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-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.

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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 participating 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.

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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.

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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

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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".

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ARTICLE WRITING

Clinically relevant scientific advances during recent years include the 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 rigour of the 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 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. 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 a written permission letter, and it should be submitted along with the manuscript.

Review articles: The format for reviews substantially differ 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 that 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 with 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 Conclusion. 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.

-Keywords : 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.

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.

INSTRUCTIONS to AUTHORS

The first paragraph should introduce the general topic or problem and emphasize 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 the 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 historical 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 be 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 describe 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

INSTRUCTIONS to AUTHORS

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 gro-ups 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 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 belong. 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 consideration. 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 reader may 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 as-sumptions, 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 the 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 a 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 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: References are numbered (Arabic numerals) consecutively in the order in which they appear in the text (note

INSTRUCTIONS to AUTHORS

that references should not appear in the abstract) and listed double-spaced at the end of the manuscript. The preferred method for identifying citations in the text is using within parentheses. Use the form of the "Uniform Requirements for Manuscripts" (http://www.icmje.org/about-icmje/faqs/icmje-recommendations/). If the number of authors exceeds seven, list first 6 authors followed by et al.

Use references found published in peer-reviewed publications that are generally accessible. Unpublished data, personal communications, statistical programs, papers presented at meetings and symposia, abstracts, letters, and manuscripts submitted for publication cannot be listed in the references. Papers accepted by peer-reviewed publications but not yet published ("in press") are not acceptable as references.

Journal titles should conform to the abbreviations used in "Cumulated Index Medicus".

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

Journal article:

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;8:5-9.

Book chapter:

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:61-8.

Entire book:

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:

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

Journal article in press:

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

Book in press :

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:

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:

Rhoton AL. Microsurgery of the Arnold-Chiari malformation with and without hydromyelia in adults. Presented at the Annual Meeting of the American Association of Neuro-logical 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 the Acknowledgments section.

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- **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 a historical precedent. Instead, indicate the point in the manuscript by providing citation by superscribing.

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 the 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 significance 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

INSTRUCTIONS to AUTHORS

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

1. Morphometric analysis

Anesthesiology

Animal study

Basic Science

1. Biology
2. Biochemistry
3. Biomaterials
4. Bone mechanics
5. Bone regeneration
6. Bone graft
7. Bone graft substitutes
8. Drugs

Disc

1. Disc Degeneration
2. Herniated Disc
3. Disc Pathology
4. Disc Replacement
5. IDET

Disease/Disorder

1. Congenital
2. Genetics
3. Degenerative disease
4. Destructive (Spinal Tumors)
5. Metabolic bone disease
6. Rheumatologic

Biomechanics Cervical Spine

1. Cervical myelopathy
2. Cervical reconstruction
3. Cervical disc disease
4. Cervical Trauma
5. Degenerative disease

Complications

1. Early
2. Late
3. Postoperative

Deformity

1. Adolescent idiopathic scoliosis
2. Kyphosis
3. Congenital spine
4. Degenerative spine conditions

Diagnostics

1. Radiology
2. MRI
3. CT scan
4. Others

INSTRUCTIONS to AUTHORS

Epidemiology

Etiology

Examination

Experimental study

Fusion

1. Anterior
2. Posterior
3. Combined
4. With instrumentation

Infection of the spine

1. Postoperative
2. Rare infections
3. Spondylitis
4. Spondylodiscitis
5. Tuberculosis

Instrumentation

Meta-Analysis

Osteoporosis

1. Bone density
2. Fractures
3. Kyphoplasty
4. Medical Treatment
5. Surgical Treatment

Outcomes

1. Conservative care
2. Patient Care
3. Primary care
4. Quality of life research
5. Surgical

Pain

1. Chronic pain
2. Discogenic pain
3. Injections
4. Low back pain
5. Management of pain
6. Postoperative pain
7. Pain measurement

Physical Therapy

1. Motion Analysis
2. Manipulation
3. Non-Operative Treatment

Surgery

1. Minimal invasive
2. Others
3. Reconstructive surgery

Thoracic Spine

Thoracolumbar Spine

Lumbar Spine

Lumbosacral Spine

Psychology

Trauma

1. Fractures
2. Dislocations

Spinal cord

1. Spinal Cord Injury

Spinal stenosis

1. Cervical
2. Lumbar
3. Lumbosacral

Tumors

1. Metastatic tumors
2. Primary benign tumors
3. Primary malign tumors

INSTRUCTIONS to AUTHORS

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JOURNAL OF TURKISH SPINAL SURGERY

CONTENTS

ORIGINAL ARTICLES

EDITORIAL

Dear Colleagues,

I hope you have been able to find some relief from the incredible hot spell currently gripping our country. Perhaps it will afford you an opportunity not normally available to find a comfortable place to relax, grab a cool drink and take the time to digest all of the pertinent information in this issue of our professional journal.

Once again, sincere appreciation goes to all the reviewers, assistant editors, secretaries, and the Galenos publishing team for the efforts they all expended in order to put this issue together. It includes eight clinical research studies. Please review it very carefully, and apply as many new techniques and information as possible into your practice.

The first study examines “Recurrent Lumbar Disk Herniations: The Efficacy of Re-Operation”. The second study is a “Retrospective Analysis of Patients who Underwent Surgical Treatment for Spinal Cord Tumors Between 1999 and 2022”. The third, is a clinical study entitled, “Should Pelvic Fixation be Included in Neuromuscular Scoliosis Surgery?” The fourth article is “Split Cord Malformation in Adults: Symptoms, Surgical Treatment and Results”, while the fifth study, is a clinical article investigating “Normative Values for Cervical and Lumbar Range of Motion in Healthy Young Adults”. The sixth study is “Perioperative Management in Scoliosis Surgery: Spinal Muscular Atrophy Versus Adolescent Idiopathic Scoliosis”. The seventh article evaluates “Management of Thoracolumbar Fractures: Clinical, Functional and Radiological Outcomes in a Single Institution”. In the eighth study, the authors studied correlations. It is titled “Assessing Preoperative Cardiac Risk in Adult Spinal Deformity Surgery: Correlation between Modified Frailty Score with Revised Cardiac Risk Index”.

Once again, this is an unusual time, so I would like to thank everyone, especially the dedicated reviewers, who worked to get this issue out to our colleagues. I hope everyone appreciates the amount of work that goes into publishing every issue. Please take the time to read it and incorporate whatever is pertinent for you into your practice. Our mission remains, as always, to keep you abreast of all the latest developments in our field, and we offer this issue to you to further that goal. I wish my readers a wonderful holiday with their families. Stay cool and stay safe.

With kindest regards,

Editor in Chief

Metin Özalay, M.D., Prof.

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RECURRENT LUMBAR DISK HERNIATIONS: THE EFFICACY OF RE-OPERATION

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ABSTRACT

Objective: Lumbar disk herniations (LDH) are common in neurosurgical practice. However, recurrence is a fearful complication of LDH surgery and the re-operation technique is always on debate. The aim of this study was to analyze the efficacy of re-operation in patients with recurrent LDH.

Materials and Methods: The data of patients who underwent re-operation for treating recurrent LDH were retrospectively reviewed. The demographic, clinical, and radiological features of patients were analyzed, and visual analog scale (VAS) and straight leg raising (SLR) test results were compared.

Results: A total of 60 patients underwent re-operation between 2019 and 2022. The mean age was 48.3 years and the body mass index was between 30 and 35 in 28 (47%) patients. Patients who underwent simple discectomy had less early low back pain and patients who underwent posterior segmental instrumentation had lower lumbar and radicular leg pain VAS at the postoperative 1st year follow-ups. VAS scores and SLR tests were significantly improved after the re-operation in both groups. Dura defect occurred in 6 patients (10%) and was repaired successfully in all patients. No mortality was observed.

Conclusion: Re-operation is a feasible option for the treatment of recurrent LDH. VAS scores and SLR tests are improved after re-operation. However, appropriate patient selection is crucial for better clinical outcomes.

Keywords: Lumbar disk herniation, recurrence, re-operation, complication

INTRODUCTION

Lumbar disc herniation (LDH) is one of the common surgical routines of neurosurgery. One of the complications of surgical treatment is recurrence. After the first surgery, after a pain-free period for at least 6 months, the onset of low back and/or leg pain[1] and the radiological support of recurrence at the same level and/or from the same side, the diagnosis of recurrent LDH is made. Regardless of the duration, disc herniations that occur at the same level and/or on the same side after surgery are considered as recurrent LDH. Pseudo-recurrence is the term used for herniation that develops at a different level after the first surgery, even if the patient does not have a pain-free period. Recurrence rates after LDH surgery range from 7% to 26% in the literature[2-6]. Recurrence is most common at the level of L4-L5 with a rate of 69%[7]. It is followed by the L5-S1 level. It is thought that the L4-L5 level is the most active segment of the spine. Recurrence is more frequently seen in men compared to women with a rate of 58%. There are publications in the literature showing that female patients after spinal surgery are clinically worse than male patients. Ozger and Kaplan[8] found that there was no difference between the genders in the geriatric age group. Obesity has also been associated with various patient-related factors such as young age, male gender, heavy-duty work and smoking status, and alcohol use[9]. The surgical techniques in recurrent disc surgery are important for the surgeon, the patient and the society. Repeat mini-open microdiscectomy technique and decompression plus fusion technique are the options for re-operation. Preoperative radiological features of the patient is crucial for the appropriate selection of the surgical technique in recurrent disc herniations[10]. In this study, we aimed to analyzed our results on the re-operation of patients with recurrent LDH and to compare with the literature.

MATERIALS AND METHODS

The data of recurrent LDH that we operated in our clinic between 2019-2022 were retrospectively analyzed based on the incidenc, the most common level, the sex ratio, the mean age, the mean recurrence times, the patients' presence of fusion surgery, presence and repair of dura defect, Body Mass Index (BMI) of the patients, smoking status, preoperative/

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postoperative visual analogue scale (VAS) scores (Figure 1), pre- and postoperative examinations according to our previous surgeries of patients who were first performed in our center and straight leg raising (SLR) tests. Pre- and postoperative SLR and VAS scores were statistically compared.

Statistical Analysis

Parameters such as age, sex, BMI, smoking condition, VAS score, SLR condition, level of disc herniation, dura defect, posterior segmental instrumentation (PSI) and other quantitative parameters were analyzed. Categorized variables were explained as number of patients (n) and percentage (%) with descriptive statistics. The SPSS 15.0 for Windows program (Statistical Package for the Social Sciences Inc., Chicago, IL, USA) was used for statistical analysis. Two independent group comparisons were performed by student's t-test when the numerical variables provided normal distribution condition, otherwise the Mann-Whitney U test was performed. Statistical significance level was accepted when the p value <0.05. This study was approved by the University of Health Sciences Turkey, Gülhane Training and Research Hospital, Clinical Researchs Ethics Committee (decision no: 2022/164, date: 25.01.2023).

RESULTS

Between 2019-2022, we operated on 60 patients for recurrent LDH. Thirty-three (55%) patients were male and 27 (45%) were women. The mean age of the re-operated patients was 48.3 years (Table 1). When preoperative radiological examinations of all patients were examined before the first surgery, it was observed that there was no instability in any patient. We performed simple discectomy for microscopic discectomy in patients whose first surgery was performed in our clinic. BMI of 5 of 60 patients was <18.5 (8%), of 19 of them was between 18.5-29.9 (32%), of 28 of them was between 30-35 (47%), of 8 of them was >35 (13%), 2 of the male patients had a BMI <18.5 (6%), 13 of them had a BMI between 18.5 and 29.9 (39%), 13 of them had a BMI between 30-35 (39%), 5 of them had a BMI of >35 (16%). We found that 3 of the patients had a BMI <18.5 (11%), 6 of them had a BMI between 18.5-29.9 (22%),

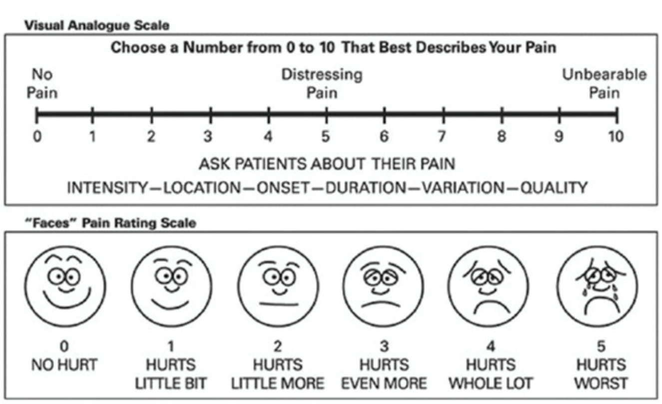

Figure 1. VAS scale
VAS: Visual analogue scale

15 of them had a BMI between 30-35 (56%), 3 of them had a BMI of >35 (11%) (Tables 2A, 2B). Thirty-two (55%) of the patients smoke regularly and 28 (45%) do not smoke. Twenty-two (67%) of male patients are smokers, and 10 (37%) of female patients are smokers (Table 3). We examined the VAS score of the patients who underwent discectomy and PSI in the same session for preoperative, early postoperative and postoperative 1 month and 1 year follow-ups for low back pain and leg pain. Each preoperative patient had low back and radicular leg pain. The mean VAS for low back pain was 7.49/10 and 8.29/10 for radicular leg pain. VAS 7/10 for low back pain in men, VAS 8.1/10 for low back pain in women, VAS 7.8/10 for radicular leg pain in men, VAS 8.9/10 for radicular leg pain in women, patients who had PSI in the same session with preoperative lumbar surgery rated 8.3/10, VAS 9.12/10 for leg pain (Table 4A). Average VAS 6.66/10 for early postoperative low back pain, mean VAS 3.87/10 for radicular leg pain, VAS 7.9/10 for low back pain in patients who underwent decompression and PSI in the same session, VAS 7.9/10 for leg pain (10 VAS evaluated as VAS 4B). VAS comparisons of the patients at the early postoperative

Table 1. Distribution of patients based on gender

Total number of patient	Male patient	Female patient
60	33 (55%)	27 (45%)

Table 2A. Definitions for BMI

BMI	<18.5	18.5-24.9	25-29.9	30-34.9	>35
Definition	Weak	Normal	Overweight	Obese	Morbid obese

BMI: Body Mass Index

Table 2B. Distribution of patients based on BMI

Total patient	Male	Female	BMI
5 (88%)	2 (6%)	3 (11%)	<18.5
19 (32%)	13 (39%)	6 (22%)	18.5-29.9
28 (47%)	13 (39%)	15 (56%)	30-35
8 (13%)	5 (16%)	3 (11%)	>35

BMI: Body Mass Index

Table 3. Smoking condition

Total	Male	Female
32 (55%)	22 (67%)	10 (37%)

Table 4A. Preoperative visual analogue scale score in patients who underwent decompression and PSI

	Total	Male	Female	Decompression and PSI in the same session
Low back pain	7.49	7	8.1	8.3
Radicular pain	8.29	7.8	8.9	9.12

PSI: Posterior segmental instrumentation

1st month and 1st year controls are also available in Tables 4C and 4D. VAS scores were improved after the re-operation and this was statistically significant (p=0.015). Preoperative motor neurological deficit was present in 37 (62%) of the 60 patients we operated. We observed that motor neurological deficit progressed at a rate of 1/5 in the early postoperative period in 1 patient. We observed that the motor deficit was the same as the preoperative condition in the postoperative 1st month and 1st year follow-up, together with the physical therapy program. We observed that motor neurological deficit was improved more in the early postoperative period in 12 patients, and in 29 patients in total, the motor neurological deficit was improved in the postoperative follow-up compared to the preoperative period. At the preoperative examination, 37 patients (62%) had SLR positive. Preoperative SLR positivity was present in 12 (86%) patients who underwent decompression and PSI in the same session. In the early postoperative and postoperative 1st year examinations, the rate of SLR positivity decreased to 4 (6%) patients and 1 (2%) patient. In patients who underwent PSI, it decreased to 1 (7%) and it improved in the 1st year postoperatively (Table 5). The SLR was improved after the first year in re-operated patients and this was statistically significant (p=0.02). Eighteen patients relapsed left L4-L5 disc herniation (29%), 17 patients relapsed right L4-L5 disc herniation (27%), 17 patients relapsed left L5-S1 disc hernia (27%), 7 patients relapsed right L5-S1 disc herniation. We operated (12.5%), 2 patients for recurrent left L3-L4 disc herniation (3%), 1 patient for recurrent left L4-L5, left L5-S1 disc herniations (1.5%) (Table 6). We operated on average 33 weeks after the previous case. The first surgery of 39 patients (65%) was performed in the other hospital. The first surgery of 21 patients (35%) was performed in our clinic (Table 7). The mean recurrence time of patients who had their first surgery performed in our clinic was 36 months. Dura defect occurred in 6 patients (10%), and dura defect occurred in 1 (7%) of the patients who underwent PSI (Tables 8A, 8B). We performed duraplasty with fascia in 5 patients (83%), and in 1 patient with a synthetic graft (17%) (Table 9). We operated on 3 patients (5%) within the first week. We performed decompression and fusion in 14 patients (23%) in the same session. In every patient, we operated on, we put a drain in the operating room. The drains of the patients without dural defect and PSI were removed on the 1st postoperative day. Drains of patients with dural defect and patients who underwent PSI were removed on average on the 2nd postoperative day. Patients with no dural defect, who had only discectomy, were discharged on the 2nd postoperative day. Patients with dural defect and PSI were discharged on the 3rd or 4th postoperative day.

Table 4B. Early postoperative VAS score in patients who underwent decompression and PSI

	Total	Male	Female	Decompression and PSI in the same session
Low back pain	6.66	6.3	7.1	7.9
Radicular pain	3.87	3.6	4.2	3.8

PSI: Posterior segmental instrumentation, VAS: Visual analogue scale

Table 4C. Postoperative 1st month VAS score in patients who underwent decompression and PSI

	Total	Male	Female	Decompression and PSI in the same session
Low back pain	2.57	2.3	2.9	1.8
Radicular pain	1.93	1.8	2.1	1.6

PSI: Posterior segmental instrumentation, VAS: Visual analogue scale

Table 4D. Postoperative 1st year VAS score in patients who underwent decompression and PSI

	Total	Male	Female	Decompression and PSI in the same session
Low back pain	1.92	1.7	2.2	1.3
Radicular pain	1.63	1.5	1.8	1.2

PSI: Posterior segmental instrumentation, VAS: Visual analogue scale

Table 5. SLR comparion in patients who underwent decompression and PSI

	Total	Male	Female	Decompression and posterior segmental instrumentation in the same session
Preop SLR (+)	37 (62%)	26 (78%)	11 (40%)	12 (86%)
Early postop SLR (+)	4 (6%)	2 (6%)	2 (7%)	1 (7%)
Postop first year	1 (2%)	1 (3%)	0	0

PSI: Posterior segmental instrumentation, SLR: Straight leg raising

Table 6. Distribution of the patients based on level of disc herniation

Level	Number	%
Left L4-L5	18	29
Right L4-L5	17	27
Left L5-S1	17	27
Right L5-S1	7	12.5
Left L3-L4	2	3
Left L4-L5, Left L5-S1	1	1.5

Table 7. Distribution of the patients based on the first surgery

Total number of patient	First surgery in other center	First surgery in our department
60	39 (65%)	21 (35%)

Table 8A. Total number of dura defect

Total number of patient	Patients with dura defect	Patients without dura defect
60	6 (10%)	51 (90%)

Table 8B. Dura defect incidence in patients who underwent PSI

Number of patient who underwent PSI	Dura defect	No dura defect
14	1 (7%)	13 (93%)

PSI: Posterior segmental instrumentation

Table 9. Treatment of dura defect

Total patient with dura defect	Duraplasty with fascia	Duraplasty with synthetic defect
6	5 (83%)	1 (17%)

DISCUSSION

Re-operation in recurrent LDH is quite difficult compared to the initial surgery, especially due to dense granulation tissue and fibrosis. As a surgical technique, mini-open microdiscectomy is most frequently preferred technique for re-operation[10-13]. Fusion is not recommended in routine surgery[14]. Epidural fibrosis and scar tissue make it difficult to reveal the intervertebral disc anatomy clearly, but also increases the risk of complications such as dural defect and root injury. It is known that the amount of scar tissue is not associated with surgical outcomes and epidural scarring does not cause radicular pain unless it puts pressure on the nerve. Therefore, it may not be necessary to routinely target complete scar tissue excision in this situation, which may reduce the risk of dural rupture[15]. The most common complication of re-operation in recurrent LDH is dural tear. Our dural tear rate was 10%. Studies have shown that dural tear is 2.5 to 4.7 times more common in revision surgery than in primary surgery[16-18]. To reduce this rate, in patients without flavum hypertrophy, flavotomy can be performed at the first surgery to reveal the anatomy, thus reducing the possible recurrence of epidural fibrosis, which can facilitate our work in the next surgery. Facet joint instability is a possible cause of recurrent disc herniation, but it is difficult to diagnose a facet instability in these patients. Dynamic X-rays may give some information about the facet joint instability. Removal of the facet joints during the first surgery may contribute to the development of instability, as well as recurrence[19]. So, the instrumentation and fusion surgery may be inevitable in these patients. The concept of segmental instability has been defined by American Academy of Orthopedic Surgeons as "the occurrence of movement above normal when there is any load on the spine". When anatomical or physiological pathologies related to the vertebral body, intervertebral disc, facet joints, ligaments or muscles occur or after disc surgery, the subsystems cannot perform their normal stabilization function and spine instability develops as a result of enlargement in the neutral region[19,20]. As a result of the changes in the structures that keep the spine stable, the capacity to limit the movement decreases and the lumbar segment can move above the normal physiological limits. Especially after LDH surgery, the development of degeneration in the intervertebral disc, then the decrease in the height of the intervertebral disc, and the loosening of the ligaments, the load on the facet joints increases. Then the degeneration and deformation process begins in the facet joints. As a result of all these pathological changes, lumbar spinal stenosis, compression due to facet joint hypertrophy, facet separation, foraminal stenosis, hypertrophy of the ligamentum flavum, and loosening of the interspinous ligaments may occur. Then, spinal stability is lost and degenerative segmental instability develops[20]. Instability that occurs after recurrent disc surgery is called secondary instability[21]. Although different rates of deviation and angulation have been reported, deviation of 3 mm or more on neutral radiographs and detection of 3 mm or more translation and angulation of 10 degrees or more on dynamic radiographs are accepted as "radiological instability" criteria (Figure 2)[22]. In the patient's previous surgery, both the patient's anatomical variation and the surgeon's preference, both the risk of recurrence increases and instability develops as a result of facet joint separation, and fusion is controversial in patients who have undergone medial facetectomy. Detailed examination of the patient's radiological imaging in the preoperative period, decrease in the height of the disc space in the magnetic resonance imaging study, development of listhesia in the lumbar computed tomography, hypoextension in the case of hyperextension (Figures 2A, B and 3) and calcified disc, wide decompression and PSI may be considered in hernias, since the total excision of the calcified material is difficult and the pressure on the spinal root cannot be fully removed (Figure 4). In addition, to reveal the normal anatomical structures without granulation intraoperatively, advancing superiorly and laterally, medial retraction of the root is performed by medial facetectomy, which may create an inflammatory process. Lumbar fusion reduces or eliminates segmental motion, stabilizes the spine, reduces mechanical stresses across the degenerated disc space, and may reduce the likelihood of recurrence in the affected disc area[23]. In previous studies, patients with recurrent discectomy and patients with recurrent LDH who underwent fusion without radiological instability were compared, and no statistical difference was found in patients' VAS, Oswestry Disability Index, and quality-adjusted life year scores and complication rates[24]. It is also known that patients who undergo simple lumbar discectomy have a faster recovery process and cause less cost than those who undergo fusion[25]. In addition, in patients with recurrent LDH surgery, in whom fusion is not performed but simple re-discectomy is planned, endoscopic surgery has become routinely used in recent years. This technique can be considered in appropriate cases due to the shorter hospital stay and lower complication rate[26]. Polat et al.[10] performed a retrospective study on the re-operation of recurrent LDH in 50 patients and they found that disc degeneration grade, degree of foraminal stenosis and facet joint degeneration, sagittal instability grade, facetectomy rate, adjacent segment degeneration and number of microdiscectomies are higher in patients who underwent stabilization. They also pointed out that preoperative radiological evaluation is important for proper surgical approach and low surgical risks[10]. In our study, we compared patients who underwent decompression and PSI in the same session with patients who had simple re-discectomy. We used VAS scores for the comparison of low back and radicular leg pains. Patients who had simple re-discectomy had less early low back pain. However, we found that patients

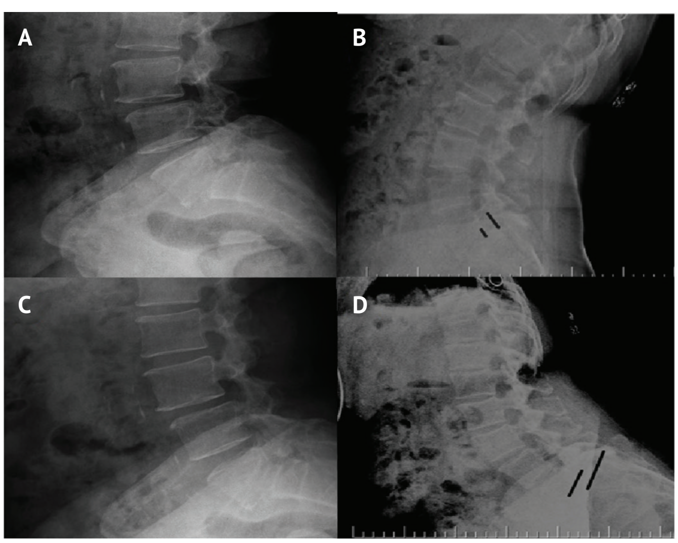

Figure 2. A-D) Instability can be shown in hyperflexion-hyperextension graphies by the measurement of translation and angulation

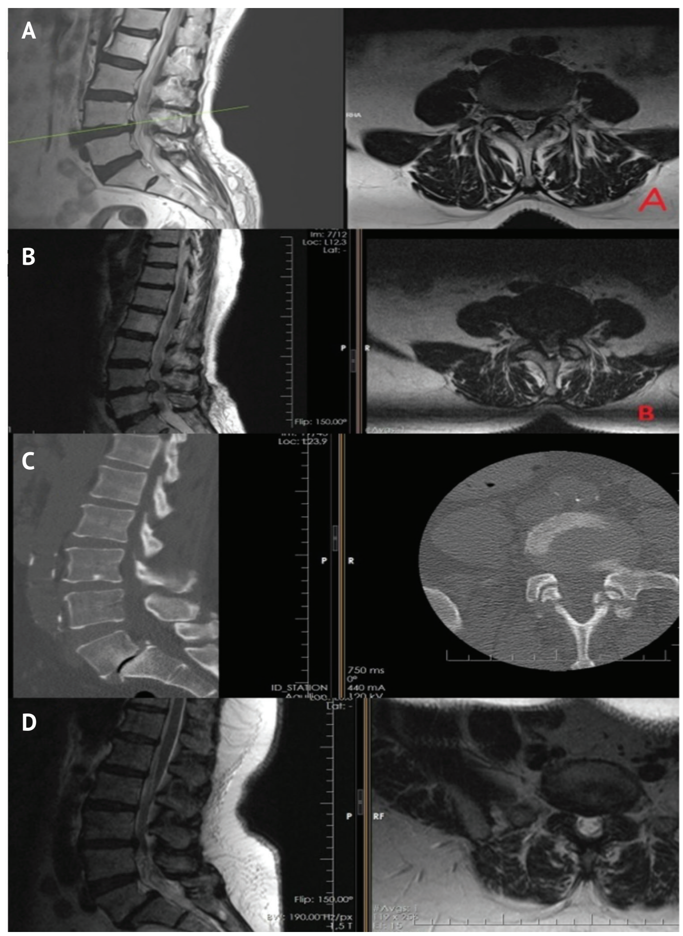

Figure 3. A) Preoperative (before the first surgery) T2 axial MRI of a patient with left L4-5 disc herniation. **B)** Preoperative (before the second surgery) T2 axial and sagittal MRI of the same patient. Disc height was reduced and facet joint was degenerated in this patient. **C)** Sagittal and axial lumbar CT scans show grade 2 spondilolisthesis. **D)** Sagittal and axial lumbar MRI scans show grade 2 spondilolisthesis

MRI: Magnetic resonance imaging, CT: Computed tomography

Figure 4. Calcified disc material at the L5-S1 level is seen on the sagittal lumbar CT scan of the patient
CT: Computed tomography

who underwent PSI had lower lumbar and radicular leg pain VAS at the postoperative 1st year follow-ups (Table 4D). We found that there was no significant difference in complication rates for both (p=0.1). We showed that VAS scores and SLR results of the patients who underwent re-operation for recurrent LDH are improved in the postoperative period if the appropriate surgical technique is selected. This is the strongest part of our study. However, low patient population and retrospective nature of the study are the limitations of this paper.

Study Limitations

Our research has some limitations. The first is the small number of cases. Second, because it is a retrospective study, the data were analyzed over the files, and the unsaved data of the patients could not be accessed.

CONCLUSION

LDH is the most frequently performed surgery in the neurosurgery routine. Recurrence of disc herniation continues to be an important problem in neurosurgery, both for the surgeon and for the patient, in both microscopic and endoscopic surgical approaches. Although there is still no consensus on the etiology of relapse, younger age, male gender, working in hard labor, smoking status, and the patient's anatomy are considered risk factors for recurrence. In addition, although re-operations cause physical and psychological difficulties for the patient, they also cause a significant cost in terms of workforce loss. VAS scores and SLR test are usually improved after re-operation. It is very important to decide on the type of surgery for recurrence by carefully examining the radiological images of the patient and to inform the patient about the possible outcomes.

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Ethics

Ethics Committee Approval: This study was approved by the University of Health Sciences Turkey, Gülhane Training and Research Hospital, Clinical Researchs Ethics Committee (decision no: 2022/164, date: 25.01.2023).
Informed Consent: Retrospective study.
Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.O.D., M.C.E., A.K., Concept: M.O.D., A.K., Design: M.C.E., A.D., Data Collection or Processing: M.C.E., Analysis or Interpretation: M.O.D., A.K., A.D., Literature Search: M.O.D., Writing: A.K., A.D.
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RETROSPECTIVE ANALYSIS OF PATIENTS WHO UNDERWENT SURGICAL TREATMENT FOR SPINAL TUMOR BETWEEN 1999 AND 2022

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ABSTRACT

Objective: To present our results of spinal tumor surgery and to compare them with the current literature.

Materials and Methods: We retrospectively evaluated 281 patients with spinal tumors who had been operated in our department between 1999 and 2022; regarding their preoperative, intraoperative and postoperative clinical and histopathological characteristics in detail and compared our results with current literature.

Results: Male patients were predominant and the mean age of patients with metastatic spinal tumors was significantly higher than those with primary tumors. 63% of spinal tumors were primary and the remaining 37% were metastatic. Ependymoma, schwannoma, and meningioma were the most common histological types, whereas metastatic spinal tumors mostly arise from lung, prostate and breast cancers. The most common anatomical locations of spinal tumors were the lumbosacral (51.6%) and thoracic (43.8%) regions. Total excision was higher in primary tumors, whereas gross total and subtotal excisions were higher in metastatic tumors. Intraoperative neuromonitoring was used in 40.2% of all surgeries. Improvement rates in postoperative physical examination were higher in metastatic spinal tumors. Most patients in the primary spinal tumor group did not exhibit any motor or sensory deficits during both pre- and postoperative periods.

Conclusion: Most spinal tumors is primary and benign in nature. An adequate number of excisions could be achieved with appropriate surgical techniques, and total excision must be aimed in primary spinal tumors.

Keywords: Spinal tumor, spinal cord, microsurgery, outcome

INTRODUCTION

Spinal tumors have high morbidity rates. The morbidity rate decreases when early diagnosis and appropriate treatment methods are applied[1]. As a treatment; surgical approaches, chemotherapy and radiotherapy are performed[2,3]. In parallel with technological advances, diagnostic possibilities have also increased. In addition, with the advancement of technology, the development of microsurgery and the widespread use of electrophysiological examinations intraoperatively have made the surgical procedure more reliable and easier and has increased the success rate in surgical treatment[4]. The anatomical location of spinal tumors, histological type, their changing growth rates and the neurological status of the patient at admission are the most important parameters that determine the prognosis of the disease[5]. Today, thanks to the use of intraoperative neuromonitoring, the development of preoperative and intraoperative radiological imaging techniques, the widespread use of microsurgery and the development of microsurgical techniques, clinical outcomes of spinal tumor surgery are much better than in previous times[3,4,6,7]. In this study, the data of 281 patients who were operated in our clinic with the diagnosis of spinal tumor between 1999-2022 were analyzed. Patients were examined in detail in preoperative (age, gender, complaints in admission, neurological examination, radiological imaging), intraoperative (surgical technique, extent of resection, use of intraoperative neuromonitoring), postoperative (examination, pathology result) periods. We aimed to contribute to the literature by analyzing our results and comparing with previous series.

MATERIALS AND METHODS

The patients who were admitted to our hospital between 1999 and 2022, who were evaluated by the neurosurgery clinic and who were diagnosed with spinal tumors and operated on as a result of the evaluation, were included in our retrospective study. Between these dates, 389 patients who were operated after physical and radiological examinations were identified. The histopathological diagnosis of 71 of these patients were not reported as spinal tumor. Detailed data of 37 patients could not be reached. So, the study was carried out with 281 patients with spinal tumors.

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Inclusion Criteria:

- Patients who were operated for spinal tumor
- Patients who were clinically and radiologically followed up by our department.

Exclusion Criteria:

- Patients who had the diagnosis without spinal tumor
- Patients who were lost in follow-up period
- Patients without detailed data.

Ethical Approval

The study protocol was approved by the University of Health Sciences Turkey, Gülhane Scientific Researches Ethical Board in conformity with the Declaration of Helsinki (approval number: 2022/123, approval date: 14.09.2022).

Outcome Measures

Patients' age (mean age and age groups), gender, presenting symptom (pain, motor deficit, paresthesia, incontinence), tumor location (anatomical location, location according to dura mater), tumor histological type, type of excision, use of intraoperative neuromonitorization (IONM), Type of surgery (emergency, elective), presence of bone metastases, and postoperative status of the patients (no change, improvement, no improvement, or worsening) were included in the analyses. Total resection refers to the absence of residual tumor on initial postoperative magnetic resonance imaging (MRI) studies, gross total resection refers to the removal of at least 95% of the tumor on intraoperative view at the end of operation and the initial postoperative MRI. The subtotal resection was defined as the resection of 80-95% of the tumor. Partial resection was defined as resection of tumor between 20 and 80%. Histological types of tumors were divided into primary and metastatic spinal tumors. Tumor type in primary tumors and primary tumor origin (lung, prostate, breast, etc.) in metastatic tumors were recorded. The location of spinal tumors was classified first anatomically (cervical, thoracic and lumbosacral) and then according to dura mater (intradural intramedullary, intradural extramedullary, extradural, intradural + extradural, bone and soft tissue involvement). First of all, demographic characteristics, location, clinical and intraoperative characteristics of spinal tumors were defined. These features were then compared between primary and metastatic tumors.

Statistical Analysis

Statistical analyzes were performed using SPSS version 21.0 (Chicago, USA) package program. The conformity of the variables to the normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogrov-Smirnov, Shapiro-Wilk test). Descriptive statistics were expressed as mean and standard deviation in normally distributed numerical data, median and minimum-maximum values in non-normally distributed data, and numbers and percentages in nominal data. Normally distributed numerical variables were used between the two groups, the "Independent groups t-test" was used. Numerical variables that were not normally distributed were analyzed using the "Mann-Whitney U test" between the two groups. Chi-square analysis and Fisher exact test were used to compare nominal data. Values below $p<0.05$ were considered statistically significant in the statistical analyzes in the study.

RESULTS

The mean age was 43.1±13.6 years (2-83 years). 61.6% of the patients were male and 38.4% were female. The male/female ratio was 1.6/1 (Table 1). Six (2.1%) patients were children (younger than 18 years old), and 275 patients were adults. The most common symptoms of patients were pain (neck pain and back pain) (62.3%), motor deficit in legs and arms (34.2%), paresthesia/hypoesthesia (19.6%) and incontinence (anal or urinary) (10%), respectively. The most common location of spinal tumors was lumbosacral region (51.6%). In the cervical region, it was very rare (9.3%). 17.1% of the patients had spinal tumor at multiple levels. 39.5% of spinal tumors were intradural extramedullary, 17.4% intradural intramedullary, 32% extradural, 1.1% intradural + extradural, and 10% bone and soft tissue locations (Table 2). Of the spinal tumors, 63% were primary and 37% were metastatic. The most common primary

Table 1. Age and gender distribution of patients

	Number (%)
Age	43.1±13.6 (Mean age)
0-18 years	6 (2.1)
19-30 years	23 (8.2)
31-45 years	156 (55.5)
46-60 years	60 (21.4)
61+	36 (12.8)
Gender	
Female	108 (38.4)
Male	173 (61.6)

Table 2. Locations of tumors

	Number (%)
Anatomical location	
Cervical	26 (9.3)
Thoracic	123 (43.8)
Lumbosacral	145 (51.6)
Location based on dura mater	
Intradural	163 (58.0)
Extramedullary	111 (39.5)
Intramedullary	49 (17.4)
Extradural	90 (32.0)
Intradural + extradural	3 (1.1)
Bone and soft tissue involvements	28 (10.0)
Multi-level involvement	48 (17.1)

tumors were ependymoma (13.8%), schwannoma (10.7%) and meningioma (8.2%) (Table 3). In metastatic tumors, lung (7.1%), prostate (4.9%) and breast (4.2%) cancer metastases were most common (Figures 1-3). Extent of resection was total in 32.7%, gross total in 35.6%, subtotal in 20.6%, and partial in 11% of patients. IONM was used in 40.2% of the patients. We not used IONM in patients with metallic clips, cardiac pacemakers, biomechanical metallic implants, cerebral lesions or injuries, skull defects, and history of epilepsy. Most of the surgeries (72.2%) were elective and less (27.8%) were emergency. 24.2% of patients had bone metastases. Motor deficit or incontinence was present in 33.8% (n=95) of the patients before surgery (Figures 4, 5). When the patients with motor deficit or incontinence were examined, no change was observed in the physical examination in 55.7% of these patients after the operation, while improvement was observed in the physical examination in 37.8% of them. Patients with preoperative motor deficit or incontinence but no change in physical examination findings after surgery comprised 18.9% of the operated patients, and patients with improvement in physical examination findings comprised 12.8% of the operated patients. In 6 patients, physical examination findings worsened after surgery. Patients with spinal tumors were divided into 2 groups as primary and metastatic according to the origin of tumor. The mean age of patients with metastatic spinal tumor was significantly higher (p=0.010). However, no significant difference was observed in terms of gender (p=0.805) (Table 4). Patients with primary and metastatic tumors were compared according to their presenting symptoms. While motor deficit (p<0.001) and incontinence (p<0.001) were significantly higher in metastatic tumors; paresthesia was more common in primary tumors and it is statistically significant (p<0.001). However, there was no significant difference between primary and metastatic tumors in terms of pain at presentation (p=0.112). Primary and metastatic tumors were also compared according to their locations. While lumbosacral (p=0.009), intradural (p<0.001), extramedullary (p<0.001), intramedullary (p<0.001) locations are significantly more common in primary tumors, thoracic (p=0.004), extradural (p<0.001) locations in metastatic tumors squeezed harder. In addition, bone and soft tissue involvement was significantly higher in metastatic spinal tumors (p=0.020). While 7.9% of primary spinal tumors were presented in multiple levels, 32.7% of metastatic tumors were at multiple levels. Multi-level involvement was significantly higher in metastatic spinal tumors (p<0.001). Primary and metastatic tumors were compared in terms of intraoperative characteristics. While the frequency of total excision (p<0.001) was significantly higher in primary tumors, the frequency of gross total (p=0.020) and subtotal (p<0.001) excision was higher in metastatic tumors. The frequency of the use of IONM (p<0.001) was significantly higher in metastatic tumors. In addition, the frequency of emergency surgery (p<0.001) and bone metastasis (p<0.001) was significatly higher in metastatic tumors (Table 5). Primary and metastatic

Table 3. Distribution of spinal tumors based on histo-pathological diagnosis

	Number (%)
Primary	177 (63.0)
Ependymoma	39 (13.8)
Schwannoma	30 (10.7)
Meningioma	23 (8.2)
Astrocytoma	12 (4.2)
Lipoma	8 (2.8)
Osteosarcoma	6 (2.1)
Arteriovenous malformation	5 (1.8)
Ewing Sarcoma	5 (1.8)
Neurofibroma	5 (1.8)
Osteoblastoma	5 (1.8)
Plasmocytoma	5 (1.8)
Multiple myeloma	4 (1.4)
PNET	4 (1.4)
Teratoma	4 (1.4)
Arachnoid cyst	3 (1)
Aneurysmal bone cyst	3 (1)
Dermoid Tumor	3 (1)
Endodermal cyst	2 (0.7)
Epidermoid tumor	2 (0.7)
Intraosseous hemangioma	2 (0.7)
Osteochondroma	2 (0.7)
Ganglioneuroma	1 (0.4)
Hemangioblastoma	1 (0.4)
Leiomyosarcoma	1 (0.4)
Myeloid sarcoma	1 (0.4)
Paraganglioma	1 (0.4)
Metastatic tumors	104 (37.0)
Lung CA	20 (7.1)
Prostate CA	14 (4.9)
Breast CA	12 (4.2)
Lymphoma	10 (3.5)
RCC	8 (2.8)
Colon Ca	6 (2.1)
HCC	4 (1.4)
Rectum CA	4 (1.4)
Thyroid CA	4 (1.4)
Gastric adenocarcinoma	3 (1)
Malignant melanoma	2 (0.7)
Malignant epithelial tumor	1 (0.4)
Ovarian CA	1 (0.4)
Unknown origin	15 (5.3)

HCC: Hepatocellular carcinomas, PNET: Primitive neuroectodermal tumor tumors were compared in terms of postoperative neurological examination. In metastatic tumors, the proportion of patients with improvement (p<0.001) and no change (p<0.001) in physical examination findings was higher, whereas in primary spinal tumors, most patients did not change before and after surgery (p<0.001) (Table 6).

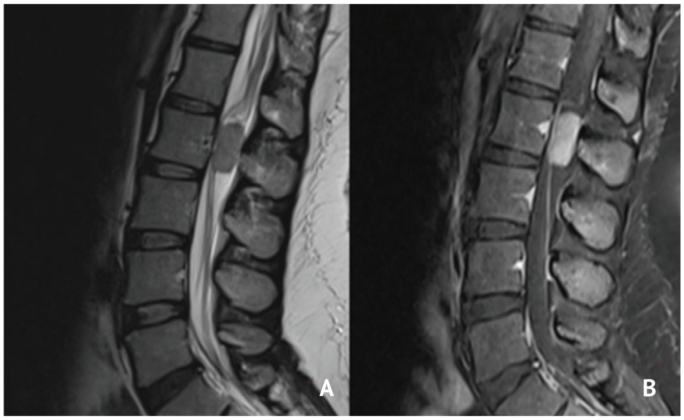

Figure 1. Intradurally located ependymoma at L2 level, MRI sections **A)** T2-weighted MRI, sagittal section, **B)** T1-weighted MRI, sagittal section after IV contrast injection
MRI: Magnetic resonance imaging, IV: Intravenous

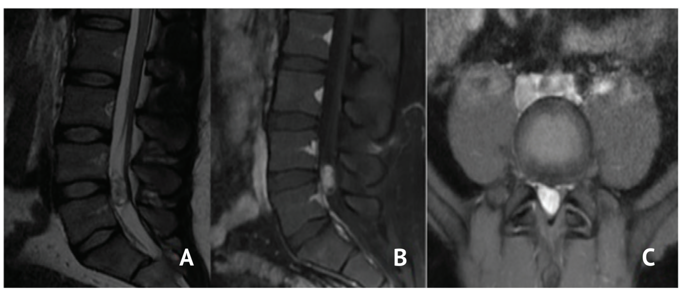

Figure 2. Intradural schwannoma at L4-L5 level, MRI sections **A)** T2-weighted MRI, sagittal section, **B)** T1-weighted MRI, sagittal section after IV contrast injection, **C)** T1-weighted MRI, axial section after IV contrast injection
MRI: Magnetic resonance imaging, IV: Intravenous

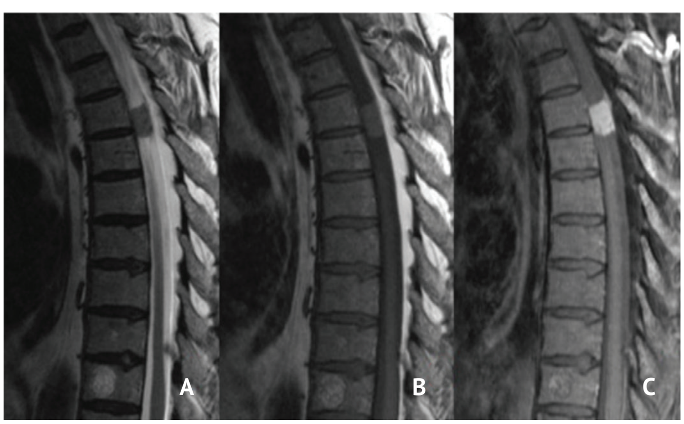

Figure 3. Intradural extramedullary meningioma at T4 level, MRI sections **A)** T2-weighted MRI, sagittal section, **B)** T1-weighted MRI, sagittal section, **C)** T1-weighted MRI, sagittal section after IV contrast injection
MRI: Magnetic resonance imaging, IV: Intravenous

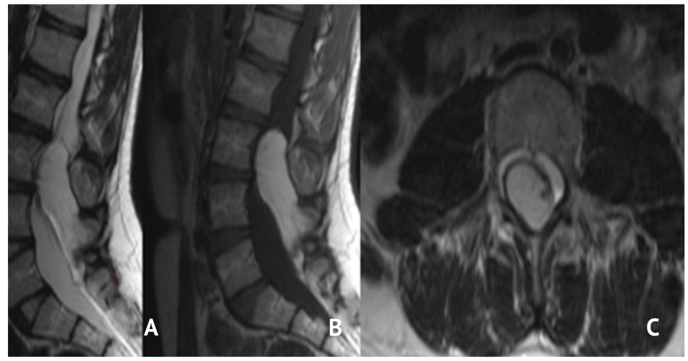

Figure 4. Lipoma at intradural location between L3-L5, MRI sections **A)** T2-weighted MRI, sagittal section, **B)** T1-weighted MRI, sagittal section, after IV contrast injection, **C)** T2-weighted MRI, axial section
MRI: Magnetic resonance imaging, IV: Intravenous

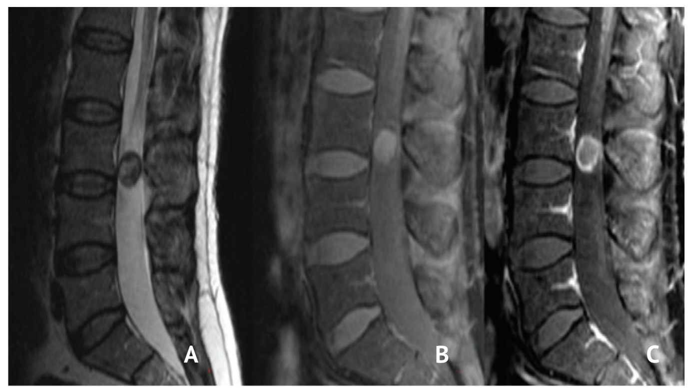

Figure 5. Intradural paraganglioma at L3-L4 level, MRI sections **A)** T2-weighted MRI, sagittal section, **B)** T1-weighted MRI, sagittal section, **C)** T1-weighted MRI, sagittal section after IV contrast injection
MRI: Magnetic resonance imaging, IV: Intravenous

Table 4. Comparison of primary and metastatic spinal tumors based on the age and gender of the patients

Demographic feature	Primary tumor (n=177)	Metastatic tumor (n=104)	p value
Age*	41.5±13.4	45.8±13.7	0.010†
0-18 years	6 (2.1)	0	
19-30 years	15 (9.8)	8 (7.7)	
31-45 years	109 (61.6)	47 (45.2)	
46-60 years	28 (15.8)	32 (30.8)	
61+	19 (10.7)	17 (16.3)	
Gender			0.805††
Female	69 (39.0)	39 (37.5)	
Male	108 (61.0)	65 (62.5)	

*Mean ± SD
†Independent Samples t-test, ††Chi-square test, SD: Standard deviation

Table 5. Comparison of primary and metastatic spinal tumors based on excision type, use of IONM, and bone mestatasis

	Primary tumor (n=177) (%)	Metastatic tumor (n=104) (%)	p value
Excision type			
Total excision	85 (48.0)	7 (6.7)	**<0.001**
Gross total excision	54 (30.5)	46 (44.2)	**0.020**
Subtotal excision	23 (13.0)	35 (33.7)	**<0.001**
Partial excision	15 (8.5)	16 (15.4)	0.074
IONM			**<0.001**
Yes	98 (55.4)	5 (14.4)	
No	79 (44.6)	89 (85.6)	
Type of surgery			**<0.001**
Emergent	3 (1.7)	75 (72.1)	
Elective	174 (98.3)	29 (27.9)	
Bone metastasis			**<0.001**
Yes	15 (8.5)	53 (51.0)	
No	162 (91.5)	51 (49.0)	

IONM: Intraoperative neuromonitorization

Table 6. Comparison of primary and metastatic spinal tumors based on clinical outcome

Postoperative outcome	Primary tumor (n=177)	Metastatic tumor (n=104)	p value
Unchanged	168 (94.9)	71 (68.3)	**<0.001**††
Improvement	6 (3.4)	30 (28.8)	**<0.001**††
Worsening	3 (1.7)	3 (2.9)	0.673ᵋ

†Chi-square test, ᵋFisher exact test

DISCUSSION

After the use of laminectomy in spinal tumor resections in 1887, great developments were achieved in the diagnosis and treatment of spinal tumors[2,8]. Spinal tumors can be primary tumors originating from spinal cord, meninges or bone cells, as well as metastatic lesions that can invade the spinal cord and surrounding tissues. Most primary tumors are histopathologically similar to primary intracranial tumors, however, they are much rarer[7,9]. Since clinical symptoms are not specific, a significant portion of patients can be diagnosed as degenerative spinal disease, cervical spondylopathy or intervertebral disc herniation. Today, spinal tumors can be easily recognized by MRI. However, since specific intraspinal tumors are associated with mortality, physicians should be aware of the characteristics associated with spinal tumors[10]. Therefore, our study aimed to describe the demographic, clinical and intraoperative characteristics of a large case series operated for spinal tumors. In our study, the mean age of the patients was 43.1 years (between the 4th and 5th decades) (Table 1). In addition, there was a male predominance among the patients. Temiz et al.[11] reported that spinal tumors affect men more and the male/female ratio is 2/1. In this study, it was stated that the frequent follow-up of metastatic tumors in males increased male dominance in spinal tumors. In our study, however, no such gender difference was observed between primary and metastatic tumors. The prevalence of male sex in some types of primary spinal tumors has been previously reported. It is known that especially schwannoma and ependymomas are more common in males. Therefore, male dominance may have been observed in our study. Asiltürk et al.[12] analyzed 96 patients who were operated for spinal tumors, and the mean age was reported as 49.3±22.7 years. In this study, the male/female ratio was reported as 1.1. Materljan et al.[13], on the other hand, stated that the mean age was 49 years in their series in Croatia. In the study of Dang et al.[14], it was reported that 70% of spinal tumors were observed between the ages of 18-59. In our study, 85.1% of spinal tumors were between the ages of 19-60 years. It was very rare between 0-18 years (2.1%). Studies on the demographic characteristics of spinal tumors often consist of case series. However, more accurate definitions can be made in population-based studies. In the population-based study of Schellinger et al.[15], 3,226 spinal tumors were reached, and the age of occurrence of these tumors was 51 years. However, in the study, it was reported that 55% of the cases were women, which was attributed to the fact that the most common primary tumors were meningiomas and that meningiomas were observed more frequently in women. In our study, however, the most common primary tumors were not meningiomas, on the contrary, ependymoma and nerve sheath tumors, which were reported to be more common in males, were more common. The fact that spinal tumors are asymptomatic and do not cause specific symptoms may delay the diagnosis. Instead of spinal tumor diagnosis, diagnoses that cause similar complaints such as spondylopathy or discopathy can be considered. In our study, the main symptoms in spinal tumor patients were pain (62.3%), motor deficit (34.2%), paresthesia (19.6%), and incontinence (10%). In the study of Asiltürk et al.[12], it was stated that the most common complaint at presentation was pain or radicular pain. Similarly, Dang et al.[14] reported that pain (77.6%) and neurological symptoms (45.2%) were frequently observed, but only primary spinal tumors were included in this study. In the study of Kelley et al.[16], the most common symptoms were pain (79.4%) and neurological symptoms (31.1%). In this study, primary spinal bone tumors were evaluated. It is known that primary spinal cord tumors are frequently located intradurally. In a review by Grimm and Chamberlain[17], it was stated that 60% of primary spinal tumors were intradural extramedullary (30% meningioma, 30% peripheral nerve sheath tumor), and 40% were intradural intramedullary (60% ependymoma, 40% glioma). In our study, similar to these data, it was observed that 61.6% of primary spinal tumors were extramedullary and 26.6% were intramedullary. Primary spinal tumors were very rarely located extradurally (5.1%). Among the primary tumors, it is well known that schwannomas and meningiomas from nerve sheath tumors are observed more frequently in the intradural extramedullary localization, while ependymomas are more frequently observed in the intradural intramedullary region. Although spinal cord tumors are not common, the development of neurological complications during surgery is a major concern. IONM is a frequently used method to avoid iatrogenic injuries during surgery. For this purpose, electromyographic methods such as somatosensory evoked potentials, transcranial motor evoked potentials and dorsal column mapping are preferred[7]. With the use of IONM in spinal cord tumors, spinal cord injuries can be prevented in most of the cases. For this reason, IONM was preferred in approximately 40% of the patients in our study. It was especially preferred in intramedullary tumors. But the presence of metallic implants and clips in the patient's body and previous cerebral lesions or skull defects are relative contraindications for IONM. In addition, it is sometimes difficult to set-up IONM, especially in emergent cases. While total excision (35.6%) and gross total excision (35.6%) were performed in most of our patients, subtotal excision (20.6%) or partial resection (11%) was performed in a small number of patients. Total excision rates were decreasing, especially in metastatic spinal tumors. Among the primary tumors, ependymoma (13.8%), schwannoma (10.7%) and meningioma (8.2%) were the most frequently observed tumors. Although these three tumor types were reported to be common in most studies, their frequencies varied between studies. Temiz et al.[11] reported that the most common tumors among primary spinal tumors were ependymoma (21.9%), schwannoma (16.4%) and meningioma (13.6%), similar to our findings. Schellinger et al.[15] reported that meningioma (29%), nerve sheath tumors (24%) and ependymomas (23%) were frequently observed among primary tumors. In the retrospective case series reported by Gelabert-González[18], it was stated that the most common primary intramedullary tumors were ependymoma (15.4%), while the most common extradural tumors were meningioma (33.9%) and schwannoma (31.5%). In the study of Asiltürk et al.[12], the most common primary spinal tumors were reported to be meningioma (16.2%), schwannoma (15.7%), and ependymoma (9.4%). Primary origins of metastatic tumors are frequently lung, breast, kidney, prostate and bowel. However, different rates have been reported in the literature. In the study of Zairi et al.[19], it was stated that the most common primary sites in 317 patients with metastatic spinal tumor were breast (25.2%), multiple myeloma (18.9%), and lung (16.4%), respectively. In a population-based study conducted by Sohn et al.[20] in Korea, metastatic spinal tumors between 2009 and 2012 were evaluated, and the most common tumor origins were lung (28.1%), liver/biliary (12.9%), breast (10.2%), colon (9.1%), stomach (8.9%) and prostate (5.8%). In the study of Hikata et al.[21], the most common locations were lung, breast and thyroid. In the study of Temiz et al.[11], it was stated that the most common metastases originate from the lung and prostate. In the study of Wang et al.[22], the most common origin site was the lung (36.4%). The type of resection was closely related to the spinal tumor type in our study. While the total or gross total resection rate in primary spinal tumors approached 80%, this rate remained around 50% in metastatic lesions. Although not evaluated in our study, failure of total resection may be associated with poor prognosis[23]. It was observed that metastatic tumors often did not improve after surgery compared to primary tumors. Total surgical resection of spinal tumors in children can be achieved by laminotomy with low incidence of future spinal deformity[24]. Laminectomy is mostly preferred technique in adult patients. On the other hand, in patients with metastatic tumors, the rate of patients whose neurological loss improved after surgery was also high. The possible reason for this may be that primary tumors do not often cause neurological loss[25]. In our study, it was observed that patients who had no neurological loss before surgery in primary tumors were discharged in the same way after surgery.

Study Limitations

Our study had some limitations. As it was retrospective, it included all the limitations of this design. Our study included cases between 1999-2022. Therefore, the number of spinal cord cases was high (n=281). However, it can be said that diagnosis and imaging methods were less developed in the early period compared to today. This may have affected the primary and metastatic tumor distributions. However, similar distributions have been expressed for tumor types in more recent case series. Finally, our study did not evaluate the survival data, length of hospital stay, intraoperative characteristics, or health expenditures of primary and metastatic tumors. Spinal tumor epidemiology can be further elucidated with prospective studies evaluating these variables.

CONCLUSION

Spinal tumors are frequently observed in 4th and 5th decades and in male patients. It frequently causes pain and neurological symptoms. Most of the operated spinal tumors consisted of primary tumors. While the most common primary tumors were ependymoma, schwannoma and meningioma, the most common primary sites in metastatic tumors were lung, prostate and breast cancer. Metastatic tumors are frequently seen in older patients and cause more severe symptoms. They are observed more frequently in the thoracic region compared to primary tumors. While primary tumors were mostly seen in intradural intramedullary and intradural extramedullary locations, the majority of metastatic tumors were located extradurally. Compared to primary tumors, metastatic tumors showed multi-level involvement, required emergency surgery, and had low total excision rates.

Ethics

Ethics Committee Approval: The study protocol was approved by the University of Health Sciences Turkey, Gülhane Scientific

Researches Ethical Board in conformity with the Declaration of Helsinki (approval number: 2022/123, approval date: 14.09.2022).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.K., M.C.E., N.Ç.T., Concept: A.K., N.Ç.T., Design: A.K., M.C.E., N.Ç.T., Data Collection or Processing: A.K., M.C.E., Analysis or Interpretation: A.K., M.C.E., N.Ç.T., Literature Search: A.K., N.Ç.T., Writing: A.K., M.C.E., N.Ç.T.

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SHOULD PELVIC FIXATION BE INCLUDED IN NEUROMUSCULAR SCOLIOSIS SURGERY?

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ABSTRACT

Objective: The aim of the current study was to compare the activity levels and radiological outcomes of patients who underwent neuromuscular scoliosis (NMS) surgery with and without pelvic fixation.

Materials and Methods: Thirty-three NMS patients aged 10-20 years with a pelvic obliquity (PO) of 15° or more and a follow-up of at least 24 months who underwent posterior surgery for NMS at two different centers were included in the study. Out of the 33 patients, 16 without pelvic fixation (WoPF) and 17 with PF (WPF) underwent posterior spinal surgery. Radiological results and independent movement levels according to the Gross Motor Function Classification System (GMFCS) were compared in the two groups.

Results: The follow-up period of the patients was 46.69±21.95 months in WoPF and 43.88±20.05 months in WPF, and there was no significant difference between the two groups in postoperative radiological values (p=0.763). In the PO values, postoperative improvement was more pronounced in the WPF group (WoPF: 14.31°±8.292; WPF: 9.35°±5.338), but there was no statistically significant difference between the two groups (p=0.087). Patients' GMFCS levels were higher in the WPF group than in the WoPF group (WoPF: 2.75±1.29; WPF: 3.76±1.03). GMFCS levels of patients in both groups did not change and were similar to pre-operative levels.

Conclusion: The study demonstrated that NMS surgery with PF was not significantly different clinically and radiologically from surgery without PF. Considering PF-related complications in NMS surgery, surgery without PF may be an option in NMS patients with PO.

Keywords: Neuromuscular scoliosis, pelvic fixation, pelvic obliquity, activity level

INTRODUCTION

Pathological muscle tone in neuromuscular diseases causes advanced spinal curvature, asymmetric spinal growth due to secondary vertebral growth suppression on the concave side of the curve, and thus advanced spinal deformity[1]. Neuromuscular scoliosis usually consists of a characteristic C-shaped deformity with pelvic obliquity and imbalances in the coronal and sagittal planes. Scoliosis greater than 10° is commonly observed in individuals with neuromuscular disorders, with an average prevalence of 41%. Additionally, there is a positive correlation between the incidence of scoliosis and the severity of spinal curvature, which tends to increase with higher levels of the Gross Motor Function Classification System (GMFCS) in these patients[2]. While bracing can be used to promote trunk positioning and head control in the early stages of neuromuscular scoliosis, it does not significantly impact the natural progression of the deformity[3]. However, surgical treatment is recommended for patients with curves exceeding 40°, despite the higher complication rate associated with surgical interventions for neuromuscular scoliosis.

Pelvic fixation is commonly employed as an adjunct procedure during posterior surgery to address both spinal and pelvic deformities in patients with advanced neuromuscular scoliosis and pelvic obliquity. However, the utilization of pelvic fixation in patients with neuromuscular scoliosis remains a subject of controversy, primarily limited to non-ambulatory patients presenting with both scoliosis and pelvic obliquity. While certain studies have reported that pelvic fixation in neuromuscular scoliosis surgery with pelvic obliquity can result in improved spinal curvature and pelvic correction[4-6], it is important to note that the pelvic fixation to scoliosis surgery can lead to increased revision rates and additional morbidity. The inclusion of pelvic fixation in conjunction with posterior spinal fusion has been associated with an elevated incidence of surgical complications. These complications include prolonged operative time, increased blood loss, heightened exposure to X-rays due to additional imaging requirements, and higher rates of pseudoarthrosis and skin ulceration[7-9].

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The aim of this study was to compare the clinical and radiological outcomes of patients with and without pelvic fixation in addition to posterior spinal surgery for neuromuscular scoliosis with pelvic obliquity and to evaluate the effect of pelvic fixation on patients' activity levels.

MATERIALS AND METHODS

The study obtained approval from the Ethics Commission of Gazi University (approval number: 05, approval date: 21.03.2023) prior to conducting the research. It involved a retrospective review of patients who underwent posterior spinal surgery for neuromuscular scoliosis, performed by two experienced spine surgeons at two different medical centers. The inclusion criteria encompassed patients within the age range of 10 to 20 years, with a minimum clinical and radiological follow-up period of 2 years, and a pelvic obliquity exceeding 15°. Patients with insufficient follow-up or those who underwent revision surgery were excluded from the study. The patient population was divided into two groups: Those who received pelvic fixation in addition to posterior spinal surgery WPF group and those who did not receive pelvic fixation (WoPF group). The study included a total of 33 patients, with 16 in the WoPF group and 17 in the WPF group. A comprehensive comparison was conducted between patients in both groups, taking into account both clinical and radiological findings. The present study investigated the clinical findings of patients by examining the activity levels using the GMFCS during preoperative and postoperative assessments.

In the analysis of the radiological findings, the study involved the assessment of plain radiographs of the patients at different time points: Preoperatively, early postoperatively (at 6 weeks), and during the last follow-up visit. The main focus was on measuring the Cobb angle of the primary spinal curvature and the angles of pelvic obliquity in the coronal plane using plain radiographs. Pelvic obliquity was assessed using the Maloney method[10], which measures the angle between the line perpendicular to the line connecting the iliac wing tips and the line connecting T1 and S1 (Figures 1a, c; Figures 2a, c). In the sagittal plane, the study involved measuring the angles of thoracic kyphosis and lumbar lordosis (Figures 1b, d; Figures 2b, d). Additionally, in the coronal plane, the angles of pelvic obliquity and scoliotic curvature of the spine were assessed. The analysis also included evaluating the extent of correction and potential loss of correction in the angles of thoracic kyphosis and lumbar lordosis in the sagittal plane. Furthermore, a comparison was made between the two groups to determine if there was a statistically significant difference.

Surgical Technique

All procedures were performed by two senior surgeons in two different centres using a standard posterior surgical approach. After general anaesthesia, the patient was placed in the prone position. Silicone pads were placed on the appropriate areas of the patient to prevent both pressure sores and bleeding. After sterile draping of the surgical field, a long incision was made in the posterior midline. The folds were crossed. The supraspinous and interspinous ligaments were preserved and the paraspinal muscles were dissected subperiosteally. To avoid proximal and distal junctional kyphosis, care was taken to protect the facet muscles and ligaments of the upper and lower vertebrae to be instrumented. After exposure of the levels to be instrumented, pedicle screws were inserted using a freehand technique. Pedicle screws measuring 6.5 mm in the lumbar and lower thoracic region, and 5.5 mm in the middle thoracic region, were inserted. Intraoperative radiographs were utilized to assess the adequacy of screw placement. The 6 mm diameter titanium rods were manually adjusted to achieve the desired sagittal alignment. Initially, the rod on the concave side was positioned. By rotating the rod approximately 90 degrees clockwise to correct the scoliotic curvature, the rod was secured by tightening the top screw on the neutral vertebra. Subsequently, the rod on the convex side was implanted. Derotation tubes were placed on both the neutral and apical vertebrae, and appropriate derotation of the apical vertebra was achieved. The concave side was then distorted, while the convex side was compressed, and the top screws were tightened.

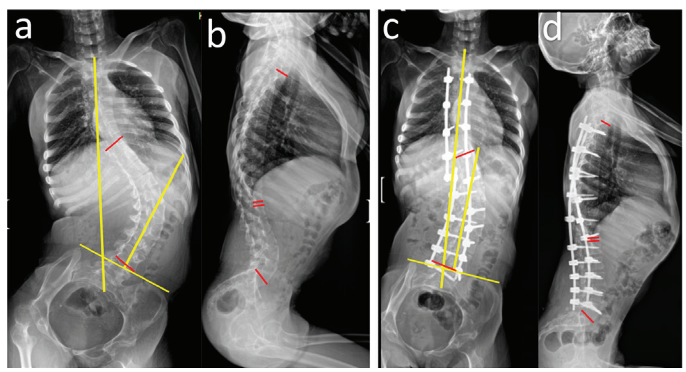

Figure 1. Preoperative and postoperative plain radiographs of a patient undergoing posterior spinal surgery without pelvic fixation. (**a, b:** Preoperative anterior posterior and lateral radiographs; **c, d:** Postoperative anterior posterior and lateral radiographs)

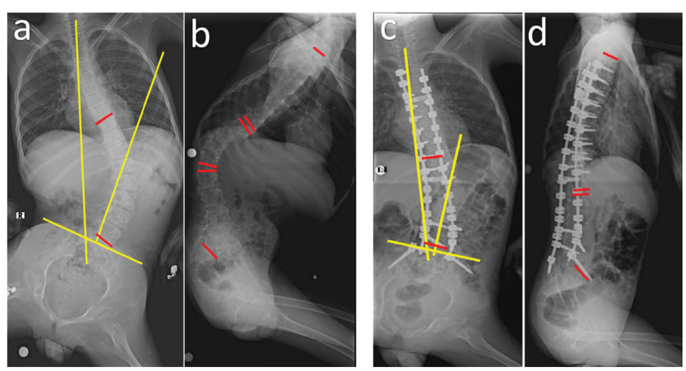

Figure 2. Preoperative and postoperative plain radiographs of a patient undergoing posterior spinal surgery with pelvic fixation. (**a, b:** Preoperative anterior posterior and lateral radiographs; **c, d:** Postoperative anterior posterior and lateral radiographs)

Throughout these procedures, continuous monitoring of sensorimotor and motor evoked potentials was maintained.

The instrumentation levels were T3 or T4 level cranially. In the WoPF group, it was placed caudally at the L5 level. In WPF patients, iliac screws were inserted under fluoroscopic guidance and fixed to the rods using iliac connectors.

No thoracoplasty was performed in any patient. On the first postoperative day, ambulatory patients who were hemodynamically stable were mobilized and nonambulatory patients were seated at the bedside.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY). A significance level of $p<0.05$ was considered statistically significant. Categorical variables were presented as numbers and percentages, while continuous variables were expressed as mean ± standard deviation. The chi-square test was used to compare categorical variables. The normality of continuous variables was assessed using visual examination (histogram and probability graphs) as well as analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). For data comparison, the independent samples t-test and Mann-Whitney U test were employed based on the evaluation of normality.

RESULTS

In the group WoPF, the patients had a mean age of 16.81±1.8 years, while in the group WPF, the mean age was 15.76±1.2 years. The mean follow-up periods for the WoPF and WPF groups were 46.69±21.95 months (ranging from 26 to 96 months) and 43.88±20.05 months (ranging from 26 to 90 months), respectively (Table 1). Among the patients in the WoPF group, 8 (50%) out of 16 had cerebral palsy, 3 (19%) had Duchene muscular dystrophy, 3 (19%) had spinal muscular atrophy, and 2 (12%) had Friedreich ataxia. In the WPF group, 6 (35%) out of 17 patients had cerebral palsy, 7 (41%) had Duchene muscular dystrophy, 2 (12%) had spinal muscular atrophy, 1 (6%) had Friedreich ataxia, and 1 (6%) had Ullrich muscular dystrophy (Table 2).

Radiologically, the preoperative scoliosis angles were found to be higher in the group WoPF compared to the group WPF. The mean Cobb angles were 78.0°±15.75 in the WoPF group and 57.59°±19.4 in the WPF group (Table 3; p=0.006). However, there was no statistically significant difference observed in Cobb angles between the early postoperative (6th week) measurements (19.25°±8.614 in the WoPF group; 20.41°±12.089 in the WPF group) and the final control radiographs (22.00°±8.914 in the WoPF group; 20.53°±12.053 in the WPF group) (Table 3; p=0.709; 0.763).

In terms of pelvic obliquity, the preoperative values were 24.50°±10.532 in the WoPF group and 20.41°±7.500 degrees in the WPF group with no significant difference. At the early (12.69°±7.726 in the WoPF group; 9.41°±5.444 in the WPF group) and final postoperative controls (14.31°±8.292 in the WoPF group; 9.35°±5.338 in the WPF group), pelvic obliquity values improved more in the WPF group (Table 3). However, there was no statistically significant difference between the two groups (preoperative p=0.260; postoperative p=0.217 in early control and p=0.087 in final control) (Table 3).

On sagittal plane radiographs, thoracic kyphosis angles were higher in patients without PF than in patients with PF preoperatively (45.25°±24.349 in the WoPF group; 28.35°±19.493 in the WPF group), in early postoperative (34.69°±9.958 in WoPF group; 30.29°±9.399 in WPF group) and final control radiographs (36.69°±10.682 in WoPF group; 30.88°±9.158 in WPF group), the thoracic kyphosis angle values were higher in patients without PF. However, there was no statistically significant difference between the two groups (Table 3) (early postoperative control: p=0.363; final follow-up: p=0.179).

Table 1. Demographic characteristics and basic information of the patients

	WoPF group	WPF group	p value
Patients (n)	16	17	
M ± SD (age)	16.81±7.305	15.76±5.019	0.845
Follow-up M ± SD (month)	46.69±21.951	43.88±20.056	0.709

WoPF: Without pelvic fixation, WPF: With pelvic fixation, M: means, SD: Standard deviation

Table 2. Neuromuscular diseases

	WoPF group [n (%)]	WPF group [n (%)]
Cerebral palsy	8 (50%)	6 (35%)
Duchene muscular dystrophy	3 (19%)	7 (41%)
Spinal muscular atrophy	3 (19%)	2 (12%)
Friedreich ataxia	2 (12%)	1 (6%)
Ullrich muscular dystrophy	0	1 (6%)

WoPF: Without pelvic fixation, WPF: With pelvic fixation

The mean lumbar lordosis values were 47.19°±16.204 in those without PF and 28.24°±23.012 in those with PF (p=0.011). At early postoperative control, mean lumbar lordosis angles were 40.50°±8.075 in those without PF and 33.18°±15.989 in those with PF, and 42.13°±8.107 in those without PF and 32.47°±15.529 in those with PF. Lumbar lordosis angles were not significantly different between the two groups in the early and final postoperative controls (early postoperative control: p=0.245; final follow-up: p=0.068) (Table 3).

When assessing the activity levels of the patients based on the GMFCS, the mean preoperative level for patients in the group WoPF was 2.75±1.291. Among the WoPF patients, there were 4 patients at level I, 3 patients at level II, 2 patients at level III, and 7 patients at level IV. There were no patients in level V. In contrast, the mean GMFCS levels for patients in the group WPF were higher compared to the WoPF group, with a mean of 3.76±1.033. In the WPF group, there was 1 patient at level I, 2 patients at level II, 4 patients at level III, 8 patients at level IV, and 2 patients at level V. Among the WPF patients, 9 (56%) were non-ambulatory, while among the WoPF patients, 14 (82%) were non-ambulatory. At the last postoperative follow-up, there were no changes in the activity levels in both groups, and the GMFCS levels remained the same as preoperatively (Table 4).

DISCUSSION

The necessity of pelvic fixation in surgical interventions for neuromuscular scoliosis remains uncertain. The findings of the current study align with the perspective that argues against the need for pelvic fixation. The outcomes of the current study revealed no significant clinical or radiographic differences between patients who underwent surgery with and WoPF. These results suggest that pelvic fixation may not provide additional benefits in terms of clinical and radiographic outcomes in patients with neuromuscular scoliosis.

Although neuromuscular scoliosis surgery carries a high reported complication rate of 47%, surgical intervention is still recommended for advanced cases of scoliosis[11]. One effective approach to address pelvic obliquity is the incorporation of pelvic fixation during posterior surgery. However, it is crucial to carefully consider the potential additional morbidities associated with this technique[12]. Generally, pelvic fixation is performed in nonambulatory patients who present with pelvic obliquity in the context of neuromuscular scoliosis[4,13,14].

In their study, Hasler et al.[14] recommended the use of pelvic fixation in the surgical treatment of neuromuscular scoliosis patients with rigid pelvic obliquity greater than 150, particularly in nonambulatory patients. They emphasized the importance of pelvic and scoliosis correction in these cases. However, Farshad

Table 3. Results of preoperative and postoperative radiological evaluation of the patients

	WoPF group (°) (M ± SD)	WPF group (°) (M ± SD)	p value
Cobb angle			
Preoperative	78.00±15.752	57.59±19.413	0.006
Early control	19.25±8.614	20.41±12.089	0.709
Final follow-up	22.00±8.914	20.53±12.053	0.763
Pelvic obliquity angle			
Preoperative	24.50±10.532	20.41±7.500	0.260
Early control	12.69±7.726	9.41±5.444	0.217
Final follow-up	14.31±8.292	9.35±5.338	0.087
Thoracic kyphosis angle			
Preoperative	45.25±24.349	28.35±19.493	0.041
Early control	34.69±9.958	30.29±9.399	0.363
Final follow-up	36.69±10.682	30.88±9.158	0.179
Lumbar lordosis angle			
Preoperative	47.19±16.204	28.24±23.012	0.011
Early control	40.50±8.075	33.18±15.989	0.245
Final follw-up	42.13±8.107	32.47±15.529	0.068

WoPF: Without pelvic fixation, WPF: With pelvic fixation, M: means, SD: Standard deviation

Table 4. Results of the GMFCS evaluation

GMFCS levels	WoPF group (M ± SD)	WPF group (M ± SD)	p value
Preoperative I/II/III/IV/V	4/3/2/7/0 (2.75±1.291)	1/2/4/8/2 (3.76±1.033)	0.028
Final follw-up I/II/III/IV/V	4/3/2/7/0 (2.75±1.291)	1/2/4/8/2 (3.76±1.033)	0.028

WoPF: Without pelvic fixation, WPF: With pelvic fixation, M: means, SD: Standard deviation, GMFCS: Gross Motor Function Classification System et al.[15] conducted an investigation to determine the benefits of pelvic fixation in both ambulatory and non-ambulatory patients with neuromuscular scoliosis and pelvic obliquity. Their study included 49 patients who underwent posterior surgery for neuromuscular scoliosis. The researchers reported a complication rate of 50% in patients WPF, compared to 29% in patients WoPF. They found that complications were primarily attributed to implant failure and observed no significant difference between the two groups in terms of pelvic obliquity correction and correction of scoliotic curves. Based on their findings, Farshad et al.[15] concluded that pelvic fixation is not mandatory for patients with nonambulatory neuromuscular scoliosis. Furthermore, they cautioned against the use of pelvic fixation to avoid complications in patients with scoliosis greater than or equal to 60° and up to 35°[15].

In the current study, the majority of patients included were non-ambulatory individuals with CMFCS level III-IV. Radiological assessment revealed that patients who underwent pelvic fixation exhibited better outcomes in terms of correcting pelvic obliquity associated with obesity. However, no statistically significant difference was observed between the two groups. Following a minimum follow-up period of 2 years, patients WoPF demonstrated an average increase of 20 degrees in pelvic obliquity angle. Nonetheless, there was no significant difference in pelvic obliquity angles between the two groups during the early postoperative period and at the last follow-up assessment.

During the early postoperative period, scoliosis angles were effectively corrected at the bender level in both groups, and no significant increase in scoliosis angles was observed in either group at the final follow-up. In terms of radiological measurements in the sagittal plane, it was noted that the WoPF group had higher angles of thoracic kyphosis and lumbar lordosis preoperatively compared to the non-WoPF group. However, there were no statistically significant differences in thoracic kyphosis and lumbar lordosis angles between the two groups during the early postoperative period and at the final follow-up (as indicated in Table 3).

When considering the impact of pelvic fixation on patients' activity levels, there is a limited number of studies available in the literature regarding this matter in the context of neuromuscular scoliosis surgery[16,17]. In a study conducted by Menger et al.[18], involving 25 patients, they reported a clinical regression in activity level in one patient who underwent pelvic fixation. Among 8 patients with limited ambulation, 2 reported a subjective decrease in their walking ability. Drake et al.[4], in a retrospective analysis of 118 patients, including 11 non-ambulatory individuals, who underwent surgery for neuromuscular scoliosis, investigated the impact of pelvic fixation on ambulation. They reported no decrease in patient activity levels.

In the current study, it was observed that patients WPF generally had lower preoperative and postoperative CMFCS levels. However, it was not find any significant positive or negative changes in the preoperative and postoperative GMFCS scores in both groups (Table 4).

Study Limitations

The study had several limitations that should be acknowledged. Firstly, its retrospective design introduces inherent limitations in terms of data collection and potential biases. Secondly, important parameters such as the duration of surgery, blood loss, length of hospital stay, postoperative intensive care requirements, and rates of revision were not reported, which could have provided valuable insights into the surgical outcomes. However, despite these limitations, the study was able to present a comparison of radiological values between patients with and WoPF, as well as an assessment of activity levels.

CONCLUSION

The current study findings indicate that pelvic fixation does not offer significant advantages in terms of radiological outcomes and activity levels among patients undergoing surgery for neuromuscular scoliosis with pelvic obliquity. Consequently, it suggests that pelvic fixation may not be obligatory in the surgical management of patients with neuromuscular scoliosis and moderate pelvic obliquity. Considering the potential complications associated WPF, surgical intervention WoPF could be a viable alternative for patients with neuromuscular scoliosis who do not exhibit severe pelvic obliquity. However, further research is necessary to validate these findings and establish more comprehensive guidelines for selecting surgical approaches in this specific patient population.

Ethics

Ethics Committee Approval: The study obtained approval from the Ethics Commission of Gazi University (approval number: 05, approval date: 21.03.2023) prior to conducting the research.
Informed Consent: Retrospective study.
Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.Y., Ö.F.K., A.Ş., Concept: A.C.B., A.Y., M.A.T., S.Y., B.K.Y., A.Ş., Design: A.C.B., M.A.T., Ö.F.K., S.Y., A.Ş., Data Collection or Processing: A.C.B., S.Y., B.K.Y., Analysis or Interpretation: A.Y., M.A.T., Ö.F.K., S.Y., B.K.Y., A.Ş., Literature Search: A.C.B., A.Y., Ö.F.K., S.Y., B.K.Y., Writing: A.C.B., M.A.T., S.Y.
Conflict of Interest: The authors have no conflicts of interest to declare.
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SPLIT CORD MALFORMATION IN ADULTS: SYMPTOMS, SURGICAL TREATMENT AND RESULTS

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ABSTRACT

Objective: This is a rare report of patients with clinically silent split cord malformation (SCM) unrecognized until adulthood. The symptoms of patients with SCM rarely manifests in adulthood. When it does, it is characterized by an acute neurologic change. There are insufficient studies in the literature on the natural history of adult patients with SCM. In this article, we retrospectively present the long-term postoperative follow-up of adult patients with SCM.

Materials and Methods: Patients operated with the diagnosis of SCM between 2000 and 2021 were evaluated. It was analyzed retrospectively. Patients without at least 6 months of follow-up and patients with incomplete epicrisis and radiological images were not included in the study.

Results: Ten patients were included in the study. Patients were followed up for 6-72 months (mean 37.5 months). All patients were female. The most common symptoms were pain in the legs, back pain, lower extremity weakness, and bladder dysfunction. It was found that the symptoms started with excessive physical activation for the first time. All patients were successfully treated surgically. All those undergoing surgery experienced symptomatic relief even at the initial follow-up.

Conclusion: SCM may be asymptomatic in childhood and symptomatic in adulthood. Neurological deficits may be attributed to traction injury derived from an osseous septum due to excessive physical activation. An excellent outcome may be obtained from the resection of the septum and untethering of the filum.

Keywords: Adult diastematomyelia, diastematomyelia, diplomyelia, syringomiyelia, split cord malformation

INTRODUCTION

Split cord malformation (SCM) is an extremely rare form of congenital spinal dysraphism[1]. There is a bony or fibrous septum extending anteriorly to posteriorly leading to the formation of two split cords, each surrounded by a dural layer or a single dural sac. It is often accompanied by spina bifida. It is usually diagnosed in childhood. Patients often have skin lesions. Neurologic deficits and spinal deformities may be seen in the lower extremities, bladder and intestines. Very rarely, aseptomatic dystraphism may be diagnosed incidentally[2].

Symptoms usually appear in patients in young childhood. Therefore, very few patients remain undiagnosed until adulthood[3]. There is also a very small group of patients whose complaints appear in adulthood[3-8]. Generally, there may be a history of trauma that may cause the onset of complaints. Pain is the most common complaint and mostly involves the perianal region. Loss of strength in the legs and urologic problems are also common[6,7].

Since this disease is very rare, there are no large case series in the literature. There are small series of articles or case reports. It is therefore difficult to find scientific data on how best to treat patients or improve their quality of life. To further elucidate this rare condition, 10 cases of SCM in adults are presented, and clinical presentation, diagnostic evaluation, management and outcome are discussed.

MATERIALS AND METHODS

We performed surgical intervention on 10 adult patients with SCM between 2000 and 2021. We retrospectively analyzed the medical reports of these cases. This study was approved by Erciyes University Institutional Ethics Committee (decision no: 2022/682, date: 12.10.2022). Only patients older than 18 years with new symptoms and SCM were included in the study. All patients underwent preoperative computed tomography (CT) and magnetic resonance imaging (MRI) scans. Postoperative MRI scans were obtained in all patients. All patients underwent laminectomy or hemilaminectomy for septum removal and dura repair. After the dura was stripped

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from the bony spur, the spur was removed. The medial side of the dura of the hemichords was opened and cut. Connective formations such as fibrous band and dentate ligament were sectioned. Associated intraspinal pathologies such as dermoid and epidermoid cysts were also removed as appropriate. The filum was cut distally in all patients. A waterproof dura closure was performed (Figures 1-4). Resection of the septum was always performed before dissection of the filum to prevent ischemic damage from spinal cord retraction.

Data were analyzed in terms of demographic characteristics, admission characteristics, radiological findings and follow-up outcomes. Pain, motor deficit, sensory deficit and urinary symptoms were evaluated at follow-up.

Statistical Analysis

No statistics were made due to the low number of cases.

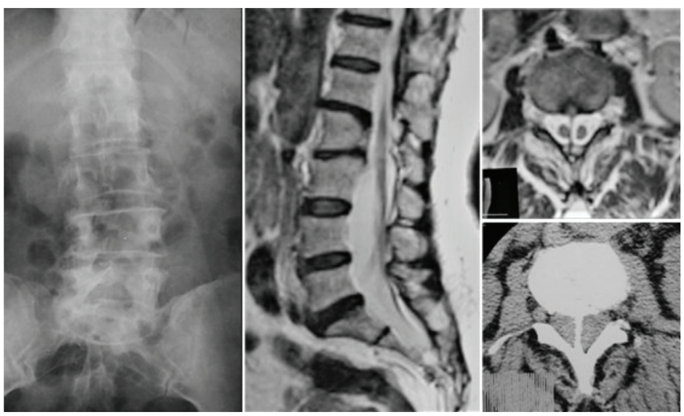

Figure 1. A 64-year-old female applied with complains of pain, numbness, weakness, neurogenic claudication and incontinence in legs after running. Plain X-ray revealed a bony spur at L2-L3 levels. CT showed a bony spur extending from the lamina of L2 through the midline of the spinal canal to the posterior margin of the L2-L3 disc space. MRI showed a bisection of the spinal cord and conus medullaris were tethered to L4 level

CT: Computed tomography, MRI: Magnetic resonance imaging

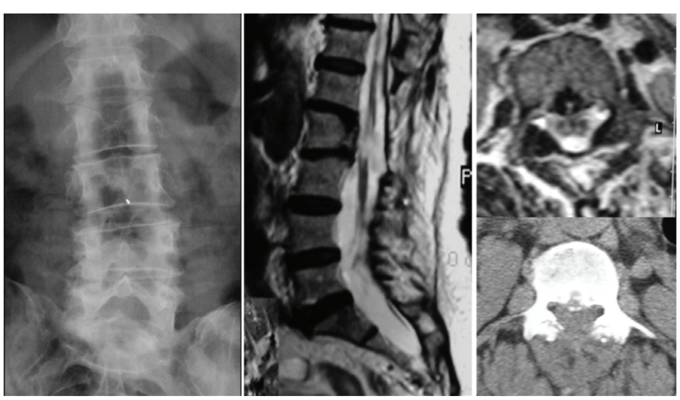

Figure 2. At 12 months follow-up, she returned to her job, she reported complete resolution of her back and legs symptoms but incontinence continues. MR and CT shows bone spur removal and no tethering of spinal cord

CT: Computed tomography, MRI: Magnetic resonance imaging

RESULTS

There were 10 female patients and no male patients. The mean age of the patients was 42.1 years (range 19 to 64, median value 43). The mean follow-up period was 37.5 months (range 6-72 months, median value 28). Pain was the predominant presenting feature in most cases. Eight patients presented with low back pain and all patients presented with leg pain. Sphincter dysfunction was present in 5 patients. Paraparesis was present in 2 patients and motor weakness in the lower extremities in 5 patients. Six of the patients had sudden onset of low back and radicular pain, neurogenic claudication and paraparesis after traumatic events such as sports activities or heavy lifting. SCM was associated with syringomyelia in 3 patients, dermoid cyst in 2 patients, neuroenteric cyst in 1 patient, congenital vertebral fusion in 2 patients and scoliosis in 3 patients.

In the postoperative period, 6 of 8 patients with low back pain and all 10 patients with leg pain were improved. All 4 patients with motor deficits were improved. However, sphincter deficits

Figure 3. A 29-year-old female applied with complains of low back pain, sometimes right leg pain for 6 months. It was increases when leaning forward. Bilateral foot thumbs were dorsal fleksion 3/5. CT showed a bony spur extending from the lamina of L1 through the midline of the spinal canal to the posterior margin of the L1-L2 disc space. MRI showed a bisection of the spinal cord and conus medullaris were tethered to L4-5 levels

CT: Computed tomography, MRI: Magnetic resonance imaging

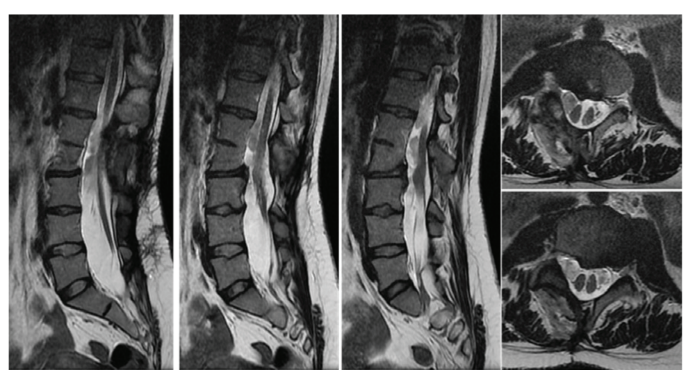

Figure 4. At 8 months follow-up, she had no symptoms. MR shows bone spur removal and no tethering of spinal cord

MR: Magnetic resonance

were improved in only 2 of 5 patients, and improvement could not be documented in the other 3 patients. One patient was continued to have frequent urination postop (Table 1). No postoperative complications were observed.

DISCUSSION

SCM is a rare form of spinal dysraphism characterized by a single cord cranially and caudally, a duplicated cord centrally, and two distinct dural sacs separated by a septum. It may be a bony, cartilaginous or fibrous septum.
Pang et al.[1] categorized SCMs into two different groups: Those in which one or two dural tubes are present, and those in which the medial septum is rigid or not rigid. In type I SCM, the separation of the osseo-cartilaginous septum results in two dural tubes. Type II SCM refers two hemichords separated with a non-rigid septum, both located within a single dural tube. Huang et al.[8] reported that 78.8% of patients had type I SCM and 21.2% had type II SCM. In our study, 90% of the patients were type I SCM. This is in contrast to the review by Karim Ahmed et al.[2] in which type I and II SCM represented 54.5% and 45.5% respectively.

Patient Demographics and Associated Conditions

In adults, SCMs are most commonly found in the lumbar spine (51.9%), followed by the lumbosacral spine (16.9%) and thoracic spine (13.2%)[3]. In our study, 90% of the patients were in the lumbar spine.
In a review of the literature consisting of 146 cases of adult SCM[3], it was reported that 25.3% of the patients were male with a mean age of 26.8 years at first presentation. The most common associated condition was tethered cord syndrome (59.8%), followed by hypertrichosis (44%) and epidermoid cyst (14.1%)[3]. In our study, all patients were female and the mean age at first presentation was 42.1 years. The most common associated conditions were tethered cord syndrome (42%) and syringomyelia (42%), scoliosis (28%), epidermoid cyst (14%) and neuroenteric cyst (14%).
Traditionally, SCMs were believed to be pediatric disorders defined by the onset of neurological deficits in early childhood. The presence of scoliosis, lumbar skin patches, progressive foot deformities, calf and foot atrophy, and bowel, bladder and gait disorders in the pediatric population draws attention to the possibility of SCMs. These are caused by traction on the conus with elongation of the spinal column in the presence of a taut cord[5-7,9-13]. Although this condition originates in embryogenesis, there is a poorly characterized subset of SCM patients who subsequently become symptomatic in adulthood[12]. Few cases have been documented in the adult population[1,5,7,8,10,12,14-22].
The etiology of diastematomyelia symptoms in adult patients is not clearly understood. Progression of neurologic dysfunction, back pain, spinal cord and cauda equina dysfunction may be seen in both childhood and adult patients. In addition to these symptoms, most of these patients have midline skin anomalies such as skin hair growth hemangiomas, lipomas and sinus tracts associated with spinal dystrophism[5,7,8,10,12].
Especially in the presence of anorectal anomaly (67%), meningocele manqué (54%) and diastematomyelia (38%), there is a high rate of syringomyelia with occult spinal dysraphism with a tethered spinal cord from a tight filum terminale[23]. Many theories have been presented to explain the origin of terminal syringomyelia. Terminal syringomyelia was found in 2 of our patients and cervicothoracic syringomyelia was found in one. The epicenter of terminal syringomyelia is almost always rostral and close to an occult spinal disraphic defect, so its pathogenesis is more likely to be related to the spinal disraphic lesion[23]. However, we did not find a relationship between cervicothoracic syringomyelia and lumbar diastematomyelia.

Clinical Features

The most common symptom in patients is low back and leg pain (68.5%), radicular pain and paresthesia (51.8%), and lower extremity weakness (50.9%)[3]. In our study, the most common symptoms were leg pain (100%) and low back pain (80%).
Neurologic symptoms are thought to result from the movement of the spinal cord within the spinal canal and subsequent local injury to neural elements due to traction by the dentate ligament[11], bony prominence[24] or tethered cord. In patients with SCM in adulthood, there is usually a trauma that forces flexion and extension of the spine before the onset of symptoms. During this trauma, the septum locally damages the spinal cord. Trauma has been documented to be a triggering factor in this disease[8,24]. Our cases also support this concept. In our study, the onset of SCM symptoms in 6 of 10 patients was associated with acute events such as aggressive sports and heavy lifting. There was no neurocutaneous stigma.

Imaging Features

X-ray evaluation is the first step in the radiologic evaluation of patients with SCM. With these images, pathologies that can be found in adult SCM patients such as scoliosis, spina bifida, tapering of the vertebral corpus, and partial anomalies in the vertebrae are seen. CT may be useful in identifying the midline osseous/osteocartilaginous septum and bony abnormalities (e.g. butterfly vertebra, hemivertebra, Klippel's Feil, spina bifida). CT scan is the preferred tool to elucidate the bony anatomy of the deformity. MRI is useful for identifying SCM and visualizing neural elements. MRI can also reveal tethered cord malformations associated with SCM, intramedullary lipoma, hydromyelia, Chiari malformations, and meningocele/myelomeningocele[1,14,22,24,25]. MRI is preferred to visualize the cord and conus region and to detect other intraspinal abnormalities associated with spinal dysraphism[4,8,10].

Treatment

Karim Ahmed et al.[2], reported that neurologic function in adult SCM remained unchanged in 90% and worsened in 10% in

Table 1. Summary of the patients

No	Age	Sex	SCM levels	Conus levels	Associated pathology	Initial symptoms	Inkontinans	NC	Skin sign	Low back pain	Leg pain	Paraparesis	Lower extr weakness	Symptom provacation	Follow-up
1	28	F	T11-12 (type II)	L2-3	Syringomyelia (C7-T1), scoliosis	SA					+/-		+/-	Walking	12
2	51	F	L2-3	L3-4	Syringomyelia (T12-L1)				+	+/-	+/-			Walking	72
3	55	F	L4	L5-S1	Dermoid cyst (L3-4)		+/+		+	+/+	+/-				14
4	29	F	L2-3	L4	Enteric cyst (L2), congenital vertebral fusion, scoliosis	HL				+/-	+/-	+/-	+/-	Bending	26
5	64	F	L2	L3	Syringomyelia (C7-T3), Klippel Feil syndrome, congenital vertebral fusion	SA	+/+	+		+/-	+/-	+/-	+/-	Bending	84
6	53	F	L1-2	L5			±/-			+/+	+/-			Bending	72
7	52	F	L4-5	S2		SA	+/±			+/-	+/-		+/-	Working	6
8	19	F	L2-3	L4	Scoliosis					+/-	+/-			Walking	30
9	35	F	L2	L5-S1	Dermoid cyst (L5-S1)	SA	+/±		+	+/-	+/-		+/-	Bending Working	33
10	35	F	L4	L5		HL					+/-				26

NC: Neurogenic cloudication, HL: Heavylifting, SA: Sport activities the conservative treatment group. In the surgical group, pain improved in 91.1%, remained unchanged in 7.1% and worsened in 1.8%. Russell et al.[7] also reported that surgical intervention resulted in symptomatic improvement in 95.8% of patients who underwent surgical treatment. Therefore, symptomatic adult SCM should be treated surgically. Postoperative complications occurred in 4.3% of all surgical cases and reoperation was required in 2.1% of cases[3].

Prophylactic spur removal and ligament release are recommended in children with SCM. For complete bone spur removal, wide dural opening and duraplasty are often necessary[4,8,12,26]. The role of surgery in adult patients is controversial. In symptomatic patients, the bony septa must be removed to prevent neurologic damage. Routine prophylactic removal is not recommended in asymptomatic patients[7,12]. As seen in our patients, there may also be a return of neurologic findings after surgical removal of the bone spur. Hazneci et al.[27] reported that surgical resection should be performed with neuromonitoring in patients with SCM associated with spinal teratoma and that the results were better in surgeries performed at an early age.

Akay et al.[13], reported that tethering structures requiring surgical intervention are more common in type I SCM. There is an influential view that these malformations are caused by fibrous septa or bony protrusions that interfere with the attachment of both hemicords. Therefore, these attachment defects are thought to be associated with neurologic symptoms. In such cases, surgery aims to remove the septum that prevents the hemichords from connecting to each other and to free the hemichords. In addition, if the patient has a thickened filum terminale or inferior location of the conus, a filum sectioning and releasing is required. The location of the conus should be determined preoperatively[26]. In our cases, connective formations such as fibrous bands, dentate ligaments were excised, and the filum terminale was sectioned and released. In addition, associated intraspinal pathology such as dermoid and epidermoid cysts.

In our study, all symptomatic adult SCM cases were operated. Those operated on underwent hemilaminectomy or laminectomy, septum resection and dural repair and dissolution of the filum. Resection of the septum was always performed before dissolution of the filum, thus preventing ischemic damage from cord retraction against the bony septum by a suddenly dissolving cord. In our study, operative treatment resulted in recovery in all 4 patients (100%) with preoperative neurologic deficit.

Study Limitations

The fact that the number of cases in this study was 10 is a limiting factor, but it should be kept in mind that a very rare disease was analysed. Another limiting factor is that the study was performed retrospectively. The follow-up period of the patients may be longer.

CONCLUSION

SCM is an extremely rare spinal dystrophism characterized by caudal separation of a spinal cord into two or more cores. The disease is diagnosed by skin lesions or neurologic deficits in early childhood and was considered a childhood disease. There is a poorly characterized subset of SCM patients who subsequently become symptomatic in adulthood. When these patients are operated on, successful outcomes are achieved for pain and strength loss, while urinary incontinence does not appear to benefit satisfactorily. It can be said that long-term follow-up after surgery in these patients is also meaningful in terms of revealing the results.

Ethics

Ethics Committee Approval: This study was approved by Erciyes University Institutional Ethics Committee (decision no: 2022/682, date: 12.10.2022).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.M., Concept: H.U., A.Ş., R.K.K., Design: A.K., H.U., Ş.O., R.K.K., Data Collection or Processing: M.M., R.K.K., Analysis or Interpretation: A.K., H.U., Ş.O., Literature Search: M.M., A.K., A.Ş., Writing: M.M., Ş.O., R.K.K.

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NORMATIVE VALUES FOR CERVICAL AND LUMBAR RANGE OF MOTION IN HEALTHY YOUNG ADULTS

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ABSTRACT

Objective: The cervical and lumbar spines are the more mobile parts of the spinal column than the thoracic spine. Reference range of motion (ROM) measurements is one of the important clinical outcome measures used in patient assessment and follow-up of treatment efficacy. The aim of this study was to obtain normative values of cervical and lumbar ROM in young adults.

Materials and Methods: The sample comprised 300 healthy volunteers (198 female, 102 male, mean age: 21.4±1.9 years, range, 18-29 years). Cervical (C) and lumbar (L) ROM values were measured in three planes with a two-arm digital goniometer according to the American Academy of Orthopaedic Surgeons (AAOS) criteria. The mean ROM measurements were analyzed according to gender using the Mann-Whitney U test.

Results: Cervical ROM values were determined to be: cervical flexion 57.7±8.2°, extension 59.1±10.2°, right-left lateral flexion 42.1±7.9°-41.4±7.7°, and right-left rotation 71.1±10.5°-70.2±9.7°. There was no statistically significant difference between the genders with respect to the cervical ROM ($p>0.05$). The lumbar ROM values were determined to be lumbar flexion 69.9±14.5°, extension 40±10.2°, right-left lateral flexion 36.3±6.4°-36.2±6.6°, and right-left rotation 38.4±8.7°-38.6±9.4°. The lumbar flexion ROM values were statistically significantly higher in females than in males ($p=0.043$).

Conclusion: The flexion and extension angles of the lumbar spine in the sagittal plane were higher in females than in males, and there was no difference between the genders regarding all the other cervical and lumbar joint ROM values. These goniometrically measured cervical and lumbar ROM values were found to be generally similar to the widely used reference values of AAOS and Kendall McCreary. Further research is needed on the effects of individual differences such as physical activity or inactivity.

Keywords: Range of motion, cervical, lumbar, goniometer, spine

INTRODUCTION

The entire set of vertebrae which constitutes the spinal column typically comprises 33 bony vertebral segments, divided into five regions. These are seven cervical segments, twelve thoracic, five lumbar, five sacral, and four coccygeal segments[1,2]. The widest ranges of motion are in the cervical and lumbar segments, which can move in three planes.

The movements that occur in the spine are flexion and extension in the sagittal plane, axial rotation in the horizontal plane and lateral flexion in the frontal plane. Axial rotation occurs by sliding and rotation, while other movements occur by sliding in the intervertebral joints. The degree of movement of the spinal column varies in the cervical, thoracic, and lumbar regions because of the anatomic differences of the vertebrae at different levels. The thoracic region has less range of motion (ROM) than the other regions due to the rib cage, which is connected to the costae and sternum[1-3]. The greatest flexion and extension movements of the cervical spine occur between C5-C6, axial rotation movements occur between C1-C2 and lateral flexion movements occur between C4-C5[1,3,4].

In the lumbar spine, the greatest flexion and extension occur between L4-L5, the greatest lateral flexion between L2-L3, and the greatest axial rotation occurs between the L5-S1 vertebrae[5,6]. It is important for the spine to have normal ROM values in order to maintain daily life activities without limitations. At the same time, it is very important for a stable spine that the movement remains within normal limits. The movement provided by the active functioning of the muscles in the spine is limited by the facets, capsule, disc, anterior and posterior ligaments and stability is maintained[1,2].

Normal ROM measurements are one of the important clinical outcome measures used in patient assessment and follow-up of treatment efficacy and illness progression. However, there is great variation in the normal ROM values in the literature, which can be attributed to differences in study design, gender, age, cultural characteristics, physical activity and sports activities[1,7,8].

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The use of active or passive ROM measurements, correct stabilization and positioning of the participant during the measurement and the methods used for measurement may also lead to different results. Goniometers (universal, digital, electrical and fibreoptic) are the most commonly used devices for the ROM measurements. More sophisticated methods such as flexible ruler, inclinometer, Schober test, X-ray radiography, videofluoroscopy, ultrasonography or computerized analyses can also be used to determine ROM[7-10].

Currently, the American Academy of Orthopaedic Surgeons (AAOS) or Kendall values are used as reference for normal ROM values. To the best of our knowledge, no studies have been conducted to determine normative spinal ROM values in Turkey[9-12].

Due to the complex structure of the columna vertebralis and the occurrence of multiple movements at the same time (spinal coupling) and the limited movement in the thoracic region, normal ROM measurements of the spine are generally performed in the cervical and lumbar regions. Therefore, the aim of this study was to determine the normative values for range of movement of the cervical and lumbar regions of the spine in a Turkish population.

MATERIALS AND METHODS

This descriptive, cross-sectional study was performed according to the STROBE criteria. All the study procedures were in compliance with the Declaration of Helsinki and the study protocol was approved by the Bandırma Onyedi Eylül University Health Sciences Non-Interventional Research Ethics Committee (decision no: 2023-64, date: 13.04.2023). All participants were informed about the study and signed informed consent forms.

The study inclusion criteria were defined as age 18-30 years, good general health, and voluntary participation. Patients were excluded from the study if they had any orthopedic, neurological or rheumatic disease, any congenital deformity, had a history of spinal surgery, had experienced trauma or undergone surgery in the last 6 months, were suspected or definitely pregnant, or were using any neurological or psychiatric medication. The study included 300 healthy voluntary participants (198 female, 102 male) who were studying at Marmara University, Faculty of Health Sciences between April and May 2023. The ROM measurements were performed by a highly experienced physical therapist in a screened-off section of the physiotherapy practice laboratory.

Demographic information was recorded according to the statements of the participants. Height was measured using a wall-mounted Mesilife, Q100 height meter, and body weight using scales sensitive to 0.1 kg. The active ROM in all planes was evaluated using the measurement methods defined by the AAOS[10,11]. A two-arm digital goniometer (Baseline® Digital Absolute + Axis®) with a 360 degree dial was used to measure the ROM of the spine. The axis of rotation (Pivot) connecting the movable arms of the goniometer was placed on the axis of motion determined for the cervical and lumbar spine[8,10,13]. When the measurements were being taken, the participants were correctly and comfortably positioned and care was taken not to change the desired movement. For each of the movements, oral and visual explanations were given before the measurement. All the joints were positioned according to the anatomic position, which was then considered as the starting point of 0 degrees. All the joint movements that were within the 180° ROM from the starting position of 0 degrees were evaluated[9,10]. When taking the measurements, care was taken to ensure that the goniometer was not in contact with the body parts in order not to interfere with the movement. Each measurement was repeated three times and repetitions with no more than 5% difference between them were recorded as ROM.

Range of Motion Measurements

All the cervical spinal ROM measurements were taken with the subject seated upright on a stable stool. For the measurement of cervical flexion and extension ROM, the subject was seated sideways to the physiotherapist. The pivot point was placed on the lateral projection of the acromion, the fixed arm of the goniometer was kept parallel to the ground, and the moving arm of the goniometer followed the midline of the tragus during movement[10-14].

During the cervical lateral flexion ROM measurement, the physiotherapist sat behind the subject. The pivot of the goniometer was placed on the 7th cervical vertebral spinous process (C7), the fixed arm was kept parallel to the ground, and the moving arm followed the spinal protrusions of cervical spine. If the cervical spinous processes were not visible, the moving arm of the goniometer followed the midline of the cervical spine during the movement. Care was taken not to rotate the head while taking the measurement[10-14].

The physiotherapist stood behind the seated subject during the cervical rotation ROM measurements. The pivot of the goniometer was placed on the superior midpoint of the head, the fixed arm of the goniometer was placed parallel to the opposite shoulder to be rotated, and the moving arm was placed to follow the tip of the nose[10-14].

During the flexion and extension measurements of the lumbar spine, the researcher stood lateral to the participant. The pivot of the goniometer was placed on the hip at the lateral projection of the lumbosacral joint. The fixed arm was held perpendicular to the ground and the moving arm followed the lateral projection of the trunk towards the axilla. Care was taken to ensure that there was no movement from the hip joint during the measurement.

During the lateral flexion measurement, the physiotherapist stood behind the subject. The pivot point of the goniometer was placed at the midpoint of the lumbosacral joint, the fixed arm of the goniometer was kept parallel to the spina iliaca posterior superior and parallel to the ground, and the moving arm followed the spinal processes of the lumbar vertebrae towards C7. Care was taken to avoid rotation, flexion and extension of the trunk while taking the measurements.

During the lumbar rotation ROM measurement, the physiotherapist stood behind the subject seated on the stool. The pivot point was placed in the centre of the head, the fixed arm of the goniometer was kept parallel to the ground and the moving arm of the goniometer was followed parallel to the acromion opposite to the direction of rotation. In the right and left rotation measurements, care was taken to ensure that the subject did not rotate the cranium.

Statistical Analysis

The data obtained in the study were analyzed statistically using IBM SPSS Statistics vn. 23 software (Statistical Package for Social Sciences). Numerical data were expressed as mean and standard deviation values, and numerical data as frequency and percentages. Conformity of the data to normal distribution was evaluated with the Kolmogorov-Smirnov test. The mean ROM measurements were analyzed according to gender using the Mann-Whitney U test. The minimum number of samples to be included in the study at the 5% margin of error and 90% confidence level is 273 participants.

RESULTS

Evaluation was made of 300 healthy volunteers with a mean age of 21.4±1.9 years (range: 18-29 years), comprising 198 females with a mean age of 21.2±1.8 years and 102 males with a mean age of 21.7±2.2 years.

For the whole study sample, the mean height was 168.7±9 cm and the mean weight was 62.9±12.9 kg, recorded as 163±5.8 cm and 56.4±8.2 kg for females, and 178±6.2 cm and 75.5±10.7 kg for males. The mean body mass index (BMI) was 20.9±2.7 (16.1-31.2) for females and 23.8±3.2 (17.2-35.9) for males (Table 1). Right-side dominance was determined in 296 subjects, and left-side dominance in 4. The cervical and lumbar ROM measurements of the participants are presented in Table 2. The cervical ROM values of female and male participants are presented in Figure 1 and the lumbar ROM values are presented in Figure 2. The lumbar flexion ROM values were determined to be statistically significantly higher in females than in males ($p=0.043$). No significant difference was determined between the genders in respect of the other lumbar ROM measurements. There was no statistically significant difference between the genders in respecct of the cervical ROM values ($p>0.05$).

Table 1. Demographic variables

Gender	Female (n=198)	Male (n=102)
Age	21.2±1.8	21.7±2.2
Height (cm)	163±5.8	178±6.2
Weight (kg)	56.4±8.2	75.5±10.7
BMI (kg/m^2)	20.9±2.7	23.8±3.2

BMI: Body mass index

Table 2. Mean cervical and lumbar range of motion values

Range of motion (°)		Mean ± SD Median (min-max)
Cervical	Flexion	57.7±8.2 58 (34-78)
	Extension	59.1±10.2 60 (25-82)
	Right lateral flexion	42.1±7.9 42 (20-78)
	Left lateral flexion	41.4±7.7 41 (19-73)
	Right rotation	71.1±10.5 72 (43-95)
	Left rotation	70.2±9.7 70.5 (42-90)
Lumbar	Flexion	69.9±14.5 70.5 (38-120)
	Extension	40±10.2 40 (15-71)
	Right lateral flexion	36.3±6.4 36 (17-60)
	Left lateral flexion	36.2±6.6 36 (16-58)
	Right rotation	38.4±8.7 40 (12-60)
	Left rotation	38.6±9.4 39 (10-69)

SD: Standard deviation, Min-max: Minimum-maximum

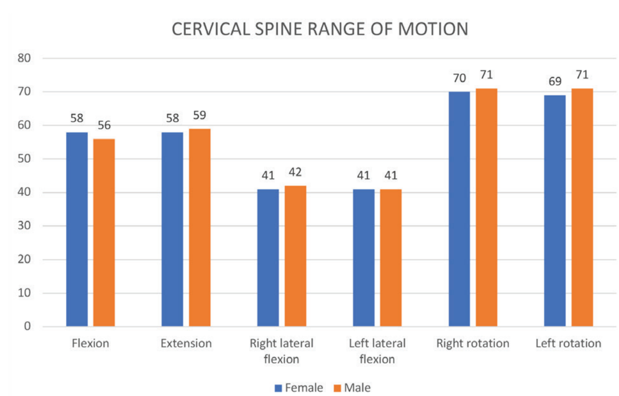

Figure 1. Cervical range of motion values for males and females

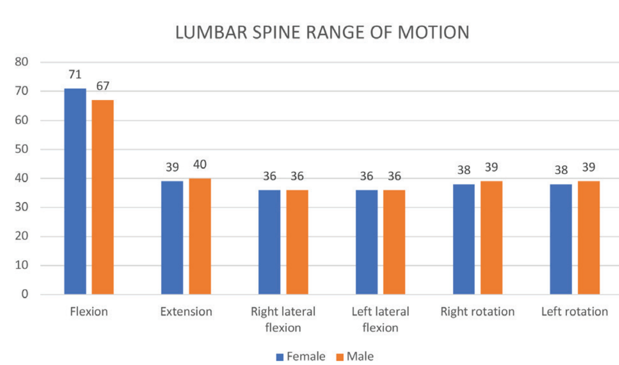

Figure 2. Lumbar range of motion values for males and females

DISCUSSION

The aim of this study was to investigate the normative cervical and lumbar spinal ROM values in the sagittal, frontal and transverse planes, using a digital goniometer on 300 healthy individuals. The results showed that the cervical and lumbar ROM values obtained appeared to be similar to the widely accepted normative references of the AAOS and Kendall et al.[9].

Assessment of cervical and lumbar ROM is an essential diagnostic tool used by healthcare providers to evaluate the mobility and function of the neck and lower back. It involves measuring the degree of movement in different directions, including flexion, extension, lateral flexion, and rotation. Accurate assessment of the cervical and lumbar ROM is important to be able to detect musculoskeletal abnormalities, such as stiffness, pain, and mobility reduction. It is also a method that is used to help determine the effects on spinal mobility of spinal diseases such as wiplash injuries, disc herniation, degenerative joint diseases, spinal stenosis and spondylolisthesis. Moreover, the assessment of ROM is critical in developing an appropriate treatment plan, monitoring the progression of therapy, and determining the effectiveness of interventions. Therefore, precise and consistent measurement of cervical and lumbar ROM is vital for effective patient care and optimal treatment outcomes[7,15-20]. To evaluate the ROM of the cervical and lumbar region, a total of 12 measurements were performed with a digital goniometer, including flexion, extension, lateral flexion to the right and left, and axial rotation to the right and left sides.

Normal cervical flexion-extension ROM values are stated as 45-45 degrees according to the AAOS and 65-50 degrees according to Kendall et al.[9,10]. In this study, the mean cervical flexion-extension ROM was found to be 57-59 degrees (range, 34-78). Thus the cervical extension values obtained in this study were higher than those of both reference sources. In a study in Pakistan of 19 healthy subjects with an average age of 21 years, Farooq et al.[21] determined the mean cervical flexion value to be 46 degrees and cervical extension 47 degrees.

The normative value for cervical lateral flexion is 45 degrees according to the AAOS and 40 degrees according to Kendall et al.[9,10]. In the present study, the right and left lateral flexion values of 42 and 41 degrees were found to be similar to the reference values. Farooq et al.[21] reported mean lateral flexion ROM values of 33 degrees for the right side and 34 degrees for the left side.

Normative cervical rotation values are stated as 60 degrees according to the AAOS and 55 degrees according to Kendall et al.[9,10]. In the present study, the right and left side rotation ROM values were found to be 71 and 70 degrees respectively, slightly higher than the reference values. The mean cervical rotation values were found to be 65 and 66 in the study by Farooq et al.[21]. Wilson-Smith et al.[22] stated cervical lateral flexion to be in the range of 26 to 35 degrees. The mean lumbar flexion ROM value is stated as 80 degrees according to the AAOS and 90 degrees according to Kendall et al.[9,10]. In the present study, this value was found to be 70 degrees (range, 38-120 degrees). In a study by Moromizato et al.[23] in Japan of 78 healthy subjects with a similar average age to the subjects in the present study, the trunk flexion angle was found to be 35 degrees. Chertman et al.[24] evaluated lumbar ROM with a goniometer in 100 athletes and non-athletes aged between 14 and 45 years. Mean lumbar flexion was reported to be 116 degrees and the mean flexion value was seen to be higher in athletes.

The mean values for lumbar extension ROM are stated as 25 degrees according to the AAOS and 35 degrees according to Kendall et al.[9,10]. The results of the present study showed a value of 40 degrees (range, 15-71°). In a study by Moromizato et al. [23], the mean trunk extension was 28 degrees. Chertman et al.[24] reported mean lumbar extension ROM of 37.6 degrees and stated that there was no difference in trunk extension values between athletes and non-athletes. The mean values of lumbar right and left lateral flexion ROM are stated as 35 degrees according to the AAOS and 40 degrees according to Kendall et al.[9,10]. In the present study results, it was found to be 36 degrees, similar to the reference values. In the study by Moromizato et al.[23], the mean trunk extension was specified as 23 degrees.

Axial rotation normal ROM values for the lumbar region are stated as 45 degrees by the AAOS and 35 degrees by Kendall et al.[9,10]. The current study value was found to be 38 degrees, similar to these reference values. In the study by Moromizato et al.[23], this value was determined to be 48 degrees.

The lumbar flexion ROM values of the current study female subjects were statistically higher than those of males. Moromizato et al.[23] also stated that trunk flexion and trunk rotation ROM values were higher in females in a series of 42 male and 36 female participants. Most studies in the literature are related to ROM of the extremities, and there are very few studies that have investigated spine movements. The strong aspects of the current study can be considered to be the fact that more participants were included in this study than in other studies evaluating trunk ROM and that the measurements were repeated three times and the average value was recorded for analysis.

Study Limitations

There were some limitations to this study, primarily the lack of evaluation of different age groups. There was also no evaluation of the flexibility and sporting activities of the participants. Future studies should be conducted with a larger sample and comparisons made according to different ages, BMI values, flexibility, sitting time and physical activity levels. As there was no radiological evaluation of the spine in this study, it was not known whether there were any possible spinal deformities that may have limited the ROM of the joint. Generalised joint hypermobility or connective tissue diseases are also factors limiting joint ROM, and these were not included in the study exclusion criteria.

CONCLUSION

From the results of this study it was seen that the flexion and extension angles of the lumbar spine in the sagittal plane were higher in females than in males, and there was no other difference determined between the genders in respect of the other cervical and lumbar joint ROM values. Cervical and lumbar spine ROM values may vary in healthy individuals depending on various factors such as physical activity level, lifestyle habits, occupational and sporting activities, and ligamentous laxity levels. Further research is needed to examine the effects of personal differences on joint ROM.

Ethics

Ethics Committee Approval: This prospective cross-sectional study was approved by Bandırma Onyedi Eylül University Health Sciences Non-Interventional Research Ethics Review Board with approval number: 2023-64, approval date: 13/04/2023.

Informed consent: Written informed consent was obtained from all participants.

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Authorship Contributions

Surgical and Medical Practices: A.A., T.K.Ç., B.A., Concept: A.A., T.K.Ç., B.A., Design: A.A., T.K.Ç., B.A., Data Collection or Processing: T.K.Ç., Analysis or Interpretation: A.A., T.K.Ç., B.A., Literature Search: A.A., T.K.Ç., B.A., Writing: A.A., T.K.Ç., B.A.

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PERIOPERATIVE MANAGEMENT IN SCOLIOSIS SURGERY: SPINAL MUSCULAR ATROPHY TYPE II/III VERSUS ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: Patients with spinal muscular atrophy (SMA) often require spinal surgery to slow pulmonary decline due to scoliosis restricting the pulmonary capacity. This study evaluated perioperative anesthetic management for scoliosis surgery in SMA patients and to compare it with adolescent idiopathic scoliosis (AIS).

Materials and Methods: After obtaining hospitals ethic committee approval, retrospective data between 2014 and 2023 were collected. The primary outcome measure was perioperative variables. The secondary outcome was to determine predictive factors for postoperative intensive care unit (ICU) admission.

Results: One hundred twenty five (66 female/59 male) ASA I-III patients (13.1±4.2 years) were included in the study. Of them, 49 had SMA (20 type II and 29 type III) and 76 had AIS. Forty-four SMA patients had mild to moderate restrictive lung disease and one patient was mechanical ventilation dependent. Mean age and body mass index (BMI) were lower and Cobb's angle was higher in SMA patients than in AIS patients ($p<0.05$). Instrumentation level (number of vertebrae fused) and the number of osteotomized vertebrae was higher in SMA patients ($p<0.05$). Mean duration of the surgery, estimated blood loss (EBL), EBL/total blood volume (TBV) ratio, and blood transfusion rate were higher in SMA patients ($p<0.05$). The ICU admission rate was higher in the SMA group (24.5%) compared to the AIS groups (24.5% >1.3%; $p<0.05$). Among SMA patients, five required postoperative mechanical ventilation. Hospital discharge time and complication rate was also higher in SMA patients ($p<0.05$). Receiver operation characteristics analysis revealed that preoperative poor respiratory function, prolonged surgery (>6 hours), multiple vertebral fusion (>6 levels), EBL/TBV >33%, massive transfusion, and low BMI were predictive for ICU admission.

Conclusion: SMA patients are at higher risk for major blood loss, massive transfusion, and ICU admission due to higher instrumentation level, longer operation time, and lower BMI. Preoperative risk analysis and preventive measures should be considered to enhance the success of the procedure in SMA patients due to respiratory compromise combined with complicated surgical procedures.

Keywords: Scoliosis, anesthesia, spinal muscular atrophy of childhood

INTRODUCTION

Spinal muscular atrophy (SMA) is a rare neuromuscular disorder with an incidence of 1 in 11,000 live births which is caused by homozygous deletion or mutation of the *survival motor neuron 1* gene. It is manifested by progressive muscle atrophy and muscle weakness due to denervation in the neuromuscular junction. Signs and symptoms can include floppiness in infancy, musculature weakness, weak cough, poor feeding, thrive failure, and respiratory distress depending on the severity of clinical manifestations[1]. In severe cases, feeding may be accomplished by a gastrostomy because of bulbar involvement and moreover, the patients may require noninvasive forms of supportive ventilation; ranging from non-invasive mask ventilation (continuous positive airway pressure or bilevel positive airway pressure) to mechanical ventilation dependence.

SMA is classified from type 0 to IV according to the onset age. The most common form, SMA type I accounts approximately 60% of all cases. The symptoms begin during the first 6 months after the birth and those patients cannot survive two years due to respiratory insufficiency. The patients with type II represent 20-30% of all cases and can sit independent but are not able to walk. They can survive 25 years with aggressive supportive treatments. Type III and IV SMA patients can walk independently and have a normal life expectancy[2]. SMA patients often require surgical interventions due to extremity contractures and kyphoscoliosis that limit pulmonary capacity resulting in restrictive pulmonary disease. SMA patients represent one of the most challenging surgical populations regarding anesthetic management. The problems mostly arise from the patient's poor condition combined with the difficulty of the surgical intervention[3]. Therefore, SMA patients often require intensive care at the postoperative period.

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Adolescent idiopathic scoliosis (AIS) is diagnosed in late childhood and adolescence. The patients have generally a normal health status and mild to moderate scoliosis does not cause movement or respiratory problems. Surgical treatment is recommended for patients whose curves are greater than 45° during growing, or are continuing to progress greater than 45° when growth stopped.

The aim of this study was to evaluate our anesthetic experience in pediatric scoliosis surgery, with particular focus on the SMA type II and III patients and to compare the results with healthy patients who underwent scoliosis surgery due to AIS. The primary outcome measure was perioperative variables. Secondary outcome measure was to identify the predictive factors for intensive care unit (ICU) admission in the postoperative period.

MATERIALS AND METHODS

After obtaining the Private Çankaya Hospital, Ethic Committee approval (decision no: 2023-02-01, date: 02.01.2023), a single center retrospective chart review was performed to include all children with SMA type II, type III, and AIS undergoing thoracolumbar spinal surgery including posterior spinal fusion or from 2014 to 2023. Data were retrospectively collected from the hospital's computerized database and medical files of patients. The medical records were reviewed to assess pre-operative, intraoperative and postoperative variables. The study has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) and followed the strengthening the reporting of observational studies in epidemiology guidelines[4]. Obtaining informed consent from patients was waived due to the retrospective nature of the study. A total of 136 patients (55 SMA, 81 AIS) who underwent spinal surgery at our institution were identified. Patients whose surgery was not primary and elective thoracolumbar spinal surgery and with missing data were excluded from the study.

Anesthetic Technique

The routine anesthetic protocol for scoliosis surgery in our clinic was as follows: All patients were evaluated at the preoperative period (one week before the surgery) and invited to the hospital on the day of the surgery. Preoperative respiratory functions were evaluated by physical examination, radiological imaging (chest X-ray), respiratory function test, and pulmonology consultation. An otorhinolaryngology consultation was received for an anticipated difficult airway management.

At the day of the surgery, isotonic crystalloid that contains sodium with added glucose (e.g., 0.9% sodium chloride + 5% glucose) was intravenously (IV) given in the ward for pre-hydration during the fasting period, which lasted six hours for light meals and two hours for clear fluids. IV 1-2 mg midazolam was administered as premedication before the transfer to the operating room (OR). Time-out procedures were performed in the OR to ensure patient safety. The patients were monitored with non-invasive blood pressure (NIBP), pulse oximetry, and electrocardiogram (EKG). Anesthesia was induced using propofol (2.5 mg/kg) and fentanyl (1-2 µg/kg). After three minutes of mask-bag ventilation using 100% oxygen, endotracheal intubation was made under direct laryngoscopy using a cuffed and armored endotracheal tube. Ventilatory settings were adjusted to achieve normocapnia. Anesthesia was maintained using a propofol and remifentanil based total intravenous anesthesia (TIVA). The patients were monitorized with somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) by a neuro-monitorization technician. Therefore, neuromuscular blocking agents were not used in the maintenance phase as well as in the induction phase. A central venous catheter, an invasive arterial catheter, and a bladder catheter were inserted for hemodynamic monitorization, urine output measurement, and sampling. The rate of TIVA infusion was adjusted to ensure an anesthetic depth that does not interfere with SSEP and MEP. After anesthetic preparation, the patients were positioned prone on the operating table and made sure the pressure points of the body were supported. The body temperature was monitorized and the patients were warmed up using a forced-air warming system.

A hypotensive agent (nitroglycerine) infusion was IV administered to achieve a controlled hypotensive anesthesia in the intraoperative period which is defined as a reduction of mean arterial blood pressure (MAP) to a range of 60-70 mmHg or 30% reduction of baseline MAP[5]. It was combined with IV administration of tranexamic acid (10 mg/kg bolus followed by an infusion of 2 mg/kg h) to reduce blood loss in appropriate patients.

The amount of blood loss was assessed by collecting the gauzes saturated with blood and measuring the blood amount in the suction container. Total blood volume (TBV) was calculated using the following formula: TBV = body weight (kg) x 65-70 mL/kg. A packed red blood cell (PRBC) was transfused when estimated blood loss (EBL) was higher than 30% of TBV or hemoglobin level was reduced to <8 g/dL. When PRBC transfusion exceeded two units, fresh frozen plasma (FFP) was given in 1:1 ratio of FFP to PRBC. At the end of the surgery, an epidural catheter was inserted by the spine surgeon under direct vision, if applicable. An infusion was started via an epidural patient-controlled anesthesia (PCA) device containing a mixture of 20 mL of 0.5% bupivacaine (100 mg), 5 mL of 0.05% fentanyl (250 mcg) and 75 mL saline. The PCA protocol was as follows: infusion dose: 3-5 mL/h, bolus dose: 3-5 mL, lock-out time: 30 min and 4-hours limit: 40-60 mL. If an epidural catheter was not inserted, a tramadol intravenous PCA (infusion dose: 3-5 mg/h, bolus dose: 3-5 mg, lock-out time: 30 min, and 4-hours limit: 20-40 mg) was used for postoperative analgesia. Additionally, a local anesthetic wound infiltration using a mixture containing 1 mg/kg bupivacaine and 3 mg/kg lidocaine was made by the surgeon before the wound closure. IV paracetamol (10-15 mg/kg) was given for postoperative pain relief.

After the surgery, TIVA infusion was terminated. Extubation criteria were a) hemodynamic parameters: MAP >60 mmHg, heart rate: 80-120 beats min^{-1}, sinus rhythm, lactate <1 mmol/L b) respiratory parameters: SpO_2 >95, pO_2 >80 mmHg, pCO_2<40 mmHg, tidal volume ≥8 mL/kg, respiratory rate: 14-20 min^{-1}. In addition, the patients with a modified Aldrete score ≥9 who were cooperative, normothermic, did not receive massive blood transfusion, EBL was lower than 40% of TBV, and urine output >2 mL/kg h were discharged to the service after approximately 1 hour follow-up in the post-anesthesia care unit. The patients were monitorized in the ward with EKG, NIBP and pulse oximetry. The patients who did not meet the aforementioned criteria were transferred to the ICU. The follow-up observation in the ward was provided by the service nurses. The treatment orders were made by anesthesiologist and orthopedic surgeon. Pain intensity was evaluated using visual analogue scale (VAS) and a multimodal analgesic (MMA) regimen was used for postoperative pain relief. MMA included IV paracetamol 10-15 mg/kg with 6 hours intervals, ibuprofen pO 10 mg/kg with 8 hours intervals, and PCA (IV or epidural). IV tramadol (1 mg/kg) was given to appropriate patients as rescue analgesic. The patients were discharged from the hospital when hemodynamic parameters were stable, basic laboratory findings are within normal limits, VAS scores are lower than 3, and basic physiotherapy exercises were completed.

Data Collection

All medical data were reviewed in detail to obtain demographic characteristics including age, gender, body weight (kg), length (cm), body mass index (BMI), American Society of Anesthesiologists (ASA) score, and co-morbidities; intra-operative variables including the anesthetic preparation time (min), the operative time (min), numbers of vertebra fused (n), osteotomy (yes/no), EBL (mL), blood transfusion (unit), c) postoperative course: ICU admission (yes/no), ICU discharge time (hours), postoperative blood transfusion (unit), length of hospital stay (day), and in-hospital complications (n).

Statistical Analysis

The data were analyzed using the Statistical Packages for Social Sciences for Windows version 11.5 pocket program (IBM Corp., Chicago, IL, USA). For intergroup comparisons, the chi-square test and Fisher's exact test were used to analyze nominal data and the t-test for independent samples was used for quantitative data. Data were expressed as means ± standard deviation for continuous variables and numbers, and percentages for categorical variables. Univariate cox regression analyses were performed, including variables which were significantly differed in subgroup (patients who were admitted in the ICU or not) comparisons or variables that may be clinically relevant to overall ICU admission. A p value <0.05 was considered statistically significant.

RESULTS

A total of 136 patients were included into study. Eleven patients were excluded due to missing data (Figure 1). Of the remaining 125 patients, 66 patients were female (52.8%) and 59 were male (47.2%). Mean age was 13.1±4.2 (7-17) years. 49 (39.2 %) patients had SMA and 76 (60.8%) had AIS. Of 49 SMA patients, 20 (40.8%) patients were type II and 29 (59.2%) were type III SMA and 32 (65.3%) patients had mild (ASA II), 12 (24.5%) patients had moderate restrictive disease (ASA III), and one patient was mechanical ventilation dependent (ASA III). Among patients with AIS, 4 (5.2%) patients had asthma, 2 (2.6%) patients had diabetes mellitus, and 1 (1.3%) patient had mitral valve prolapsus without requiring therapy. When demographic data were compared, it was found that the mean age, height, weight, and BMI were lower in the SMA patients compared to patients with AIS (p<0.05). Also, the ratio of healthy patients (without co-morbidity) was higher in the AIS patients than the SMA patients (p<0.05). Preoperative Cobb's angle was greater in the SMA patients (p<0.05). Demographic data were listed in Table 1. Endotracheal intubation was performed using fiberoptic bronchoscope in two patients of SMA patients after failure with direct laryngoscopy.

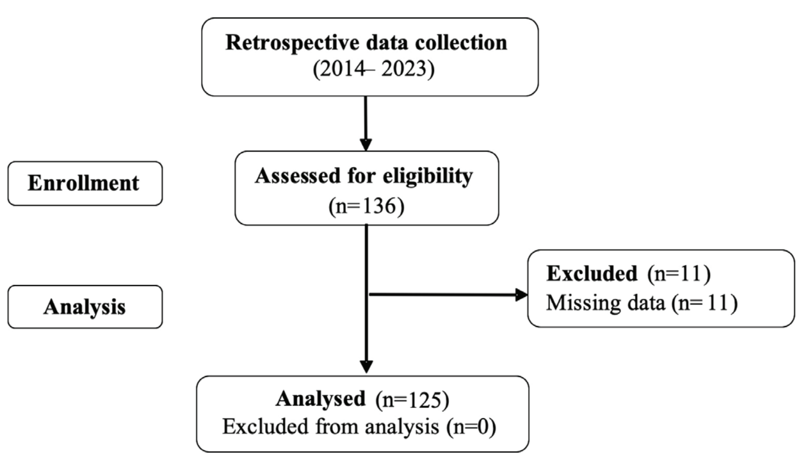

Figure 1. Study flow chart

Comparison of perioperative variables were listed in the Table 2. Instrumentation level (number of vertebrae fused), osteotomy ratio, and number of osteotomized vertebrae was higher in the SMA patients than the AIS patients ($p<0.05$). The mean duration of the surgery was longer, EBL, EBL/TBV ratio were higher also higher in the SMA patients. More patients required PRBC transfusion both in the intra- and postoperative period in the SMA patients compared to the AIS patients ($p<0.05$). The amount of PRBC transfusion was also higher ($p<0.05$). Twelve patients (24.5%) in the SMA group were required intensive care after surgery compared to 1 (1.3%) patient in the AIS group ($p<0.05$). Among SMA patients, four patients were required postoperative mechanical ventilation and extubated between 4-9 hours, and one patient was

Table 1. Demographic variables

	SMA patients (n=49)	AIS patients (n=76)	p
Gender (female/male)	26/23 (53.1/46.9)	40/36 (52.6/47.4)	0.208
Age (years)	11.1±1.2	14.8±3.4	0.04
Body weight (kg)	27.17±2.7	53.1±4.3	<0.01
Height (cm)	127.17± 5.3	155.1±3.0	0.03
BMI class (uw/n/ow/o) (n; %)	31/17/1/0 (63.3/34.7/2.0/0)	5/56/11/4 (6.6/73.7/14.5/5.2)	<0.01
ASA (I/II/III; %)	4/32/13 (8.2/65.3/26.5)	69/7/0 (90.8/9.2/0)	<0.01
Cobb's angle (°)	85.3±4.7	50.3±8.7	0.02

A p value <0.05 was considered statistically significant
SMA: Spinal muscular atrophy, AIS: Adolescent idiopathic scoliosis, BMI: Body mass index, uw: Underweight, n: Normal, ow: Overweight, o: Obese, ASA: American Society of Anesthesiologists

Table 2. Perioperative variables

Parameter/n=37	SMA (n=49)	Min-max	AIS (n=76)	Min-max	p
Instrumentation level (number of vertebrae fused)	12.5±0.4	7-14	10.4±2.1	5-13	0.02
Osteotomy ratio (n, %)	15 (30.6)	-	16 (21.1)	-	0.01
Number of osteotomized vertebrae	5	2-7	0.7	0-5	<0.01
Duration of the surgery (min)	308.24±19.6	205-510	230.8±14.3	180-315	0.01
Estimated blood loss (mL)	950.7±71.1	460-1930	865.2±40.8	640-2060	0.04
Estimated blood loss/total blood volume (%)	39.9±4.3	21.4-96.0	23.1±4.3	7.0-29.4	0.02
Intraoperative blood transfusion (n, %)	43 (87.8)	-	30 (39.4)	-	<0.01
Amount of intraoperative blood transfusion (U)	1.31±0.63	(1-4)	0.52±0.1	(1-2)	0.02
Postoperative blood transfusion (n, %)	11 (22.4)	-	12 (15.8)	-	0.03
Amount of postoperative blood transfusion (U)	0.30±0.1	(0-2)	0.18±0.1	(0-1)	0.03
Intensive care unit admission (n, %)	12 (24.5)	-	1 (1.3)	-	<0.01
Length of intensive care unit stay (h)	18.4±2.1	(18-47)	10.5	-	0.02
Hospital discharge time (day)	5.1±0.1	(4-8)	4.3±0.4	(4-6)	0.04
Postoperative complication (n, %)	5 (10.2)	-	1 (1.3)	-	<0.01

A p value <0.05 was considered statistically significant
SMA: Spinal muscular atrophy, AIS: Adolescent idiopathic scoliosis, Min-max: Minimum-maximum

Table 3. Summarizes ROC curve analysis results of numerical data which showed statistical difference in intergroup comparison

		%95 CI				
	AUC	Lower	Upper	p value	Sensitivity	Specifity
Number of vertebrae fused	0.715	0.647	0.903	**0.001**	0.807	0.501
Operative time	0.822	0.675	0.994	**<0.001**	0.711	1
Preoperative respiratory function	0.703	0.566	0.868	**0.004**	0.643	0.744
Blood loss	0.774	0.602	0.891	**0.001**	0.562	0.903
Blood transfusion	0.722	0.607	0.888	**0.002**	0.573	0.858
Body mass index	0.693	0.508	0.901	**0.002**	0.504	0.763

A p value <0.05 was considered statistically significant
ROC: Receiver operating characteristics, AUC: Area under curve, CI: Confidence interval

already mechanical ventilation dependent. The length of ICU stay and hospital discharge time were also longer in the SMA patients compared to AIS patients ($p<0.05$). Postoperative complication was observed in total 6 patients. Respiratory problems (atelectasis) were observed in 3 patients in the SMA group. One patient was transferred from the service to the ICU at the second postoperative day and treated due to the respiratory distress. Postural hypotension was observed in the remaining 3 patients. Complication rate was higher in the SMA group ($p<0.05$).

Prognostic Factors for ICU Admission

Table 3 summarizes ROC curve analysis results of numerical data which showed statistical difference in intergroup comparison. In univariate analysis, six variables of number of vertebrae fused ⩾6 ($p=0.001$), operative time >6 h ($p\leqslant0.001$), preoperative poor respiratory functions ($p=0.04$), blood loss >33.3% of TBV ($p=0.001$), blood transfusion >50% of TBV, and low BMI (underweight) ($p=0.002$) were identified.

DISCUSSION

The results of this retrospective study showed that the anesthetic management of scoliosis surgery was more complicated in patients with SMA compared to the patients with AIS. Scoliosis surgery has by itself several difficulties including prolonged duration of the surgery, intraoperative bleeding, prone positioning, major intravascular fluid shift, and the risk of neurologic complications. Blood loss may exceed 50% of patient's TBV and is related to the instrumentation level, osteotomy, increased intraabdominal pressure and engorgement of the epidural plexus, and consumption or dilution of the coagulation factors[6].

Neurologic complications may be catastrophic and neuro-monitorization with SSEP and MEP are mandatory to prevent or diagnose nerve injury in the intraoperative period. In several cases, intraoperative wake-up test may also be indicated. Prone positioning has a potential for pressure injuries that may result in pressure ulcer, optic nerve injury, corneal ulceration, inadequate peripheral venous return, and inadequate ventilation. Vulnerable areas should be supported by padding and joints and contractures should not be overstretched[7].

When physical condition of SMA patients is added to all challenges, from the point of view of anesthesia management, it should be admitted that this patient group may be considered one of the difficult patient populations in the orthopedic surgery. SMA patients are at risk for difficult airway management due to the limited mobility of cervical spine, limited mouth opening by mandibular joint ankylosis and oversized tongue that may require videolaryngoscope or flexible fiberoptic bronchoscope guided endotracheal intubation for airway safety[8].

The patients have generally increased sensitivity to non-depolarizing muscle blocking agents and their use is limited for prolonged effects. In the case of using non-depolarizing neuromuscular blockers, sugammadex may be a reliable choice to reverse the muscle relaxation. The patients are also at risk for succinylcholine-induced rhabdomyolysis and hyperkalemia[9].

There are no verified reports about malignant hyperthermia by volatile anesthetics, but volatile anesthetics may interfere with SSEP. Therefore, TIVA is considered to the best anesthetic option for maintenance. Extremity contractures may make intravenous access extremely difficult, and central venous catheterization is almost mandatory in scoliosis surgery. Nutritional status of the patients is generally poor caused by bulbar dysfunction and regurgitation and patients are underweight and flaccid due to the muscle weakness. Low muscle and fat mass may result in hypoglycemia in prolonged fasting. Blood glucose measurement should be repeated during the surgery. Perioperative cardiovascular complications are rare but cardiac malformations may be present among patients with severe SMA[10].

The most important problem is respiratory insufficiency which is caused by restrictive breathing pattern accompanied by scoliosis, weak cough and clearance of sputum. The patients are prone to pulmonary infections in the pre- and postoperative period that may rapidly progress to develop desaturation[11].

Scoliosis patients generally need critical care in the postoperative period. In our study, the ICU admission rate was 24.5% and we found that preoperative poor respiratory function, prolonged surgery (>6 hours), multiple vertebral fusion (>6 levels), intra-operative blood loss >33% of TBV, and massive transfusion are predictive for ICU admission. In a study by Akesen[12], it was reported that the ICU admission rate after scoliosis surgery in a mixed pediatric patient population was 15.3% and approximately 7% of patients required postoperative mechanical ventilation. It was found that ICU admission correlated significantly with lower body weight percentile, neuromuscular etiology, abnormal finding in chest X-ray, additional comorbidities, and estimated postoperative need for ICU in the preoperative evaluation[12]. The main difference between two studies was that our study population consisted of more SMA patients (49.2%) whereas only 23.5% of patients had neuromuscular disorder in Akesen's[12] study. When patients with neuromuscular disorders are compared, the ICU admission rate was lower in our study (24.5% vs 40%). In another study by Malik et al.[13], medical records of 1398 patients with idiopathic, congenital or neuromuscular scoliosis were reviewed who required ICU admission after correction of pediatric spine deformity. Patient and surgical factors which were associated with ICU admission were black/African American versus white race, anterior fusion, combined fusion, non-idiopathic scoliosis, preoperative ventilator dependence, asthma, having structural pulmonary abnormality, developmental delay, having a neuromuscular disorder, requiring nutritional support and a total operative time >270 minutes[13].

The results of other studies in the literature revealed that the ICU admission rate is related to the several variables such as patient's medical condition (neuromuscular disease, high Cobb angle), poor respiratory status, low body weight, extent of the surgery (number of vertebrae fused, osteotomy, prolonged surgery), intraoperative blood loss, massive transfusion, and poor nutritional status[14,15].

Therefore, we recommend several preventive measures to increase the procedural success: a) pre-operative anesthetic visit: pulmonary examination including pulmonary function test and pulmonary consultation, airway evaluation, nutritional status assessment, giving information to family about the possible complications ICU admission, and mechanical ventilation dependence[16]; b) intraoperative period: TIVA technique, tranexamic acid infusion, deliberate hypotensive anesthesia, avoiding neuromuscular blocking agents, invasive arterial blood pressure monitoring, large IV access (central venous catheterization), neuro-monitorization, MMA regimen, short acting opioids if necessary, careful fluid management, arterial blood gas analysis with short intervals, prevention of hypothermia, hypoglycemia, careful positioning, padding, and close communication with surgical team; c) postoperative period: establishing a postoperative care protocol that include extubation strategy and ICU admission criteria, postoperative non-invasive ventilation, and chest physiotherapy[17,18].

Study Limitations

This study has several limitations. First, the retrospective nature of the study may have recall and selection bias. To prevent this, same inclusion and exclusion criteria were used. The patients with missing data were excluded. The second limitation was that a comparison between a patient group with a neuromuscular disease and otherwise healthy subjects might most probably increase the bias risk. But the study focused mainly on the SMA patients. Therefore, the patients with AIS might be considered as a control group in a comparative study because all perioperative managements were same in both groups. Third, the data about hospital readmission after discharge does not exist because some patients were from out-of-town which might provide valuable information in the postoperative period.

CONCLUSION

This study showed that a structural preoperative planning including multi-disciplinary approach and postoperative care may provide a successful perioperative course in patients with SMA who underwent scoliosis surgery.

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Ethics

Ethics Committee Approval: This study was approved by the Private Çankaya Hospital Ethic Committee (decision no: 2023-02-01, date: 02.01.2023).

Informed Consent: Obtaining informed consent from patients was waived due to the retrospective nature of the study.

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MANAGEMENT OF THORACOLUMBAR FRACTURES: CLINICAL, FUNCTIONAL, AND RADIOLOGICAL OUTCOMES IN A SINGLE INSTITUTION

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ABSTRACT

Objective: The purpose of this study was to evaluate the long-term clinical, functional, and radiological outcomes of operative and non-operative treated patients with thoracolumbar fracture.

Materials and Methods: Between January 2016 and December 2021, data of patients hospitalized in our clinic due to thoracolumbar (T11-L2) fracture were collected and analyzed.

Results: Two hundred eighteen patients met the inclusion criteria. One hundred thirty eight patients (63.3%) were operated and 80 patients (36.7%) were treated with nonsurgical methods. The duration of follow-up ranged from 13 to 82 months. There was a significant difference between the first admission oswestry disability index (ODI) and visual analog scale (VAS) and the final visit ODI and VAS when both operative and nonoperative treatment patients were evaluated separately and when evaluated together. The scores at the last control visit were significantly lower than the initial scores ($p<0.001$). When the fracture level was compared with the ODI and VAS, a significant difference was observed in the ODI score at the first admission ($p=0.03$). The ODI score at first admission was highest in patients with T11 fractures and lowest in patients with L2 fractures. There was a significant correlation between the "Anterior Vertebral Body Compression Percentage %" and four-vessel cerebral angiography ($p<0.001$).

Conclusion: Patients with high vertebral depression and low functionality were operated, and regardless of the treatment protocol, pain decreased and functionality increased in all patients. The height of the vertebral corpus affects the angle of kyphosis, and surgical management is needed for the kyphotic deformity. Patients with high thoracolumbar fractures were more painful.

Keywords: Thoracolumbar junction, vertebral fracture, kyphotic deformity, pain, function

INTRODUCTION

Fractures of the thoracolumbar region account for 90% of all spinal fractures, with the majority occurring at the T11 to L2 level[1,2]. This area, known as the thoracolumbar junction (TLJ), is highly susceptible to injury due to its transition from the rigid and less mobile thoracic spine to the more flexible lumbar spine[3,4]. Causes of thoracolumbar fractures vary depending on the age of the patient, with high-energy trauma being the most common cause in younger patients, while falls from standing position to ground can cause fractures in older patients with osteoporosis[5,6]. Despite being a common fracture, there are currently no evidence-based guidelines for the ideal management of thoracolumbar fractures[7]. Conservative treatments, such as pain medications, bed rest, and bracing, are typically employed initially, with most patients successfully treated within 4 to 6 weeks. However, for patients with persistent pain or other complications, operative treatment may be necessary[8]. The instability of traumas in the TLJ and the frequent occurrence of post-traumatic deformity may result in neurological damage in 20% of cases[9-11]. Even patients without neurological injury may experience limitations in daily activities or difficulty returning to work due to chronic pain[12,13]. Therefore, appropriate management is crucial.

In this study, we aimed to evaluate the long-term functional and clinical outcomes of operative and non-operative treatment of patients with thoracolumbar fractures. We analyzed the Cobb angle of the fractured vertebra four-vessel cerebral angiography (FVCA), the Anterior Vertebral Body Compression Percentage (AVBC%), visual analog scale (VAS), and oswestry disability index (ODI) scores. By providing data on the outcomes of different treatment methods, our study can help inform the development of evidence-based guidelines for managing thoracolumbar fractures.

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MATERIALS AND METHODS

Study Design

Ethical approval was obtained from the University of Health Sciences Turkey, Gülhane Training and Research Hospital Ethical Committee (decision no: 2021-238, date: 20.05.2021), and informed consent was taken from all participants. We collected and reviewed clinical and radiological data of patients who were hospitalized in our institution for operative or non-operative treatment of the thoracolumbar fracture. We radiologically evaluated the patients with conventional X-ray and computed tomography (CT) and we investigated them clinically with VAS and ODI at their first and last visits to the hospital. We obtained CT scan from all patients after surgery to see the position of the stabilization materials as well as to observe the sufficiency of the decompression. We used the modified thoracolumbar injury classification and severity score (mTLICS) to make the surgical decision for the patients.

Selection and Description of Participants

Between January 2016 and December 2021, we admitted 287 consecutive patients with TLJ fracture to our neurosurgery department. We extracted age, gender, date of first diagnosis, fracture site, neurological signs or symptoms, pain progression from the date of diagnosis to the last follow-up, and change in quality of life from the medical records of the patients. We included patients over 18 years of age.

The exclusion criteria were inflammatory diseases such as ankylosing spondylitis and rheumatoid arthritis, history of major surgery of the thoracolumbar spine or treated with vertebroplasty and kyphoplasty of the index vertebra, incomplete radiological or clinical data, or less than 12 months of follow-up.

Treatments

We used the mTLICS system to make the surgical decision for patients, with the unanimous consent of 2 surgeons. In this system, a score of 3 points or less is considered non-operative, a score of 5 points or greater is considered operative, and a score of 4 points can be considered operative or non-operative and must be decided on an individual basis.

Conservative treatment was applied to patients with an mTLICS score less than 4 points. Conservative treatment usually includes palliative pain medicines, bed rest, and bracing. The indications for hospitalization of patients treated conservatively are comorbidities such as diabetes, hypertension, cardiac disorders, ages between 70 and 90, history of osteoporosis (fragil vertebra) and significant pain. Length of stay is determined based on the clinical and radiological condition of the patients ranged between 3 to 10 days. Ambulation with a corset was started as early as possible because prolonged bed rest may cause embolization, pressure ulcer, and pulmonary complications. The clinically and radiologically stabile patients were discharged. The patients weared corset for a period of four to 12 weeks and this period determined based on the radiographic evidence of healing, and the lack of tenderness over the fracture site. We examined follow-up standing radiographs 1-2 weeks after the ambulation. We continued the conservative treatment in patients who did not have an obvious increase in kyphotic angle of more than 10 degrees or pain during conservative treatment, but re-evaluated patients who did have these issues for operative treatment.

All patients whose mTLICS score was greater than 4 underwent posterior stabilization with pedicle screws using an open approach with a freehand technique under general anesthesia. Intermediate short-segment pedicle screws in the fractured vertebra were positioned according to pedicle integrity. In case of a single pedicle fracture, screws were positioned asymmetrically, whereas no screws were positioned in case of bilateral pedicle fracture. We checked screw positioning intraoperatively with fluoroscopic guidance. After surgery, all patients were free to move with or without support or corset.

Patients with an mTLICS score of 4 points were considered in the gray zone. Treatment planning in these patients was performed on a patient basis according to the surgeon's discretion.

Radiological Assessment

Two surgeons evaluated radiological data (CT scans) of all patients in a blinded manner. We evaluated FVCA, "AVBC %" on CT scans at the first visit and final follow-up visit. FVCA was measured on CT scan as the angle between the superior endplate of the vertebra above the fracture and the inferior endplate of the vertebra below the fracture (Figures 1A, C, Figures 2A, B).

"AVBC %" consists of the percentage of anterior vertebral body compression with respect to the average height of the anterior

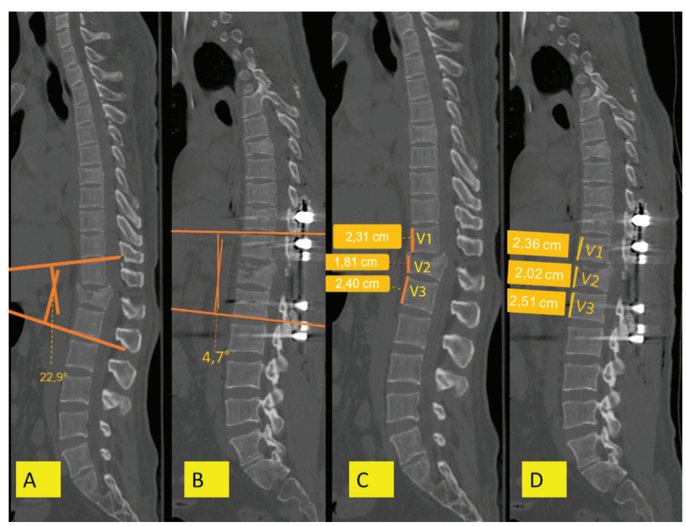

Figure 1. Twenty-one years old female a case of fall from standing position. mTLICS=2. First visit FVCA and "AVBC%" measurement **(A, B)**. After 30 day FVCA was increased 1.7°. Last visit (6 months after trauma) measurements are same with the 30th day **(C, D)**

mTLICS: Modified thoracolumbar injury classification and severity score, FVCA: Four-vessel cerebral angiography, AVBC: Anterior Vertebral Body Compression Percentage

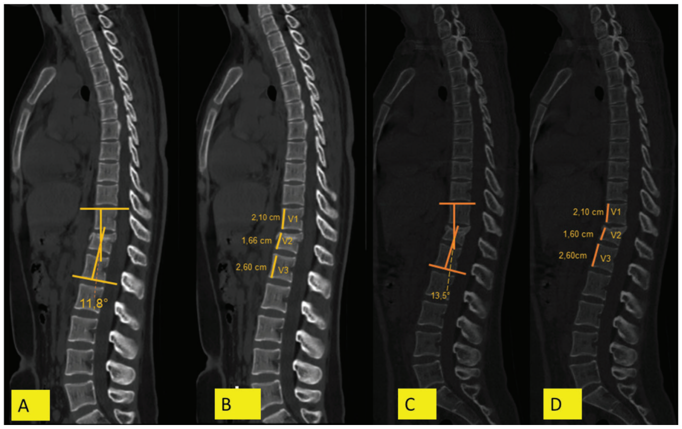

Figure 2. Thirty-four years old male fall from a height case. mTLICS=5. Pre-operative FVCA is increased (22.9°), vertebral alignment is lost **(A)**. Postoperative FVCA is decreased (4.7°) and alignment was preserved **(B)**. Preoperative and postoperative "AVBC%" measurements of relevant and adjoining vertebral bodies. After instrumentation the relevant vertebral body has gained height **(C, D)**
mTLICS: Modified thoracolumbar injury classification and severity score, FVCA: Four-vessel cerebral angiography, AVBC: Anterior Vertebral Body Compression Percentage

vertebral bodies immediately cephalad and caudad to the injury level (Figures 1B, D, Figures 2C, D).

Measurements

The functional outcomes and pain scores of the patients were assessed at their first admission and final follow-up visit using the VAS and ODI. Chronic pain was evaluated through self-reported questionnaires using the VAS, where patients were asked to rate their pain levels on a scale of 0 to 4. Group 0 represented no pain, group 1 represented mild pain, group 2 represented moderate pain, group 3 represented distressing pain, and group 4 represented severe pain. Function was evaluated using the ODI, and the results were grouped based on the patient's disability in function. ODI scores of 0-20% indicated minimal disability, 21-40% indicated moderate disability, 41-60% indicated severe disability, 61-80% indicated crippling back pain, and 81-100% indicated bedbound or exaggeration of symptoms.

Statistical Analysis

IBM SPSS Statistics software version 28.0.1.0 (IBM, SPSS, Chicago, Illinois, USA) was used for the statistical analysis of this study data. The collected data are expressed as mean ± standard deviation. The Shapiro-Wilk test was used to evaluate whether parameters were normally distributed. Independent Sample t-test was used to compare normally distributed parameters between groups, while the Kruskal-Wallis test was used for comparing data without normal distribution between groups. Mann-Whitney U test was used to analyze clinical and radiological variables, while the Wilcoxon rank-sum test and paired sample t-test were used to detect the period causing the difference between groups. Spearman's rank correlation test was used to define the direction and degree of inter-variable relationships.

RESULTS

A total of 218 patients met the inclusion criteria, with 138 patients (63.3%) undergoing surgery and 80 patients (36.7%) treated with non-surgical methods. The mean follow-up duration was 37.2±18.1 months (range: 13-82 months). Table 1 presents demographic data and basic characteristics of all reported patients. Comparison between patients treated with operative and non-operative methods revealed no significant difference in terms of age, gender, fracture level, mechanism of injury, FVCA, and VAS. However, a significant difference was found in the "AVBC%" and ODI, with the surgically treated group having a significantly lower "AVBC%" and significantly higher ODI scores (Table 2). Among patients with mTLICS 4 points, no significant difference was found between those treated with operative and non-operative methods in terms of any of the evaluated criteria (Table 3). Both operative and non-operative treatment groups showed a significant difference between the first admission ODI and VAS and the final visit ODI and VAS, with the scores at the last control visit being significantly lower than the initial scores ($p<0.001$). Comparison of preoperative and postoperative FVCA in patients treated with surgery showed a statistically significant difference, with the postoperative group having a significantly lower FVCA ($p<0.001$). When the fracture level was compared with the ODI and VAS, there was no significant difference between the fracture level and the VAS at the first admission and the ODI and VAS at the last visit. However, a significant difference was observed in the ODI score at the first admission ($p=0.03$), with the ODI score being highest in patients with T11 fractures and lowest in patients with L2 fractures (T11 > T12 > L1 > L2 in descending order). Comparison of the fracture level and FVCA revealed a statistically significant difference ($p<0.001$), with the FVCA being highest at the T11 level and decreasing downwards (T11 > T12 > L1 > L2). No significant difference was found when the FVCA and first and last admission ODI and VAS were compared (ODI first $p=0.188$, ODI last: $p=0.470$, VAS first: $p=0.425$, VAS last: $p=0.875$). Spearman's rank correlation test revealed no significant relationship between age and ODI or between age and pain VAS score. Analysis of VAS and ODI in correlation with sex revealed no significant differences. However, a significant correlation was found between "AVBC%" and FVCA ($p<0.001$).

DISCUSSION

The thoracolumbar spine is the most common region of spinal fractures, accounting for nearly 90% of all spinal fractures in adults[14,15]. The majority of thoracolumbar spine injuries occur at the junction (50-60%), followed by the thoracic (25-40%) and lumbar (10-14%) regions[1]. The rigid thoracic spine transitions to the mobile lumbar spine (T11-L2 level), resulting in increased biomechanical stress[16]. Injury to the TLJ can occur from motor vehicle accidents, falls from height, recreational accidents, and occupational injuries.

Numerous classification systems have been proposed for thoracolumbar spine injuries, but none have gained universal acceptance[17]. The first modern classification based on radiological findings and 2-column theory (anterior and posterior) was established by Holdsworth[18] in 1963. Denis defined the "3 column theory" by dividing the anterior column into two in 1983, and the definition of the middle column allowed better analysis of thoracolumbar fractures[3].

There is still controversy in the literature on the treatment of thoracolumbar vertebral fractures. An ideal classification

Table 1. Basic characteristics of all reported patients

Overall (n=218)			
Age		mTLICS	
Mean (SD) 52.513±19.920		Mean (SD) 4.165±1.613	
Range 18-90		Range 1-9	
Sex		1. 4 (1.8%)	
Female 98 (45%)		2. 46 (21.2%)	
Male 120 (55%)		3. 14 (6.4%)	
Fracture level		4. 62 (28.4%)	
T11	8 (3.7%)	5. 48 (22%)	
T12	66 (30.3%)	6. 34 (15.6%)	
L1	100 (45.9%)	7. 4 (1.8%)	
L2	44 (20.2%)	8. 4 (1.8%)	
		9. 2 (0.9%)	
Mechanism of injury		Cobb angle of the fractured vertebra (FVCA)*	
Fall from standing position	70 (32.1%)	<10	96 (44%)
Fall from a height[a]	86 (39.4%)	10-20	88 (40.4%)
Motor vehicle accident[b]	44 (20.2%)	>20	34 (15.6%)
No relevant trauma[c]	18 (8.3%)		
The anterior vertebral body compression percentage ("AVBC %")**			
Mean (SD) 65.103±16.435			
Range 10.000-99.000			

Values are presented as mean ± standart deviation or number
[a]Work accident or jumping from a height as a suicide attempt
[b]Inside or outside a vehicle
[c]After coughing, sneezing, heavy lifting
*Cobb angle of the fractured vertebra
**The anterior vertebral body compression percentage
SD: Standard deviation, mTLICS: Modified thoracolumbar injury classification and severity score, FVCA: Four-vessel cerebral angiography

Table 2. Evaluation of parameters among the non-operated and operated groups

Parameters	Non-operated	Operated	P value
	Mean ± SD	Mean ± SD	
Age	51.775±20.523	52.942±19.702	0.873+
Cobb angle	11.610±6.774	13.107±8.100	0.327*
AVBC	72.800±13.218	60.642±16.546	<0.001*^
VAS			
First visit	2.725±0.750	2.885±0.974	0.335+
Last visit	1.225±0.831	1.188±0.895	0.821+
ODI			
First visit	51.425±17.048	60.492±20.877	0.022*^
Last visit	21.275±11.681	34.666±20.814	<0.001+^

*Independent sample t-test, +Mann-Whitney U test, ^p<0.05
SD: Standart deviation, AVBC: Anterior vertebral body compression percentage, VAS: Visual analog scale, ODI: Oswestry Disability Index

Table 3. Evaluation of parameters among the non-operated and operated groups in patients with mTLICS=4 point

Parameters	Non-operated	Operated	P value
	Mean ± SD	Mean ± SD	
Age	59.000±18.631	45.826±20.772	0.124*
FVCA	10.750±5.732	12.205±9.210	0.512+
AVBC	66.250±13.925	61.608±11.625	0.362*
VAS			
First visit	47.875±15.541	2.652±0.831	0.655+
Last visit	23.125±10.105	1.000±0.904	0.273+
ODI			
First visit	47.875±15.541	53.869±22.742	0.497*
Last visit	23.125±10.105	34.217±19.064	0.130*

*Independent sample t-test, +Mann-Whitney U test
SD: Standart deviation, AVBC: Anterior vertebral body compression percentage, VAS: Visual analog scale, ODI: Oswestry Disability Index, mTLICS: Modified thoracolumbar injury classification and severity score, FVCA: Four-vessel cerebral angiography

should be able to fully identify all types of fractures, determine the prognosis and guide treatment, as well as being simple, easily applicable, diagnostically repeatable. We used mTLICS scoring in the treatment decision of our patients because it is useful in predicting surgical treatment and its repeatability is good[19]. Conservative treatment was applied to 64 patients with a score of 3 and below, and surgical treatment was applied to 92 patients with a score of 5 and above. Of 62 patients with a score of 4, 16 (25.81%) were treated conservatively and 46 (74.19%) underwent surgical treatment.

There are several studies in the literature reporting satisfactory results following both operative and non-surgical treatment. Wood et al.[2] compared the long-term outcomes of surgically and conservatively treated patients with thoracolumbar fractures and they found that the non-surgical group had a significantly better outcome. Soultanis et al.[20], in a retrospective study evaluated 75 patients with non-operated thoracolumbar fractures, reported satisfactory results. In contrast to these, Siebenga et al.[21] showed in a multicenter, prospective, randomized study that surgically treated patients had better clinical outcomes and a higher percentage of patients returning to work. In this study, in which 218 patients treated with and without surgery were compared; there was no significant difference in terms of age, gender, fracture level, mechanism of injury, FVCA and VAS; however, AVBC was significantly lower and ODI scores were significantly higher in the surgical treatment group. When the patients treated with operative and non-operative methods among 62 patients with mTLICS 4 score were compared, no significant difference was found in terms of age, gender, fracture level, mechanism of injury, FVCA, AVBC, VAS and ODI scores.

Although FVCA and AVBC are two of the objective criteria in the radiological evaluation of TLJ fractures, FVCA is a more controversial issue as there are conflicting studies on the amount of kyphosis that leads to poor results. In their study of 37 patients with thoracic and lumbar fractures, Gertzbein et al.[1] concluded that a kyphotic deformity greater than 30° was associated with an increased incidence of more severe back pain. However, Shen et al.[22] showed a poor correlation between clinical outcomes and kyphosis greater than 30°. Krompinger et al.[23] stated that if the kyphosis angle is less than 30° and the spinal canal narrowing is less than 50%, they can be defined as stable. In our study, FVCA and first and last admission ODI and VAS scores were compared and no significant difference was found. When the preoperative and postoperative kyphosis angle of 138 patients treated with surgery was compared, a statistically significant difference was found and it was found to be significantly lower in the postoperative group.

After radiologically evaluating the patients with TLJ fracture, it was necessary to evaluate how these radiologic results were reflected in clinical presentation. In our study, we examined the VAS and ODI values of our patients. In our study, when 138 patients who were operated on and 80 patients treated with non-surgical methods were compared, no significant difference was found in terms of VAS; however, ODI scores were significantly higher in the surgically treated group. When the patients with mTLICS score of 4 who were treated operatively and non-operatively were compared, no significant difference was found in terms of VAS and ODI scores. When the first admission ODI and VAS scores of all patients were compared with the last admission ODI and VAS scores, a significant difference was found where the scores at the last control were low. When the fracture level was compared with the ODI and VAS scores, there was no significant difference between the fracture level and the VAS score at the first admission and the ODI and VAS scores at the last visit, while a significant difference was observed in the ODI score at the first admission. The ODI score at first admission is highest in patients with T11 fractures and lowest in patients with L2 fractures (T11 > T12 > L1 > L2 in descending order). When the FVCA and first and last admission ODI and VAS scores were compared, no significant difference was found. Correlation analysis of VAS and ODI with gender or age did not show any significant difference.

Study Limitations

The limitations of this study include its retrospective study design and the lack of randomization. Measurement of the entire spine was not available for proper assessment of sagittal balance and pelvic incidence. This study was also limited as there was no standardized conservative treatment that was strictly administered and patient compliance varied throughout the conservative treatment period, particularly with regard to the bracing, so treatment options may be another possible factor affecting clinical outcomes. Despite these limitations, follow-up is satisfactory and evaluation of patients has been extensively documented. The risk of bias is eliminated, as preoperative values are comparable and clinical evaluations are performed by 2 surgeon.

CONCLUSION

Patients who underwent surgery had lower "AVBC %" and higher ODI scores. Based on this, it can be thought that patients with more vertebral depression and less functionality were operated on. The ODI and VAS at the final follow-up visit were lower than the ODI and VAS at first admission. This means that over time, all patients are relieved of pain and increase in functionality, regardless of the treatment protocol. The postoperative FVCA values of the patients were lower than before the surgery. This may suggest that we contributed to the correction of the kyphotic deformity with our surgery. Patients with high thoracolumbar fractures have higher ODI score at the first admission, so they are more painful due to fractures.The correlation between "AVBC%" and FVCA shows that the height of the vertebral corpus affects the angle of kyphosis. The advantages of surgery include better correction of kyphotic deformity, greater initial stability, an opportunity to perform direct or indirect decompression of neural elements, decreased requirements for external immobilization, and an earlier return to work.

Ethics

Ethics Committee Approval: This study was approved by the University of Health Sciences Turkey, Gülhane Training and Research Hospital Ethical Committee (decision no: 2021-238, date: 20.05.2021).

Informed Consent: Informed consent was taken from all participants.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.O.D., M.C.E., D.E.K., G.K., Concept: M.O.D., M.C.E., Design: M.O.D., M.C.E., Data Collection or Processing: D.E.K., G.K., Analysis or Interpretation: M.O.D., M.C.E., D.E.K., G.K., Literature Search: M.O.D., D.E.K., G.K., Writing: M.O.D., D.E.K.

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ASSESSING PRE-OPERATIVE CARDIAC RISK IN ADULT SPINAL DEFORMITY SURGERY: CORRELATION BETWEEN MODIFIED FRAILTY SCORE AND REVISED CARDIAC RISK INDEX

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ABSTRACT

Objective: Cardiac complications are one of the most important causes of death after major spinal surgery. This study aimed to evaluate the correlation between the 11-item and 5-item modified frailty index (mFI) and the revised cardiac risk index (RCRI) for predicting major adverse cardiac events (MACEs) after adult spinal deformity (ASD) corrective surgery.

Materials and Methods: This retrospective study analyzed the records of 20 adult patients who underwent spine surgery for ASD between 2022-2023. The patients' frailty and comorbidities were assessed using the mFI-5, mFI-11, and the American Society of Anesthesiologists Physical Status Classification System. RCRI was calculated to stratify the risk for predicting MACEs during hospitalization. The primary outcome was the presence of specific cardiac events within 30 days of surgery.

Results: The study found that there was a significant positive correlation between RCRI and both mFI-5 and mFI-11 scores in terms of predicting MACEs. Three out of the 20 patients had MACEs postoperatively, and among them, one patient had an RCRI score of 1 but had a higher mFI score, indicating frailty. The other two patients had low RCRI scores but were considered prefrail according to the mFI scores.

Conclusion: RCRI, mFI-5, and mFI-11 are correlated in terms of predicting cardiac risk after ASD surgery. Adding frailty scores to traditional risk estimation may provide additional prognostic information. However, this needs further investigation.

Keywords: Adult spinal deformity surgery, modified frailty index, revised cardiac risk index, major cardiac adverse events

INTRODUCTION

Even though patients undergo surgery to maintain or increase life expectancy or to improve health related quality of life, surgery is not without risks. Increasing numbers of patients need surgery at older ages and with more medical comorbidities as the population continues to age[1,2]. Among wide range of surgeries, adult spinal deformity (ASD) corrective surgery involves a significant amount of dissection, multilevel instrumentation and fusion, osteotomy, and blood loss with a considerable risk of perioperative complications[1-3].

Recent research has shown that frailty is a useful predictor of severe adverse outcomes when considering surgery for elderly patients[4,5]. Frailty is a syndrome associated with aging that is characterized by a decline in physiological reserve across a number of organ systems, which leads to a reduction in stress resistance[6] and an increased threshold for compensatory mechanisms[7]. Risk stratification using a frailty index offers a promising tool to identify patients most likely to experience complications such as neurological, implant related, surgical site infection, cardiopulmonary (hemodynamic instability, myocardial infarction, congestive heart failure, pulmonary embolism), gastrointestinal and renal. Among several assessment tools reported, 11-item modified frailty index (mFI-11), Charlson comorbity index, ASD Frailty Index and Cervical Deformity Frailty Index are among the leading frailty indices in the spine literature[8]. On the other hand, in the study by Laverdière et al.[9] where correlation between frailty status and postop outcomes were assessed in 12 studies, mFI-11-item and -5 item were the most frequently used frailty indices.

Although cardiac complications are the leading cause of death after non-cardiac surgery[10,11] there is a paucity of extensive cohort studies assessing cardiac problems in patients having spine surgery[12]. Among several tools evaluated to predict preoperatively in-hospital major adverse cardiac events (MACE), revised cardiac risk index (RCRI) is a widely utilized one[13] and along with pre-operative B-type natriuretic peptides[14,15] is currently the gold standard of risk stratification. However, these measurements do not capture or account for frailty.

The aim of this study was to evaluate the correlation between widely used mFI 11-and 5 -item and RCRI for prediction of cardiac MACEs after ASD surgery.

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MATERIALS AND METHODS

Patients

This retrospective study analyzed the records of 20 adult (age 57-83) patients who underwent spine surgery for ASD in our institution between 2022-2023. The study included patients who underwent preoperative cardiac evaluation. Frailty and comorbidities were assessed by the mFI-5, mFI-11, and American Society of Anesthesiologist Physical Status Classification System (ASA) respectively. RCRI was calculated to stratify the risk for prediction of MACEs during hospitalization. Demographical and clinical data were retrieved from patient records. The study protocol was approved by the Anadolu Medical Center Ethic Committee and the study was conducted in accordance with the Declaration of Helsinki (no: ASM-EK-23/224, date: 14.06.2023).

Frailty Risk Score and RCRI Score Calculation

The 5-item mFI-5 was validated and developed from the previously established mFI-11. The mFI-5 has five National Surgical Quality Improvement Program variables: 1) history of severe chronic obstructive pulmonary disease (COPD), 2) congestive heart failure within 30 days before surgery, 3) functional health status prior to surgery (independent versus partially or totally dependent), 4) hypertension (HT) requiring medication, and 5) diabetes mellitus (DM) with oral agents or insulin. A combined mFI score is calculated for each patient by adding the number of frailty variables present (one point per variable). The mFI-5 was categorized as 0, 1, or ⩾2. The mFI-11 item, in addition to the previous 5 parameters, included, 6) history of myocardial infarction, 7) peripheral vascular disease, 8) history of percutaneous transluminal coronary angioplasty (PTCA), coroner artery bypass grafting or angina, 9) impaired sensorium, 10) transient ischemic attack (TIA) or cerebrovascular attack (CVA) without residual deficit, 11) CVA with residual deficit. Patients were classified as robust: mFI-5, -11=0, prefail: mFI-5=1 or -11<3, frail: mFI-5⩾2 or-11⩾3[8,16].

Briefly, the RCRI was calculated by 1-point assignments for the presence of each of the following variables[17]: 1) history of ischemic heart disease, 2) heart failure, 3) CVA or TIA, 4) DM on insulin, 5) creatinine >2 mg/dL and 6) high-risk surgery (intra-thoracic, vascular, and intra-peritoneal), for a maximum score of 6. The patients were considered very very low risk (0.04%) if 0 over 6 parameters exists, low risk (0.9%) for 1-point, moderate risk (6.6%) for 2 points, high risk (>11%) for 3 points.

Outcomes

Our primary outcome was the presence a MACE defined as; ST elevation myocardial infarction, pulmonary edema, ventricular fibrillation, acute coronary syndrome with troponin elevation and complete heart block at or before 30-days.

Statistical Analysis

In the descriptive statistics of the data, mean, standard deviation, median minimum, maximum, frequency and ratio values were used. The distribution of variables was measured with the Kolmogorov-Smirnov test. The Mann-Whitney U test was used in the analysis of quantitative independent data. Chi-square test was used in the analysis of qualitative independent data, and Fisher's exact was used when the chi-square test conditions were not met. Spearman correlation analysis was used in the correlation analysis. The effect level and cut-off value were investigated with the receiver operating characteristic curve. SPSS 28.0 program was used in the analysis.

RESULTS

Patients

A total of 20 patients were included in the study. The average age of the patients was 68.3±8.8 and 70% were male. All patients underwent corrective ASD surgery through posterior approach. The average duration of the operation was 4-6 hours. Demographical and clinical data of the patients are shown in Table 1. The majority of the patients (13) had an RCRI score of 0 with an estimated very low risk (0.04%) of MACE with non-cardiac surgery. On the other hand, 12 patients were categorized as prefrail with mFI-5=1 and mFI-11=1 (Table 1).

Outcomes with RCRI and mFI

The age and gender distribution of the patients did not differ significantly between the groups with very low RCRI and low-intermediate risk RCRI (p>0.05). The ASA score was significantly (p<0.05) higher in the RCRI low-intermediate risk group than the very low RCRI risk group. There was no significant difference between the groups with very low RCI and low-intermediate RCI (p>0.05) in terms of history of HT, coronary artery disease, COPD, smoking status, ejection fraction, troponin levels, blood loss and replacement. The DM rate was significantly (p<0.05) higher in the group with low-intermediate risk RCRI than in the group with very low RCRI. There was no significant difference between the groups with very low RCRI and low-intermediate RCRI (p>0.05) for readmission, postoperative complications, and hospital stay (Table 2).

Three of 20 patients had MACEs postoperatively with one patient having an acute myocardial infarction with primary PTCA and stent implantation a week after discharge and 2 patients with troponin elevations without major ischemic electrocardiography changes treated with medical therapy. Of these 3 patients, one patient had RCRI of 1 with low risk (0.9%) however 3 with mFI-5 and mFI-11, considered frail. The other 2 patients had an RCRI of 0 with very low risk (0.04%) and 1 with mFI-5 and mFI-11 considered as prefrail.

In patients with RCRI low to moderate risk (1 to 2 points), the average of mFI-5 was 2.0±1.15 and mFI-11 was 2.29±0.95. The mFI-5 and -11 score distributions in the RCRI low-intermediate

Table 1. Demographical and clinical data of the patients

		Min-max	Average	Mean ± SD/n-%	
Age		50-83	70	68±8.8	
Gender	Female			6	30.0%
	Male			14	70.0%
HT				15	75.0%
DM				5	25.0%
CAD				2	10.0%
Smoking status				9	45.0%
EF	Normal			15	75.0%
	Reduced <55%			1	5.0%
Troponin	(-)			8	40.0%
	(+)			2	10.0%
COPD	(-)			18	90.0%
	(+)			2	10.0%
ECG: SR				20	100.0%
Blood loss		50-2500	275	557±592	
Blood usage	(-)			13	65.0%
	(+)			7	35.0%
mFI-5	0			2	10.0%
	I			12	60.0%
	II			3	15.0%
	III			3	15.0%
mFI-11	I			13	65.0%
	II			3	15.0%
	III			4	20.0%
ASA	II			13	65.0%
	III			7	35.0%
Readmission	(-)			19	95.0%
	(+)			1	5.0%
Postoperative complication	(-)			17	85.0%
	(+)			3	15.0%
Length of stay		3-20	6	6.5±3.78	
Revised cardiac risk index		0.40-6.60	0.40	0.86±1.37	
Revised cardiac risk index	Very low			13	65.0%
	Low			6	30.0%
	Moderate risk			1	5.0%

HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, EF: Ejection fraction, COPD: Chronic obstructive pulmonary disease, ECG: Electrocardiography, SR: Sinus rhythm, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, ASA: American Society of Anesthesiologist Physical Status Classification System, SD: Standard deviation, Min-max: Minimum-maximum

group were significantly ($p<0.05$) higher than the very low RCI group (Table 3 and Figures 1a, b). A significant positive correlation was observed between both the RCRI and mFI-5 ($r=0.533/p=0.016$) and mFI-11 ($r=0.655/p=0.002$) (Table 4). Significant effectiveness of mFI-5 scores [Area under the curve 0.780 (0.508-1.000)] and mFI-11 scores [Area under the curve 0.824 (0.599-1.000)] were observed in the discrimination between groups with very low RCRI and low-intermediate RCRI. Among the groups with very low RCI and RCI low-moderate, the sensitivity of mFI-5 below or above 1 was 71.4%, positive prediction was 83.3%, specificity was 92.3%, and negative prediction was 85.7% while the sensitivity was 71.4%, positive prediction was 71.4%, specificity was 84.6% and negative prediction was 84.6% for mFI-11 (Table 5).

DISCUSSION

ASD surgery carries a considerable risk for postoperative serious adverse effects because of its invasive nature[1-5]. Considering that more elderly and frail patients with several comorbidities undergo this operation, this presents unique challenges to spine surgeons and risk stratification is important to identify patients most likely to experience complications. Among the several tools evaluated to quantify the risk prediction in terms of frailty, mFI-11 and mFI-5 are among the most widely acknowledged ones[9,18]. On the other hand, RCRI has been used extensively as a prognostic model to estimate the risk of developing postoperative cardiac major adverse events in noncardiac surgery including spinal surgery[13]. Here in this study, we have found a significant positive correlation between RCRI, MFI-5 and mFI-11 with mF-11 more with RCRI in terms of MACE prediction.

A consensus conference in December of 2012, led by the International Association of Gerontology and Geriatrics and World Health Organization, defined frailty as "a medical syndrome with multiple causes and contributors that is characterized by diminished strength, endurance and reduced physiological function that increases an individual's vulnerability for developing increased dependency and/or death"[18,19]. Elevated frailty index scores have been shown as an independent predictor of surgical complications in spine surgeries[9]. Even though many assessment tools were developed to quantify risk for postoperative outcomes, unfortunately they are not without limitations in terms of feasibility and reliability. The Adult Deformity Surgery Complexity Index is a reliable instrument for calculating the complexity of ASD surgery, predicting surgical blood loss, time, and postoperative problems[20]. It was, however, developed based on expert consensus and included solely surgical data, with no frailty variables. Moreover, this index consists of 42 independent parameters which is significantly a large number causing a major limitation. The Seattle Spine Score which predicts the 30-day complication risk after ASD surgery and used frailty parameters, lacked external validation[3]. mFI is the most frequently used frailty index in spine literature,

Table 2. Groups with very low RCRI and low-intermediate RCRI

		RCRI very low			RCRI low-moderate				
		Mean ± SD/n-%		Median	Mean ± SD/n-%		Median	p	
Age		67.9±8.9		70.0	69.0±9.2		70.0	0.874	m
Gender	Female	4	30.8%		2	28.6%		1.000	X^2
	Male	9	69.2%		5	71.4%			
ASA	II	11	84.6%		2	28.6%		0.022	X^2
	III	2	15.4%		5	71.4%			
HT	(-)	3	23.1%		2	28.6%		1.000	X^2
	(+)	10	76.9%		5	71.4%			
DM	(-)	13	100%		2	28.6%		0.001	X^2
	(+)	0	0.0%		5	71.4%			
CAD	(-)	13	100%		5	71.4%		0.111	X^2
	(+)	0	0.0%		2	28.6%			
Smoking status	(-)	7	53.8%		4	57.1%		0.888	X^2
	(+)	6	46.2%		3	42.9%			
EF	Normal	11	84.6%		4	57.1%		0.313	X^2
	Low (<55%)	0	0.0%		1	14.3%			
Troponin	(-)	3	23.1%		5	71.4%		0.444	X^2
	(+)	2	15.4%		0	0.0%			
COPD	(-)	12	92.3%		6	85.7%		1.000	X^2
	(+)	1	7.7%		1	14.3%			
Blood usage	(-)	7	53.8%		6	85.7%		0.329	X^2
	(+)	6	46.2%		1	14.3%			
Blood loss		662±684		500		364±333	200	0.379	m
Readmission	(-)	13	100%		6	85.7%		0.350	X^2
	(+)	0	0.0%		1	14.3%			
Postoperative Complication	(-)	11	84.6%		6	85.7%		1.000	X^2
	(+)	2	15.4%		1	14.3%			
Length of stay		5.8±2.2		5.0		7.9±5.7	6.0	0.522	m

X^2: Chi-square test, m: Mann-Whitney U test, RCRI: Revised cardiac risk index, HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, EF: Ejection fraction, COPD: Chronic obstructive pulmonary disease, ECG: Electrocardiography, SR: Sinus rhythm, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, ASA: American Society of Anesthesiologist Physical Status Classification System, SD: Standard deviation

Table 3. The mFI-5 and -mFI-11 score distributions in the RCRI groups

		RCRI very low			RCRI low-moderate				
		Mean ± SD/n-%		Median	Mean ± SD/n-%		Median	p	
mFI-5		1.00±0.41		1.00	2.00±1.15		2.00	0.022	m
mFI-5	0	1	7.7%		1	14.3%		0.007	X^2
	I	11	84.6%		1	14.3%			
	II	1	7.7%		2	28.6%			
	III	0	0.0%		3	42.9%			
mFI-11		1.15±0.38		1.00	2.29±0.95		3.00	0.006	m
mFI-11	I	11	84.6%		2	28.6%		0.022	X^2
	II	2	15.4%		1	14.3%			
	III	0	0.0%		4	57.1%			

X^2: Chi-square test, m: Mann-Whitney U test, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, RCRI: Revised cardiac risk index, SD: Standard deviation

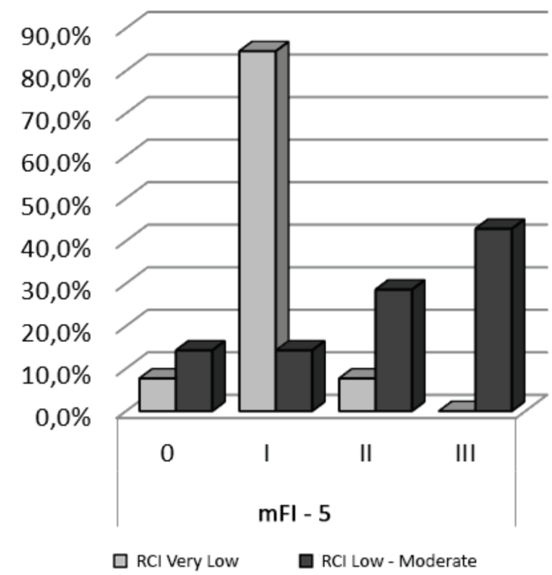

Figure 1a. The mFI-5 score distributions in the RCRI very low and low-intermediate group
RCRI: Revised cardiac risk index, mFI: Modified frailty index

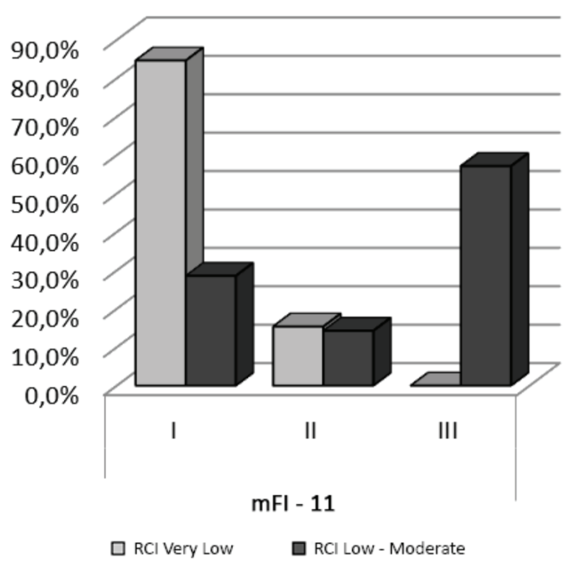

Figure 1b. The mFI-11 score distributions in the RCRI very low and low-intermediate group
RCRI: Revised cardiac risk index, mFI: Modified frailty index

consisting of 11 parameters regarding the dependency of the functional status and history of other concomitant diseases. mFI-5, the abbreviated and condensed form if mFI-11 was demonstrated to be equally effective for serious adverse event prediction in ASD surgery[21]. In our study we used mFI-5 and mFI-11 as risk assessment tools.

Among various complications after spine surgery, the rate of MACEs has been reported to range from 0.67% to 1.6 %[22-24]. Lee et al.[25] reported a 0.8% incidence of cardiac complications after lumbar fusion whereas in the study by Guyot et al.[11] this rate was 6.7%. This wide variation may result from the fact

Table 4. Correlation between RCRI, mFI-5 and mFI-11

		mFI-5	mFI-11
Revised cardiac risk index	r	0.533	0.655
	p	0.016	0.002

Speraman correlation, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, RCRI: Revised cardiac risk index

Table 5. Areas under the curve

	Area under the curve	95% confidence interval			p
mFI-5	0.780	0.508	-	1.000	0.043
mFI-11	0.824	0.599	-	1.000	0.019

ROC curve, ROC: Receiver operating characteristic

that different definitions of MACEs have been used, data from single institutions were collected and post discharge follow-up data were missing. Even though RCRI is widely accepted and used as a predictive tool to estimate risk of MACEs, it does not always make accurate assessments. Of the 3 patients with MACEs in our study, one patient had RCRI of 1 with low risk (0.9%) however 3 points with mFI-5 and mFI-11, considered frail. The other 2 patients had an RCRI of 0 with very low risk (0.04%) and 1 with mFI-5 and mFI-11 considered as prefrail. In a recent large cohort study by Gouda et al.[17], 712,808 patients were evaluated for validation of the hospital frailty risk score. The primary outcome was a composite of death, myocardial infarction or cardiac arrest at 30-days. The hospital frailty score provided additional prognostic information to traditional RCRI risk estimation. For example, for patients with an RCI of 1, the risk of 30-day death, MI and cardiac arrest ranged from 0.35% in the low frailty group to 2.12% in the high frailty group. This is similar to our finding in 1 over 3 patients with MACE who had an RCRI of 1, but 3 with mFI-5 and -11. In the other 2 patients risk scores with similar. As a single institution our sample size was too small to make such a validation.

In our study a significant positive correlation was observed between both the RCRI and mFI-5 (r=0.533/p=0.016) and mFI-11 (r=0.655/p=0.002). Of 5 parameters in mFI, insulin dependent DM and a history of congestive heart failure agree with RCRI. On the other hand, along with the parameters just mentioned, history of myocardial infarction, PTCA, ACBG (coronary artery disease) and CVA are additionally shared with RCRI in mFI-11. That might explain the slightly increased positive correlation of mFI-11 with RCRI.

Study Limitations

Findings of this study needs to be evaluated within the context of some limitations. Firstly, retrospective design limits its generalizability. Secondly, as the data of a single institution is evaluated in this study, the sample size is too small to compare or validate the frailty scores with cardiac risk scores for postoperative cardiac complications in ASD surgeries.

CONCLUSION

RCRI, mFI-5 and mFI-11 are correlated in terms of cardiac risk prediction after ASD surgery. The addition of these frailty scores may increase the prognostic information to traditional risk estimation but this needs further investigation with prospective studies with larger sample sizes and multicenter data.

Ethics

Ethics Committee Approval: The study protocol was approved by the Anadolu Medical Center Ethic Committee and the study was conducted in accordance with the Declaration of Helsinki (no: ASM-EK-23/224, date: 14.06.2023).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.K., S.K., Concept: A.K., S.K., Design: A.K., S.K., Data Collection or Processing: A.K., S.K., Analysis or Interpretation: A.K., S.K., Literature Search: A.K., S.K., Writing: A.K., S.K.

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