker and metal base of the routing device is named as Y value. Y marker is fastened on Y axis and this point is determined as ''0'' (zero) point (below row left and right).

Safe entrance angle to foramen without damage to retroperitoneal structures (α-angle) was calculated from abdominal CTs of each cadaver. Disc slope line to enter the target disc space was drawn in sagittal plane with use of axial and sagittal reconstructed abdominal CT images **(Figure 5)**. The view of this slope line in axial plane was placed in prone position in CT. A transverse line was drawn at the level of annulus of the target disc space. The angle between the line passed from entrance point on the skin to midpedicular point at the level of foramen without damaging retroperitoneal structures and the transverse line passed from annulus was recorded as the α-angle.) Y value was obtained by multiplying the tangent α and X values. The Y' marker was fixed on the Y axis by moving away from the Y marker (zero point) by Y'. The special mechanism on the Y' marker was set as an α-angle. The entrance point on the skin of the punch needle in this direction (with α-angle) was identified as the 'G' point. The distance between the midline and G point was measured as X' (**Figure 5**). X' and Y' values were measured separately for each distance (L1-L2, L2-L3, L3-L4, L4-L5) under C-arm fluoroscopy using the angles obtained from CT with this routing device. Foramen was punctured with the 18-gauge needle that passed through the Y' marker at each disc distance. Needle was seen on midpedicular line in AP view and posterior vertebral line in lateral view (Kambin's triangle) of fluoroscopy (**Figure 5**).

Since it was known that exiting root was the most likely injured anatomical structure during placement of the oval cannula in TF approach, exiting roots from the L1, L2, L3, L4, L5 foramens of 4 cadavers were macroscopically examined while the cannula of endoscope was still in the foramen. The 30-cm long incision that was 6 cm off from midline was made. Skin, subcutaneous tissue, and fascia of paravertebral muscle were passed, and transverse processes were recognized after removal of erector spinae muscles. After excision of intertransverse ligament between transverse processes, quadratus lumborum and psoas muscles were retracted, and the emerging roots were revealed (**Figure 6**).

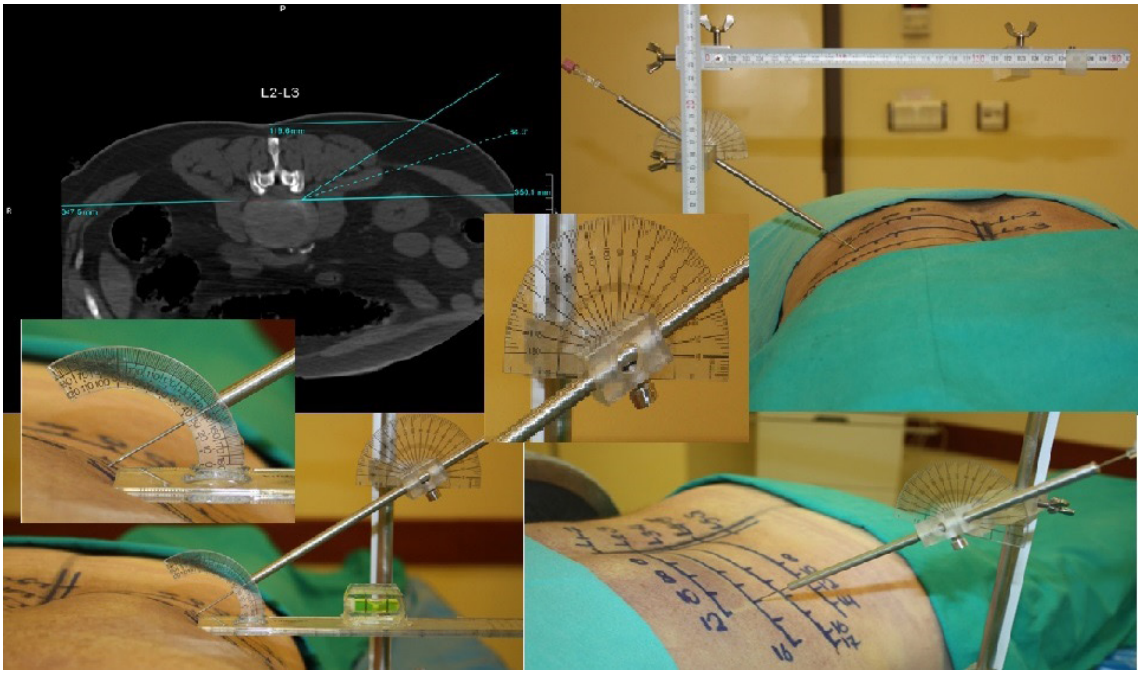

Figure-5. Calculation of the entry point to left L2 foramen at L2-3 level from the abdominal CT α=34°, X'=11.96~12cm. Cadavers' abdominal CT scans were studied and a safe angle is calculated to protect the retroperitoneal structures for every lumbar disc segment (above left). Entry at L2-L3 level to left L2 foramen. Entry angle is 34° and this value is calculated using abdominal CT. By multiplying tangent α and X value, Y' value is obtained. At the Y axis, the Y' marker is transferred from Y marker to the Y' value and stabilized. Protractor on Y' marker is positioned to the α angle value. The puncture needle is directed through this angle and entry point on the skin is named as 'E' point. The distance from the E point to the midline is defined as X' value. This figure depicts the entry of the needle on the Y' marker with a 34 degree angle which is calculated using abdominal CT. The entry point is L2-L3 level at left L2 foramen (above right). Y' is positioned to the 34° at the protractor and at this angle entry point was seen. This was controlled with water scales ruler which included protractor (below left). Skin entry at the X' distance, measured at the abdominal CT, when the X, Y, Y' markers were stabilized and entry angle direction was provided (X'=12cm). After stabilizing X, Y, Y' markers and providing entry angle, ıt confirmed same skin entry site at X' distance as measured by abdominal CT (below right).

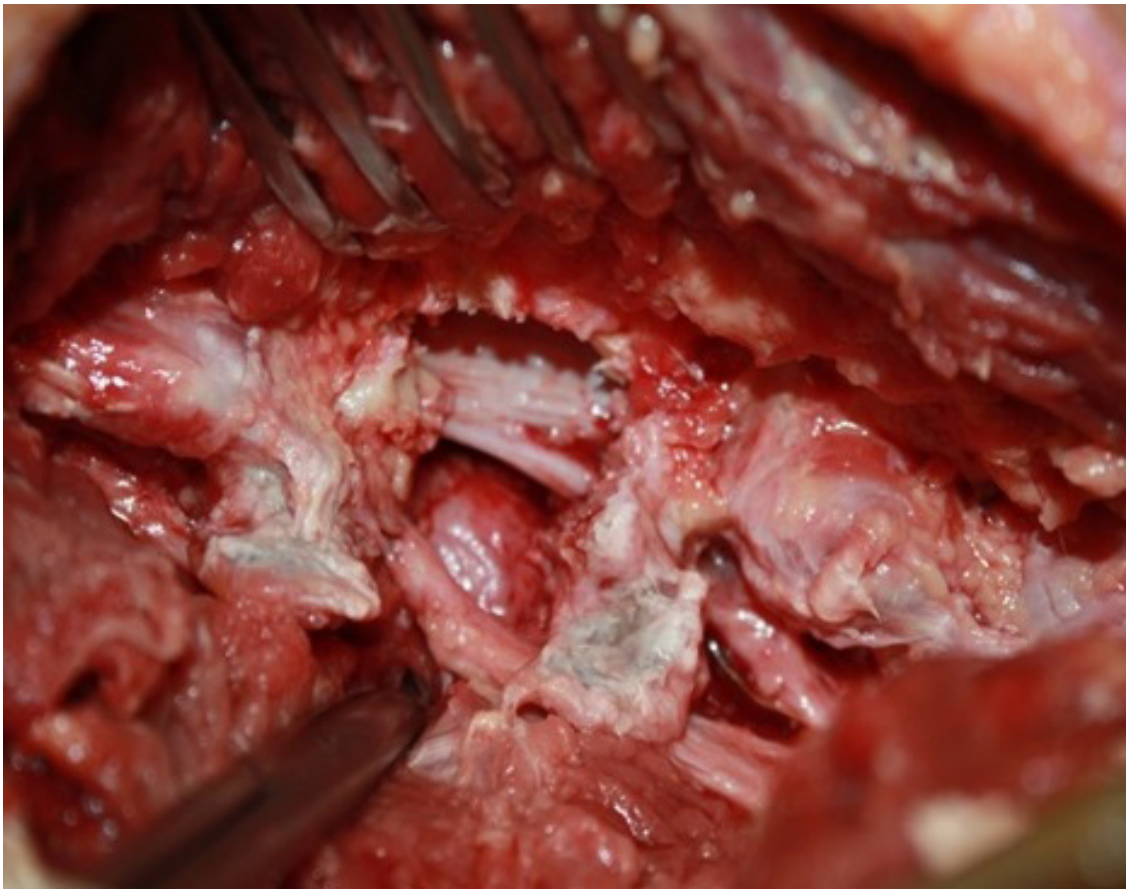

Figure-6. The triangular working zone described by kambin, is bordered medially by the traversing root and the dural sac, inferiorly by the proximal plate of the the inferior lumbar segment and anteriorly by the exiting root. Picture showing oval cannula in the triangular working zone. Opening of the oval cannula faces upwards at entry and while passing through the exiting root then it was converted downwards at the foraminal annulus.

RESULTS

This study was conducted in autopsy training hall of Forensic Medicine Institution Morgue Department, Ministry of Justice, Republic of Turkey. All fresh cadavers had no previous spine trauma or surgery. They were between the ages of 18-75. There were 10 cadavers (3 women, 7 men) in this study. Cadavers' ages ranged between 18-75, the mean age was 53.

The following results were obtained for the distance from midline and entrance angle using a safe way without damage to the retroperitoneal structures when the foramen was targeted at L1-L2, L2-L3, L3-L4, L4-L5 disc spaces in the examinations made on abdominal CTs of fresh cadavers. L5-S1 disc space had been excluded because this space could only be accessed only in one cadaver. The gender, age, weight of the cadavers and the findings obtained from abdominal CTs and routing device for each disc space were recorded (**Table 1**).

When we look at the values in Table 1, it is seen that X, Y, X', Y' parameters change according to individual differences such as age, sex, height and weight and these values could not be standardized. However, it was seen that in upper levels such as L1-2, L2-3, distance from midline was shorter and the foraminal entrance angle was increased compared to L3-L4, L4-L5 levels (**Table 2**).

The data obtained from these calculations was applied to fresh cadavers using the routing device we developed. We found that target disc space could be reached safely and easily from C-arm fluoroscopy images taken during intervention, and late endoscopic evaluations (**Figure 7, 8**).

TABLE 1

	Gender	Age	Weight	Disc Level	X′	Angle	X	Tang. Angle	Y′	Y
Case 1	M	71	78kg	L1-L2	8	35	18,4	0,7002	12,8	16
				L2-L3	10	30	18,6	0,5774	13,5	15,8
				L3-L4	11	32	20,0	0,6249	16,1	14,8
				L4-L5	16	18	17,2	0,3249	7,6	14,6
Case 2	M	60	56kg	L1-L2	8	35	18,1	0,7002	12,60	17
				L2-L3	10	32	18,2	0,364	6,62	16,8
				L3-L4	11	30	17,4	0,7002	12,1	15,3
				L4-L5	12	26	18,1	0,8391	15,1	14,7
Case 3	M	51	60kg	L1-L2	10	36	21,2	0,7265	15,4	17,7
				L2-L3	12	34	23,0	0,6745	15,5	17,3
				L3-L4	12	30	21,1	0,5774	15,3	17
				L4-L5	12	30	17,0	0,5774	9,8	16,9
Case 4	M	72	71kg	L1-L2	10	36	16,8	0,7265	12,2	20
				L2-L3	10	33	16,3	0,6494	10,5	18,8
				L3-L4	12	24	16,5	0,4452	7,3	17,6
				L4-L5	14	20	17,7	0,8391	14,7	17,3
Case 5	M	31	79kg	L1-L2	8	43	20,0	0,9325	18,6	18,8
				L2-L3	10	37	21,0	0,7536	15,8	18,2
				L3-L4	14	26	19,4	0,4877	9,4	17,2
				L4-L5	12	28	19,0	0,5317	10,1	17
Case 6	F	45	75kg	L1-L2	9	34	16,0	0,6745	10,7	22,7
				L2-L3	10	30	15,0	0,5774	8,6	20,7
				L3-L4	12	18	14,6	0,3249	4,7	19,8
				L4-L5	12	20	13,7	0,364	4,9	19,7
Case 7	M	75	80kg	L1-L2	11	24	23,0	0,4452	10,2	21,3
				L2-L3	12	18	21,0	0,3249	6,8	21
				L3-L4	10	30	20,0	0,5774	11,5	20
				L4-L5	14	20	18,0	0,364	6,5	19,8
Case 8	F	52	65kg	L1-L2	11	28	19,0	0,4663	8,8	18,4
				L2-L3	12	26	19,2	0,364	6,9	18,2
				L3-L4	13	20	18,0	0,4663	8,3	17,6
				L4-L5	14	18	18,1	0,4663	8,4	17,5
Case 9	F	35	53kg	L1-L2	10	35	16,8	0,7002	11,7	18
				L2-L3	10	32	16,6	0,6249	10,3	17,8
				L3-L4	14	26	16,2	0,4877	7,9	17,5
				L4-L5	14	21	16,0	0,3839	6,1	17
Case 10	M	37	60kg	L1-L2	8	35	18,5	0,7002	12,9	18
				L2-L3	10	32	18,1	0,6249	11,3	17,6
				L3-L4	10	26	17,7	0,4877	8,6	17
				L4-L5	10	20	17,5	0,364	6,3	16,8

TABLE 2		
Disc Level	**Mean Angle**	**Mean Distance (X') cm**
L1-L2	34.1°	9,3
L2-L3	30.4°	10,6
L3-L4	26.2°	11,9
L4-L5	22.1°	13

Recognition and retraction of exiting nerve root was easier in L3-L4 and L4-L5 disc spaces compared with L1-L2 and L2-L3 disc spaces. For this reason, exiting roots from the L1, L2, L3, L4, L5 foramens of 4 cadavers were macroscopically and endoscopically examined while the cannula of endoscope was still in the foramen. Although the foramens were larger at the upper lumbar levels, it was observed that the root diameter was smaller and the angle between root and dura mater was narrower. So, we think that nerve root damage would be more possible in upper levels (L1-L2, L2-L3) than lower levels (L3-L4, L4-L5). It was observed that traversing root damage occurred in the disc spaces of upper levels during removal of LLP for adequate decompression and exposure of traversing root.

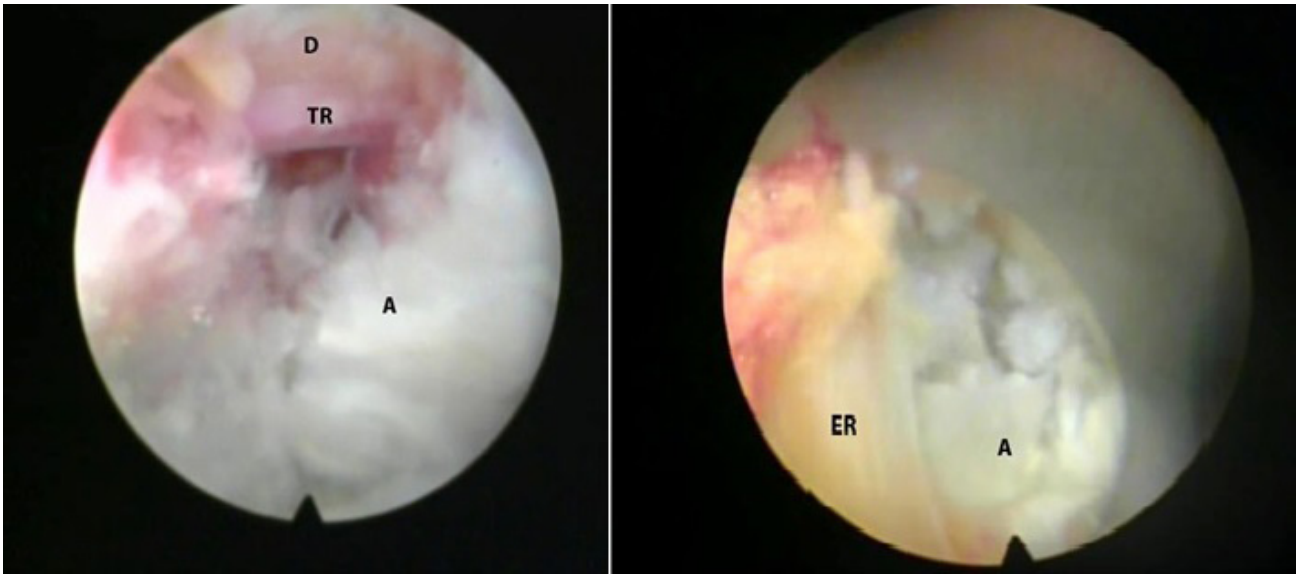

Figure-7. When the oval cannula is moved little backward and its tip is positioned cranially at the exraforaminal area, exiting root is observed. We have seen that puncture point and access angle calculated via CT scans were consistent with the fluoroscopic and endoscopic images.

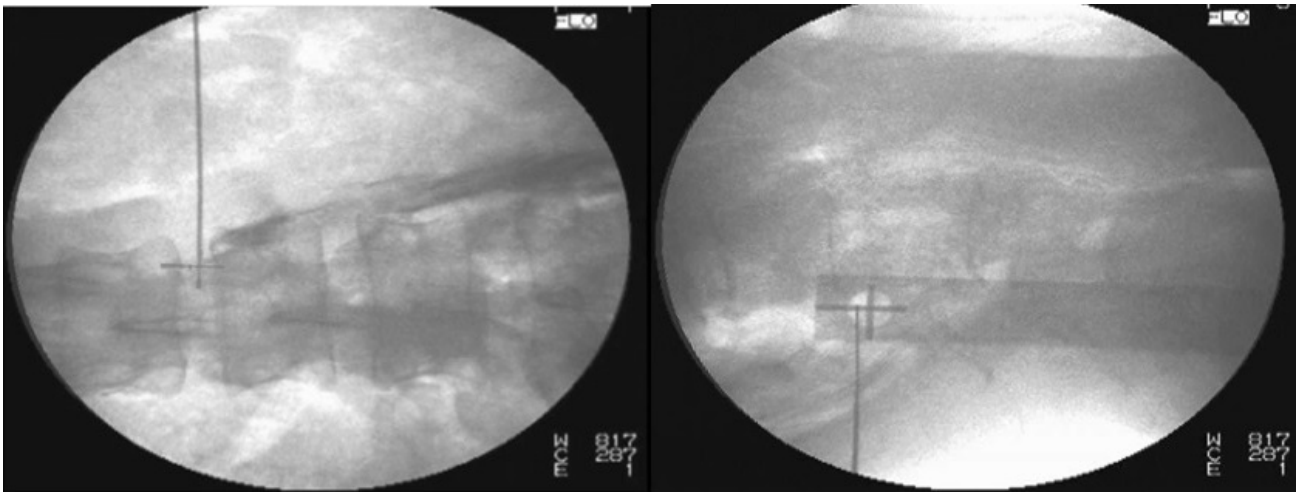

Figure-8. In each disc space, needle was directed through the Y' marker and inserted to the foramen. Needle was checked with fluoroscopy to be inside the Kambin Triangle. After obtaining desired angle to the skin entry, the needle and routing device was removed.

DISCUSSION

Lumbar disc herniation is an important cause of back and leg pain. Although the number of patients increases with advanced age, epidemiological studies showed that incidence of intervertebral disc disease is increasing in younger ages. The percentage of people who have back pain at least once in their lives is 85%. Also, back pain is the second leading cause of referral to a doctor according to the statistics from North America and Western Europe [12].

Patients who do not benefit adequately from conservative treatment methods constitute candidates for surgical treatment. Today, surgical interventions can be roughly divided into conventional discectomies and percutaneous methods. While microdiscectomy is the gold standard in conventional discectomies, percutaneous methods include chemonucleosis, nucleoplasty, intradiscal electrothermal therapy, laser discectomy, and interlaminar or transforaminal endoscopic discectomy [11,14]. Neural tissue can be directly seen only in endoscopic discectomy within these percutaneous methods.

In the early 1980s, Kambin and Gellman developed a percutaneous arthroscopic approach. This method attracted attention and its use became widespread due to high patient comfort, less invasiveness, and similar success rate compared to microdiscectomy [5]. The procedure can be performed under general or local anesthesia. In addition, with the development of instrument and devices, such as high resolution, even three-dimensional imaging systems, automatic aspirators, special shaped high speed drills, radiofrequency bipolar cautery, the endoscopic approach became safer [8].

There are some differences between microdiscectomy and endoscopic discectomy in terms of indications due to the characteristics of anatomical structures. If the sequestrated disc's upper limit passes the lower border of the cranial pedicle, or the lower limit of sequestrated part passes the middle of caudal pedicle, or most of the disc material is involved in the spinal canal, endoscopic transforaminal approach is not preferred. In addition, iliac wings disallow transforaminal approach due to closure of foramen in L5-S1, sometimes L4-L5 disc spaces. In far lateral disc herniation, FELD via TF approach gains an advantage over microdiscectomy in decompression of nerve root in extraforaminal region. However, microdiscectomy is gold standard when the disc is calcified or displaced into the spinal canal [9]. However, different surgeons have different techniques in line with their experience and use of high-tech devices. Nonetheless, the basis for the success of the operation is recognition of anatomical triangle in intervertebral foramen defined by Kambin. In recent years, the target of the percutaneous intervention has shifted from middle of the disc space to the part of disc underneath the herniated part. This causes the skin entrance point to become more lateral, and it makes protection of anatomical structures more difficult and important. In this study, we aimed to develop and evaluate the effectiveness of a device that will provide access to these triangles without damaging surrounding tissues.

Until now, various methods have been described which are based on the help of imaging devices such as C-arm fluoroscopy, biplanar fluoroscopy, and CT, or totally free estimation to determine the entrance point, entrance angle, and target [7].

Ahn et al. showed that more medial entrance point (6-9 cm lateral from midline) and steeper entrance angle (35-45°) are safer in transforaminal approach in upper levels compared to lower levels in lumbar disc herniations of 45 patients with the help of C-arm fluoroscopy [1]. Kim et al. used endoscopic transforaminal approach in 295 patients, entrance point (usually 10-14 cm lateral to midline) and angle were calculated with the help of preoperative abdominal CT. They were directed to medial pedicular line in AP view in disc herniation without ligamentous tear. They changed the entrance site more laterally in extruded/sequestrated disc herniation. This series was compared by the authors with the patients who underwent microscopic discectomy by same authors. They found no significant difference between two groups in terms of success and complication rates [7]. Kafadar et al. used abdominal CT for preoperative evaluation in 42 patients who underwent endoscopic transforaminal approach. Entrance point (8-10 cm lateral to midline) and angle were calculated with the help of abdominal CT and checked with fluoroscopy during procedure. There were no neural, vascular or intraabdominal complications [4].

Ruetten et al., who preferred accessing to spinal canal more tangentially, recommended performing abdominal and thoracic CT before surgery of upper lumbar disc spaces [9]. Peng et al. used an entrance point 12-14 cm lateral to midline, and targeted medial pedicular line in AP view, and posterior vertebral line in lateral view. Their complication rates were a bit higher than rates in previous studies (3.6% to 2.6%). On the other hand, an intramuscular psoas hematoma, which was large enough to cause hypovolemic shock in patient, was also reported recently in an endoscopic transforaminal L4-L5 discectomy performed under C-arm fluoroscopy [6].

In our study, we performed abdominal CT before operation and used our special design routing device during operation. The most appropriate angle to midpedicular line for each disc space from skin entrance point (8-16 cm lateral to midline) without damaging retroperitoneal structures was calculated

with help of preoperative abdominal CTs. This calculation was performed in L1-L2, L2-L3, L3-L4, L4-L5 disc spaces. It was seen that in upper levels such as L1-2, L2-3, distance from midline was shorter and the foraminal entrance angle was increased compared to L3-L4, L4-L5 levels. We concluded that abdominal CT should be performed before operation for calculation of entrance angle to protect retroperitoneal structures especially in L1-L2, L2-L3, L3-L4 disc herniation. Anatomic variations (lumbarisation, sacralisation) which were not recognized in C-arm fluoroscopy and may cause misdiagnosis, were also detected in abdominal CTs of cadavers.

TF endoscopic discectomies were performed with routing device using calculated entrance points and angles. Although neural foramen was larger in upper lumbar levels, it was seen that the diameter of nerve root was smaller and the angle between root and dura was narrower. For this reason, we think that exiting root injury may occur during placement of working cannula, and traversing root injury may occur during removal of ligamentous complex in upper lumbar disc spaces.

Kambin triangle was reached successfully and safely with applying data obtained from CT (X', α) and C-arm fluoroscopy (X, Y, Y') to X, Y, and Y' markers of routing device's. There was Y' marker with protractor on routing device, and the metal rod on this Y' marker had an opening through which only the punction needle could pass. This rod helped to reach the target. Also, the metal bar's back and forth movement and fixation to this mechanism contributed to operation of device. Entrance point and angle computed from CT were found to be compatible with the images obtained from fluoroscopy and endoscopy during operation.

Our specially designed routing device has achieved a definite success and safety during operation with the help of calculated entrance point and angle from abdominal CT images. For these reasons, we think our device will be very useful for clinical use.

CONCLUSION

Conventional microsurgical methods and endoscopic interventions have now similar success rates. However, the advantage of reduction in tissue trauma provided by endoscopic methods cannot be denied. Our study with fresh cadavers has also shown that endoscopic transforaminal approach can be performed safely when appropriate anatomical signs are observed and especially when our CT-based routing device is used. However, it should be noted that open surgery is also an important part of spinal surgery and surgeons must be fully qualified to cope successfully with the complications of endoscopic surgery, if necessary.

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Volume: 30, Issue: 3, July 2019 pp: 223-226 CASE REPORT

MIGRATION OF CEMENT TO THE VENA CAVA INFERIOR DURING PERCUTANEOUS VERTEBROPLASTY: A CASE REPORT

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ABSTRACT

Percutaneous vertebroplasty (PVP) is a minimally invasive and useful method for controlling the pain in patients with vertebral compression fractures. The migration of cement to the vena cava inferior following Polymethylmetacrylate (PMMA) leakage after the PVP operation is presented in this case. Control by a CT imaging should be performed although she was asymptomatic, and the necessary premedication was ensured in terms of embolism by demonstrating invasion to the VCI.

Key words: Percutaneous vertebroplasty; Polymethylmetacrylate; Migration of cement; Vertebrae fracture

INTRODUCTION

Percutaneous vertebroplasty (PVP) is a minimally invasive and useful method for controlling the pain in patients with vertebral compression fractures developing due to metastatic diseases, multiple myeloma, osteoporosis, and aggressive hemangiomas. It is a procedure performed by percutaneous injection of polymethyl methacrylate (PMMA) into the fractured vertebral corpus. Vertebroplasty is a method, which was first defined and applied by Gilbert et al. [3] in 1987, and nowadays, it is frequently used in symptomatic vertebral compression fractures resistant to conservative and medical treatment. Vertebral compression fractures mainly occur secondarily to osteoporosis, and the percutaneous vertebroplasty method is used preferably compared to the open surgical method to strengthen the vertebral corpus and alleviate the pain due to comorbid factors and low bone quality of the population with osteoporosis. In the PVP method, the corpus is strengthened and pain control is provided by percutaneous penetration into the vertebral corpus by transpedicular or extrapedicular approaches with bone needles for the operation, and the injection of PMMA bone cement into the corpus. In vertebral compression fractures that occur secondarily to osteoporosis, the complication rate of PVP is low; and these are usually minor ones. These complications have been reported to be as low as 0-5.4% [5]. However, major complications such as pedicle fracture, pulmonary embolism, invasion of cement into a major vein or spinal canal pneumothorax, spinal cord compression, epidural hematoma, subdural hematoma, and death have been reported, though at the rate less than 1% (1, 5, 7, 9). The migration of cement to the vena cava inferior following PMMA leakage after the PVP operation is presented in this case.

CASE REPORT

A sixty-seven-year-old female patient was admitted to the outpatient clinic with a complaint of backache after falling. There was no remarkable event in the history of the patient who had no neurological deficit. In the Lumbar Magnetic Resonance (MR) imaging of the patient, acute collapse fracture and bone marrow edema were observed in her L3 vertebra, and with the detection of osteoporosis

in bone densitometry, the necessary medical treatment was initiated by considering that the patient's compression fracture developed secondarily to osteoporosis. Then, PVP was performed under local anesthesia for L3 vertebra of the patient and it was observed that her pain alleviated after the operation. In the patient's control after fifteen days, upon observing acute collapse fracture in her L2 vertebra again in the Lumbar MRI taken since she indicated that her backache started again, the patient underwent PVP under local anesthesia for L2 vertebra. Due to leakage to the anterior side during the operation, the operation was terminated and the lumbar Computerized Tomography (CT) of the patient was reviewed. In the lumbar CT imaging, it was observed that the vertebroplasty cement was extruded upwardly from the anterolateral side of the L2 corpus and invaded the lumen of the VCI (Figures 1 and 2).

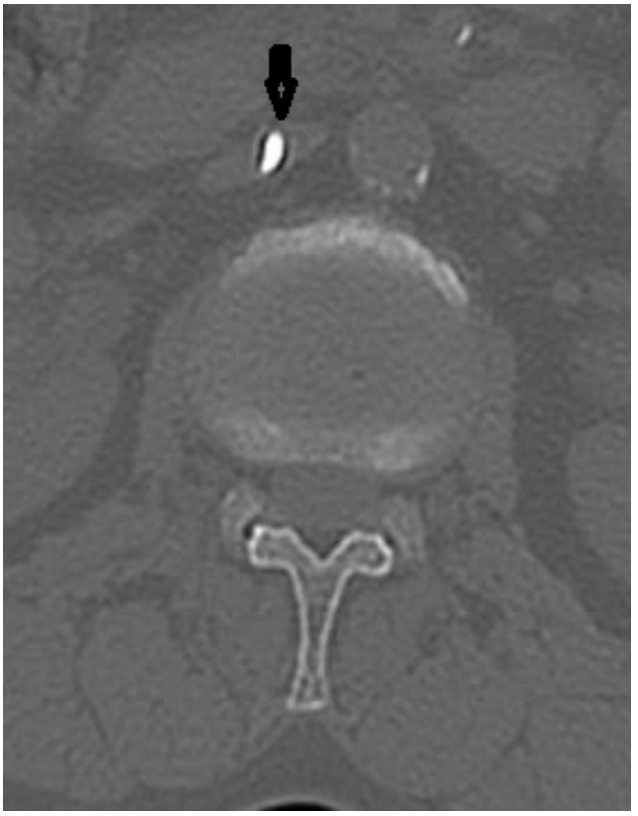

Figure-1. The arrow shows that the vertebroplasty cement is extruded and invaded the lumen of the VCI on the axial CT.

In the MR angiography performed, it was observed that the cement was in the vena cava lumen. No free fluid that would be the sign of acute bleeding around the vein and in the abdomen was observed. The patient was consulted with cardiovascular surgery. Clexane 0.4 cc subcutaneous 2x1 treatment was initiated for pulmonary embolism prophylaxis due to the lack of signs of bleeding. The patient with no additional problem in service follow-ups was discharged with the recommendation of outpatient clinic controls. After a 6 months follow-up, the patient's clinic is still uneventful.

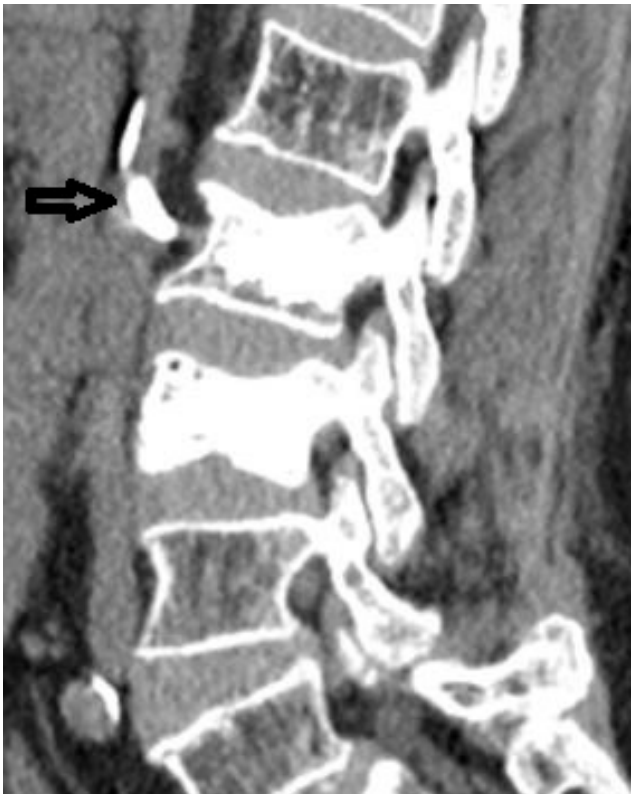

Figure-2. The arrow displays that the vertebroplasty cement is extruded upwardly from the anterolateral side of the L2 corpus and invaded the lumen of the VCI on the sagittal reformatted CT.

DISCUSSION

PVP is an effective, safe and minimally invasive procedure that is frequently used to control the accompanying pain in compression fractures developing secondarily to osteoporosis, metastatic or primary bone vertebra tumors that are unresponsive to medical treatment, and also to ensure the stability of the bone structure. The primary goal of the application was to eliminate the pain and to ensure the continuity of stability. Although PVP is an effective and easy method in eliminating the pain and ensuring stability in osteoporotic vertebral compression fractures and vertebral compression fractures developing secondarily to malignancy, there is a risk of complication by 0-5.4%

even if it is administered by experienced spinal surgeons [5]. These complications, the majority of which are minor, are usually complications that do not require intervention. The major complications of PVP include epidural and subdural hemorrhages secondarily to the medial wall injury of the pedicle, transient radiculopathies due to bone cement leakage, spinal cord compressions, arterial and venous injuries, pulmonary embolism and death (1, 2, 6, 8, 9). In a study in the literature, it was found out that cement leakage was 41% after PVP, but 96% of it was asymptomatic [4]. It was observed that leakage migrated to the paravertebral region in 32.5% of cases with cement leakage, to the epidural region in 32% of them, into the disc in 30.5% of them, to the neural foramen in 3.3% of them, into the systemic circulation in 1.7% of them [4]. In our patient, during the administration of cement during the operation, cement was administered in a controlled manner through serial shooting with a C-arm image intensifier, and the operation was immediately terminated by observing leakage to the anterior of the corpus. Since there is no leakage of cement after the PVP operation and the patient has no symptoms in the postoperative period, the patient is discharged by taking a two-way lumbar graph by surgeons. It is considered that CT imaging of the patient with cement leakage even without any symptom should be performed and the location of cement leakage should be detected.

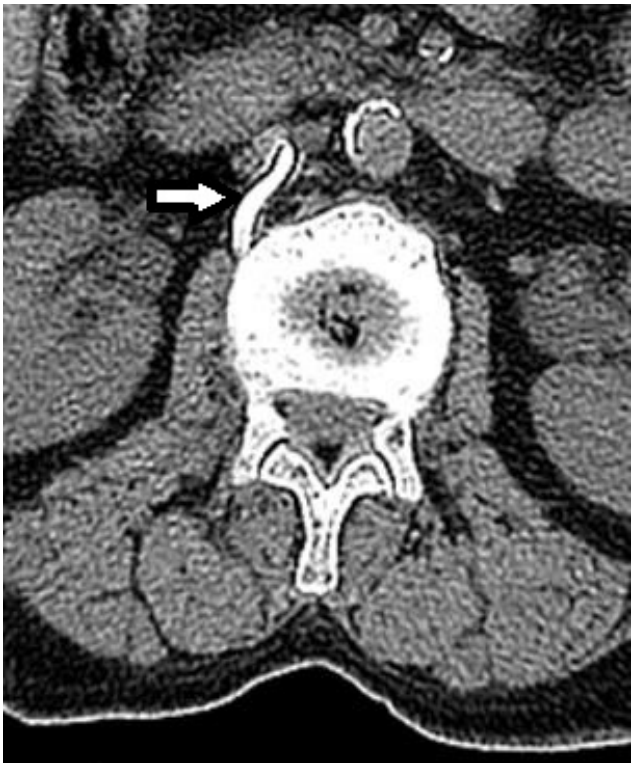

Figure-3. The arrow shows that the cement occupying a significant portion of the VCI lumen.

Another situation to be considered here is that the leakage of cement into the VCI was asymptomatic in this case. As it is seen in Figures 3, it appears that the cement occupying a significant portion of the VCI lumen did not lead to embolism or a change in the blood flow pattern within the VCI. However, a close follow-up of this patient is required for the relevant complications that may occur in the future. In the literature, there is no sufficient knowledge to create a treatment algorithm in this regard. In fact, reporting on such high ratios of the leakage of cement in the literature suggests that a close follow-up of each patient is required.

Another issue is the adjustment of cement consistency to minimize the leakage of cement. The difficulty of injection as the cement becomes hardened and increased leakage rate in the case of injection in the early stages of cement formation indicate the difficulty in finding the optimal consistency. Moreover, when the solidification rate of the cement is added as a factor, there is a serious problem of finding the optimum consistency. PMMA is likely to be replaced by a new cement material which solidifies more slowly and the injection of which does not become difficult evenly as it solidifies in the future.

CONCLUSION

PVP is an effective and reliable method for ensuring pain control and stability in vertebral compression fractures developing secondarily to osteoporosis or malignancy that does not respond to medical and conservative treatment methods. Although cement leakage frequently occurs during operation, adequate imaging is not performed since the patient is asymptomatic, and the localization of cement leakage is not determined. However, as it is seen in our patient, her CT imaging was performed although she was asymptomatic, and the necessary premedication was ensured in terms of embolism by demonstrating invasion to the VCI.

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