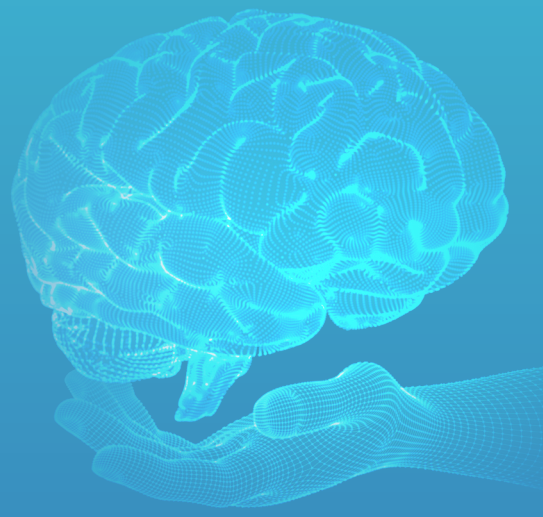
E-ISSN: 3023-784X

Advanced Radiology and Imaging



VOLUME 1 / ISSUE 3
DECEMBER 2024

galenos Publishing House
ARI
advradiology.org

advradiology.org

Advanced Radiology and Imaging

VOLUME 1 / ISSUE 3
DECEMBER 2024

EDITORIAL BOARD

VOLUME 1 / ISSUE 3
DECEMBER 2024

Advanced Radiology and Imaging

advradiology.org

Please refer to the journal's webpage (**https://advradiology.org/**) for "**Journal Policy**" and "**Instructions to Authors**".

The editorial and publication process of the Advanced Radiology and Imaging are shaped in accordance with the guidelines of the **ICMJE, WAME, CSE, COPE, EASE,** and **NISO**. The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing.

Advanced Radiology and Imaging is indexed in **Türkiye Citation Index, IdealOnline, Zenodo, Scilit,** and **Index of Academic Documents.**

The journal is published online.

Owner: Galenos Publishing House

Responsible Manager: Sonay Aydın

Publisher Contact
Address: Molla Gürani Mah. Kaçamak Sk. No: 21/1 34093 İstanbul, Turkey
Phone: +90 (530) 177 30 97 / +90 (539) 307 32 03
E-mail: info@galenos.com.tr/yayin@galenos.com.tr
Web: www.galenos.com.tr
Publisher Certificate Number: 14521

Publication Date: December 2024
E-ISSN: 3023-784X
International scientific journal published quarterly.

advradiology.org

Advanced Radiology and Imaging

VOLUME 1 / ISSUE 3
DECEMBER 2024

CONTENTS

Research Articles

Index

RESEARCH ARTICLE
Out of Context

DOI: 10.4274/AdvRadiolImaging.galenos.2024.88598
Adv Radiol Imaging 2024;1(3):47-50

Effect of Fractional Inspiratory Oxygen Concentration on Perioperative Liver Injury and Lung Imaging

Hakan Gökalp Taş[1], Faruk Subaşı[1], Ufuk Kuyrukluyıldız[1], Serhat Hayme[2]

[1]Erzincan Binali Yıldırım University Faculty of Medicine, Department of Anesthesiology and Reanimation, Erzincan, Turkey
[2]Erzincan Binali Yıldırım University Faculty of Medicine, Department of Biostatistics and Health Informatics, Erzincan, Turkey

Abstract

Objectives: To maintain gas exchange and avoid desaturation during anesthesia, oxygen supplementation is frequently used. Nonetheless, there is an ongoing discussion on the ideal fractional inspiratory oxygen concentrations (FiO_2) concentration, with practices ranging from 30% in Europe to 100% in the US. While preventing hypoxia, high FiO_2 levels can have unfavorable effects, including absorption atelectasis, which may affect liver function in the postoperative period. The purpose of this study was to investigate how perioperative liver injury is affected by varying FiO_2.

Methods: A total of 159 patients aged 18-65 years who underwent procedures lasting more than an hour were included in the study. Three groups of patients - one for each intraoperative FiO_2 concentration - were given 34%, 50%, and 70% of the total. Pre- and postoperative measures of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and international normalized ratio (INR) were used to evaluate liver function. In this prospective trial design, participants with a history of liver disease or other aggravating circumstances were not allowed to participate. Pre- and postoperative chest X-rays were compared.

Results: There were no statistically significant variations in the ALT and AST values of the groups according to the analysis. In contrast to the other groups, the group that received 70% FiO_2 had much lower INR levels. This implies that increased FiO_2 concentrations may have a protective effect against liver function, especially in individuals with impaired liver function. No significant pathological differences were detected between preoperative and postoperative chest X-ray findings.

Conclusion: According to the study findings, patients who require liver-protective medication or have poor liver function may benefit more from high FiO_2 concentrations after surgery. Although there was no indication of liver damage caused by hyperoxia, more investigation using larger samples and longer follow-up is recommended to validate these results.

Keywords: Liver, fractional inspiratory oxygen concentrations, liver failure, general anesthesia, imaging

Introduction

Pre-, during-, and post-anesthesia oxygen supplementation at concentrations above the standard atmospheric 21% is routinely used to prevent desaturation and mitigate the disruption of gas exchange caused by the residual effects of anesthetic and analgesic drugs during airway management. The ideal concentration of this additional oxygen is debatable, and regional variations exist in practice. In the US, oxygen concentrations can reach as high as 100%, whereas in Europe, a 30% concentration is typical.[1] Publications in the literature have shown a strong correlation between postoperative cardiac damage and low intraoperative fraction of inspired oxygen (FiO_2) values.[2] Similar to low FiO_2 levels, high FiO_2 levels can have a major impact on clinical outcomes. One of the negative consequences of elevated FiO_2 levels is absorption atelectasis.[3] During the perioperative phase, surgical site infections are critical. To aid in the prevention of these infections, the World Health Organization recommends setting the perioperative FiO_2 concentration to 80%.[4] Typically, the FiO_2 concentration is maintained between 30% (low) and 80% (high) to minimize the negative effects of high oxygen therapy and prevent hypoxia.[5]

Hypoxemia or ischemia due to other causes can particularly cause liver tissue damage, especially following reperfusion.[6,7] Tissue damage can also result from hyperoxia because it produces free oxygen radicals.[8]

In order to determine the ideal FiO_2 levels for patients with impaired liver function or those in need of liver-protective medication, this study aimed to examine the impact of different FiO_2 concentrations on perioperative liver injury.

Cite this article as: Taş HG, Subaşı F, Kuyrukluyıldız U, Hayme S. Effect of Fractional Inspiratory Oxygen Concentration on Perioperative Liver Injury and Lung Imaging. Adv Radiol Imaging. Adv Radiol Imaging. 2024;1(3):47-50

Address for Correspondence: Hakan Gökalp Taş MD, Erzincan Binali Yıldırım University Faculty of Medicine, Department of Anesthesiology and Reanimation, Erzincan, Turkey
E-mail: hakangokalptas@hotmail.com ORCID ID: orcid.org/0000-0001-5680-9544
Received: 07.09.2024 Accepted: 10.09.2024 Epub: 15.09.2024 Published: 18.12.2024

Methods

The investigation was planned as an observational prospective study that would be conducted in the operating room of our institution. The study was approved by Erzincan Binali Yıldırım University's Clinical Research Ethics Committee (approval number: 2022-08/5, approval date: 22.12.2022). All patients who collaborated provided written informed consent. According to G-Power analysis, the study comprised 159 patients, aged 18-65, who were categorized as American Society of Anesthesiologists (ASA) 1, 2 and 3 and underwent surgical procedures at the Mengücek Gazi Training and Research Hospital that took more than an hour to complete between January 1 and June 30, 2023. Exclusion criteria were a history of drug allergies, liver disease, drugs that affect the liver, pregnancy, electrolyte imbalances, organ failure, liver dysfunction, kidney dysfunction, obesity, cachexia, refusal to participate, or inability to cooperate.

One day before the procedure, all patients received information regarding the study protocol and procedures, and written informed consent was obtained. Preoperative chest X-rays were taken from the patients. Patients were taken to the operating room on the day of the procedure, and venous access was performed as usual through the left antecubital fossa. Peripheral oxygen saturation, non-invasive blood pressure monitoring, and three-channel electrocardiography were performed.

Based on intraoperative FiO_2 values, patients were divided into three groups: 34% (Group A), 50% (Group B), and 70% (Group C). A number of preoperative tests were noted, including international normalized ratio (INR), alanine aminotransferase (ALT), and aspartate aminotransferase (AST). General anesthesia was induced in all patients using 0.6 mg/kg of rocuronium, 1 mcg/kg of fentanyl, and 2 mg/kg of propofol. Remifentanil was infused at a rate of 0.5-1 mcg/kg/min, and 2% sevoflurane was infused at a rate of 4 L/min to maintain anesthesia. Groups A, B, and C were given oxygen-medical air mixtures with different FiO_2 concentrations: 34%, 50%, and 70%, respectively. At the end of the operation, anesthetic gases and remifentanil were discontinued, and the patients were transferred to extubation using 100% oxygen. Atropine (0.015 mg/kg) and neostigmine (0.04 mg/kg) were given. All patients underwent blood sampling for AST, ALT, and INR after extubation. After surgery, patients were moved to the postoperative recovery area. Atelectasis, effusion, infiltration, consolidation, and edema were investigated on preoperative and postoperative chest X-rays. Patients with aldrete scores >9 were moved to the ward after the scores were recorded at 5, 10, and 30 minutes. Postoperative chest X-rays were obtained from the patients in the ward. The preoperative and postoperative test results were compared, and the collected blood samples were examined.

Statistical Analysis

IBM Statistical Package for the Social Sciences (SPSS) Statistics 25.0 (SPSS Inc., Chicago, IL, USA) was used for data analysis. For normally distributed variables, descriptive statistics are presented as mean±standard deviation; for non-normally distributed variables, they are presented as median (minimum-maximum); and nominal variables are presented as frequency (%).

The significance of mean differences between the two groups was evaluated using the t-test, whereas differences in medians were evaluated using the Mann-Whitney U test. ANOVA was used to assess mean differences in comparisons involving more than two groups, and the Kruskal-Wallis test was employed to assess median differences. Both Fisher's exact test and Pearson's chi-square test were used to assess nominal variables.

When the distribution was non-normal, the Spearman correlation test was used to evaluate the relationship between continuous variables; when the distribution was normal, the Pearson correlation test was employed.

Results were considered statistically significant at a p value of <0.05.

Using one-way ANOVA and an effect size (Cohen's f) of 0.25 for the comparison of AST, ALT, and INR values among the three groups, the sample size calculation required 159 individuals. Type 1 Error (α) was set at 0.05 and Power (1-β) was set to 0.80. There was a constant participant count in each group.

Results

The study included 167 individuals with ASA classes 1, 2, and 3 who were aged 18-65 years. Two patients were omitted because of FiO_2 changes caused by desaturation, and six patients were excluded because their surgeries took less than an hour to complete. After the removal of these individuals, the study was concluded, including the 159 participants who were initially scheduled. All patients underwent blood sampling for ALT, AST, and INR measures 1 h prior to surgery and again 1 h following the conclusion of the procedure and the patients' ward transfer. The outcomes were noted and examined.

Of the participants in the study, 62% were female. The mean age of the patients was 43.32±15.20 years. The average duration of the surgeries was measured at 122.45±59.57 minutes.

Pre- and postoperative ALT, AST, and INR values in each group are summarized in Table 1.

When the preoperative and postoperative ALT results were compared, A vs. B: p=0.605, A vs. C: p=0.262, and B vs. C: p=0.545 showed no statistically significant differences were observed between the groups. The postoperative ALT results of all three groups were statistically significantly ($p<0.05$) lower than their preoperative ALT measurements (Figure 1).

There were no statistically significant differences between the groups when the preoperative and postoperative AST findings were analyzed

Table 1. Pre- and postoperative ALT, AST, and INR levels according to groups

	Preoperative			Postoperative		
	ALT	AST	INR	ALT	AST	INR
Group A	25.11±20.28	29.17±36.35	0.99±0.06	22.04±17.50	29.62±33.23	1.10±0.12
Group B	23.60±16.05	23.32±9.24	1.02±0.07	20.64±15.42	22.89±9.68	1.12±0.25
Group C	21.49±10.95	22.06±7.57	1.00±0.06	19.36±9.97	21.92±9.12	1.06±0.13

ALT: Alanine aminotransferase, AST: Alanine aminotransferase, INR: International normalized ratio

(A vs. B: p=0.123; A vs. C: p=0.070; B vs. C: p=0.784). There was no statistically significant difference (p=0.960) between the preoperative and postoperative AST results among all groups were taken into account (Figure 2).

There were no statistically significant differences between Groups A and Group B (p=0.295) or between Groups A and Group C (p=0.278) according to the examination of the INR values. In contrast to Group C, Group B's INR value was statistically considerably higher (p<0.05). Postoperative INR values were significantly higher than preoperative INR values when all groups were taken into account (p<0.05). Although all three groups had considerably higher postoperative INR values than preoperative values, Group C's increase was less noticeable than the other groups' (Figure 3).

No significant pathological findings were detected on preoperative and postoperative chest X-rays in any group. Examples of preoperative and postoperative chest X-rays are shown in Figure 4.

Discussion

To determine the ideal FiO_2 concentration for patients with borderline liver capacity or those in need of liver-protective medication, we examined the effects of several FiO_2 concentrations (34%, 50%, and 70%) on perioperative liver damage. Our findings showed that during the anesthetic process, there was no statistically significant difference in the AST and ALT levels among the various FiO_2 concentrations. In contrast to the other groups, higher FiO_2 concentrations were linked to more favorable INR findings. Therefore, we deduced that patients requiring liver-protective medicine or those with borderline liver function could benefit more from increased FiO_2 levels.

Chronic liver dysfunction significantly elevates perioperative risk. In Europe, 26 cases of cirrhosis occur every 100,000 people. As with all patients, patients with chronic liver disease may require surgery for a variety of reasons. Surgical patients with liver illness have worse morbidity and mortality rates than the general population; in patients with decompensated liver disease, these rates can reach 11.6%.[9-14]

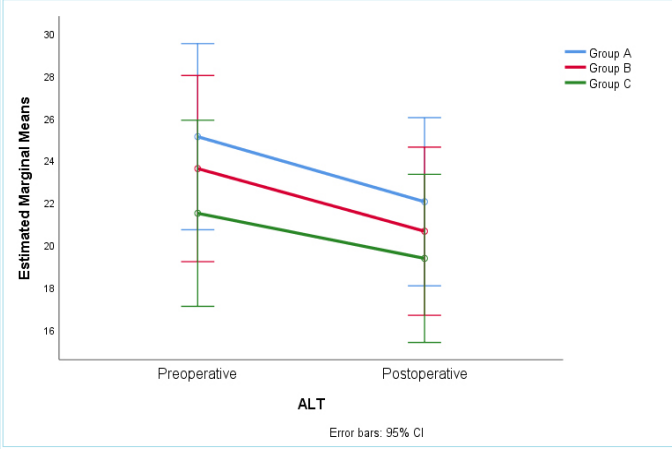


Figure 1. Pre- and postoperative ALT levels

ALT: Alanine aminotransferase, CI: Confidence interval

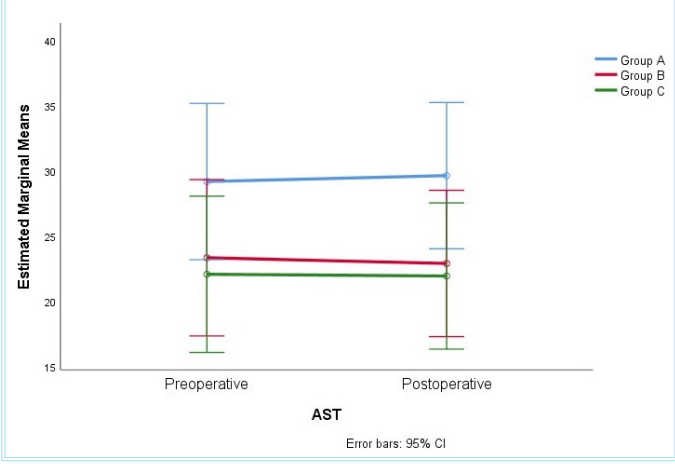


Figure 2. Pre- and postoperative AST levels

AST: Alanine aminotransferase, CI: Confidence interval

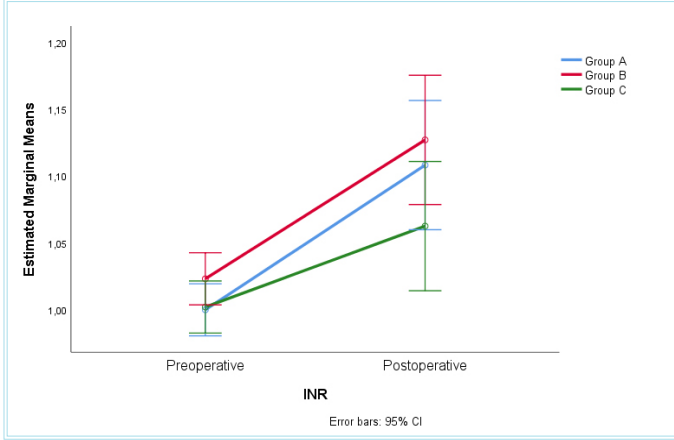


Figure 3. Pre- and postoperative INR levels

INR: International normalized ratio, CI: Confidence interval

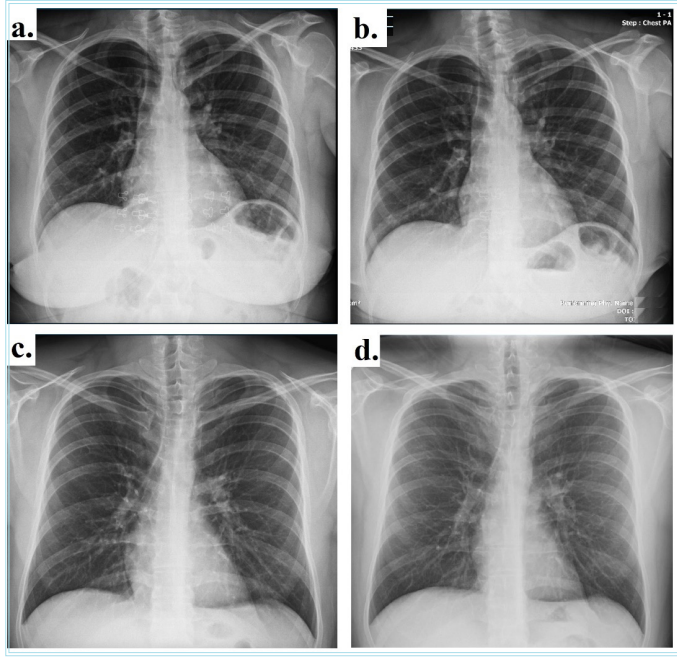


Figure 4. (**a**) Preoperative chest X-ray of a 54-year-old female patient. (**b**) Postoperative chest X-ray of the same patient. (**c**) Preoperative chest X-ray of a 27-year-old male patient. (**d**) Postoperative chest X-ray of the same patient

Worldwide, perioperative oxygen is the standard treatment for general anesthesia. The normal oxygen content in Europe is approximately 30%; however, in the US, it can range from 30% to 100%. Regarding the ideal oxygen concentration for perioperative oxygen treatment, opinions differ. According to recent research, keeping oxygen support at 80% is adequate to prevent perioperative problems.[15-18] In our study, we divided the patients into three groups and monitored them with oxygen support at FiO_2 levels of 34%, 50%, and 70%, respectively.

The literature does not contain any research on the connection between varying FiO_2 levels and liver injury. On the other hand, a study by Pedersen et al.[2] examined the development of myocardial damage in five patient groups undergoing surgery, with intraoperative FiO_2 values varying from 34% to 70%. The study revealed that myocardial damage occurred in tandem with an increase in FiO_2. Furthermore, increased FiO_2 levels were linked to a higher incidence of ischemic events, including myocardial infarction, according to a previous study. Wang et al.[6] demonstrated that ischemia and, in particular, subsequent reperfusion can cause liver damage due to reduced oxygen delivery. On the other hand, a different study conducted by Singer et al.[8] showed that hyperoxia might increase the production of reactive oxygen species, which may cause harm to organs and tissues. We found no evidence of statistically significant differences in ALT and AST levels between groups with increasing FiO_2 concentrations. Compared to the other groups, the group with 70% FiO_2 exhibited a noticeably lower INR increase. This result implies that FiO_2 levels can be advantageous for liver injury. We did not detect any evidence of liver damage related to hyperoxia because we did not exceed 70% FiO_2.

Study Limitations

The study we conducted has some limitations. Power analysis led us to include 159 patients in the study. Larger trials with more patients will yield more reliable results. Preoperatively and 24 hours after surgery, we assessed the ALT, AST, and INR levels. Long-term comparisons of the groups will be more accurate.

Conclusion

Our research concluded that, compared with the other groups, the liver benefited more from increased FiO_2 concentrations. We found that varying FiO_2 concentrations did not affect chest X-ray. Therefore, high FiO_2 concentrations may be more advantageous when liver-protective medication is needed or when liver capacity is questionable.

Ethics

Ethics Committee Approval: This study was conducted in accordance with the Declaration of Helsinki (1975), as revised in 2013. The protocol was reviewed and approved by the Clinical Research Ethics Committee of Erzincan Binali Yıldırım University (approval number: 2022-08/5, approval date: 22.12.2022).

Informed Consent: Informed consent was obtained from all patients before the day of surgery.

Footnotes

Authorship Contributions

Surgical and Medical Practices: F.S., Concept: H.G.T., Design: H.G.T., Data Collection or Processing: F.S., Analysis or Interpretation: U.K., Literature Search: S.H., Writing: H.G.T.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Kabon B, Kurz A. Optimal perioperative oxygen administration. Curr Opin Anaesthesiol. 2006;19:11-8.
2. Pedersen SS, Holse C, Mathar CE, et al. Intraoperative Inspiratory Oxygen Fraction and Myocardial Injury After Noncardiac Surgery: Results From an International Observational Study in Relation to Recent Controlled Trials. Anesth Analg. 2022;135:1021-30.
3. Rothen HU, Sporre B, Engberg G, Wegenius G, Reber A, Hedenstierna G. Prevention of atelectasis during general anaesthesia. Lancet. 1995;345:1387-91.
4. Organization WH. Global guidelines for the prevention of surgical site infection. World Health Organization; 2016.
5. Lim CH, Han JY, Cha SH, Kim YH, Yoo KY, Kim HJ. Effects of high versus low inspiratory oxygen fraction on postoperative clinical outcomes in patients undergoing surgery under general anesthesia: A systematic review and meta-analysis of randomized controlled trials. J Clin Anesth. 2021;75:110461.
6. Wang H, Xi Z, Deng L, Pan Y, He K, Xia Q. Macrophage Polarization and Liver Ischemia-Reperfusion Injury. Int J Med Sci. 2021;18:1104-13.
7. Wang ZY, Liu Y, Li SP, et al. Hypoxia inducible factor 1α promotes interleukin-1 receptor antagonist expression during hepatic ischemia-reperfusion injury. World J Gastroenterol. 2022;28:5573-88.
8. Singer M, Young PJ, Laffey JG, et al. Dangers of hyperoxia. Crit Care. 2021;25:440.
9. Wong MCS, Huang JLW, George J, et al. The changing epidemiology of liver diseases in the Asia-Pacific region. Nat Rev Gastroenterol Hepatol. 2019;16:57-73.
10. Asrani SK, Devarbhavi H, Eaton J, Kamath PS. Burden of liver diseases in the world. J Hepatol. 2019;70:151-71.
11. Martin D, Mantziari S, Demartines N, Hübner M; ESA Study Group. Defining Major Surgery: A Delphi Consensus Among European Surgical Association (ESA) Members. World J Surg. 2020;44:2211-9.
12. Benumof J. Anesthesia & uncommon diseases. (No Title). Elsevier-Health Sciences Division. 1998.
13. Klein J, Spigel Z, Kalil J, Friedman L, Chan E. Postoperative Mortality in Patients With Cirrhosis: Reconsidering Expectations. Am Surg. 2022;88:181-6.
14. Ziser A, Plevak DJ, Wiesner RH, Rakela J, Offord KP, Brown DL. Morbidity and mortality in cirrhotic patients undergoing anesthesia and surgery. Anesthesiology. 1999;90:42-53.
15. Akça O, Podolsky A, Eisenhuber E, et al. Comparable postoperative pulmonary atelectasis in patients given 30% or 80% oxygen during and 2 hours after colon resection. Anesthesiology. 1999;91:991-8.
16. Greif R, Akça O, Horn EP, Kurz A, Sessler DI; Outcomes Research Group. Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection. N Engl J Med. 2000;342:161-7.
17. Greif R, Laciny S, Rapf B, Hickle RS, Sessler DI. Supplemental oxygen reduces the incidence of postoperative nausea and vomiting. Anesthesiology. 1999;91:1246-52.
18. Goll V, Akça O, Greif R, et al. Ondansetron is no more effective than supplemental intraoperative oxygen for prevention of postoperative nausea and vomiting. Anesth Analg. 2001;92:112-7.

RESEARCH ARTICLE

DOI: 10.4274/AdvRadiolImaging.galenos.2024.09719
Adv Radiol Imaging 2024;1(3):51-4

Prevalence of Lumbosacral Transitional Vertebra in Turkish Population: A Retrospective Study

Koray Bingöl[1], Mithat Kerim Arslan[2], Mukadder Sunar[1], Kemal Buğra Memiş[3]

[1]Erzincan Binali Yıldırım University Faculty of Medicine, Department of Anatomy, Erzincan, Turkey
[2]Erzincan Binali Yıldırım University Faculty of Medicine, Department of General Surgery, Erzincan, Turkey
[3]Erzincan Binali Yıldırım University Faculty of Medicine, Department of Radiology, Erzincan, Turkey

Abstract

Objectives: To determine the prevalence of lumbosacral transitional vertebra (LSTV) in patients admitted to the hospital with various complaints in Erzincan and its surroundings and to determine the age-to-gender relationship.

Methods: Magnetic resonance images of 1,164 patients were retrospectively examined. Patients with disc degeneration, over the age of 65, patients with scoliosis, spondylolisthesis, pelvic and spinal region trauma, and patients who had previously undergone lumbar region surgery were excluded from the study. Our study is a retrospective cohort study.

Results: The prevalence of LSTV was 274 patients (23.53%), lumbarization was 264 patients (22.68%), and sacralization was 10 patients (0.85%). Correlations with age and gender variables were also investigated. When age was examined by sex, the average age of the women was calculated as 42.2±13.1 (13-64) years and that of the men was calculated as 41.8±13.0 (12-64) years. Age was statistically similar across the gender groups (p=0.386).

Conclusion: The LSTV is a frequently encountered anatomical variation. It is important to know this in advance and evaluate it, as it will reduce the risk of complications in the nerves and tissues originating from this area in both surgical and invasive interventions to the area.

Keywords: Lumbarization, sacralization, lumbosacral transitional vertebra, spinal surgery, magnetic resonance imaging

Introduction

Morphometric measurements of the human body and the contextual relationships between them constitute the basis of anatomical studies. Morphometry is the statistical presentation of some quantitative variables such as the width, length, and height of structures. The lumbosacral area is a critical area that is subjected to greater force and resistance than other parts of the body, and at this level, there is a dramatic change in the direction of transmission of forces.[1] The sacrum may contain six vertebrae in cases where an additional sacral vertebra is developed or when the fifth lumbar vertebra or the first coccygeal vertebrae are included in the area. The phenomenon of the inclusion of the fifth lumbar vertebra in the sacral region is called "sacralization", and the phenomenon of reduction of the sacral components due to the separation of the first sacral vertebra is called "lumbarization" Figures 1, 2. Lumbarization and sacralization of the lumbosacral region are referred to as the lumbosacral transitional vertebra (LSTV).[1,2] LSTV is a normal anatomical variation with characteristics of both the lumbar and sacral vertebrae and is considered a clinically important condition. LSTV, first described by Bertolotti[3] in 1917, is a variation that is usually detected randomly in patients presenting to the clinic with different and unrelated symptoms.[4] LSTVs are congenital spinal anomalies of the spine and are highly prevalent in the general population, with a reported value of 4-30%. The degrees of morphological variation in the lowest or superior sacral segment vary from the L5 vertebrae with enlarged longitudinal processes to complete fusion with the sacrum. On the contrary, the S1 vertebral segment may show varying degrees of lumbarization, such as well-formed lumbar-type facet joints, a square appearance in the sagittal plane, and abnormal articulation formation rather than merging with the rest of the sacrum.[5] In the literature; It is stated that since the existing biometric structure of the spine is disrupted in the presence of LSTV, clinical conditions such as spondylolysis, peripheral and central stenosis, intervertebral disc pathologies, and facet arthritis are encountered.[6] The literature defining the LSTV is relatively limited. There are many studies that discuss the prevalence, diagnosis, and management of LSTVs, but many of these studies show the need to reveal more population and variation

Cite this article as: Bingöl K, Arslan MK, Sunar M, Memiş KB. Prevalence of Lumbosacral Transitional Vertebra in Turkish Population: A Retrospective Study. Adv Radiol Imaging. 2024;1(3):51-4

Address for Correspondence: Mukadder Sunar MD, Erzincan Binali Yıldırım University Faculty of Medicine, Department of Anatomy, Erzincan, Turkey
E-mail: mukaddersunar@gmail.com ORCID ID: orcid.org/0000-0002-6744-3848
Received: 22.05.2024 Accepted: 17.07.2024 Epub: 18.07.2024 Published: 18.12.2024

findings to help understand LSTVs and their impact on patients.[7] There is no standard method for diagnosing LSTV. Methods such as X-rays, computed tomography (CT), and magnetic resonance imaging (MRI) are used for diagnosis. The oldest of these is direct radiographs made with X-rays. It is accepted that the diagnosis of LSTV can be best assessed using anteroposterior radiography.

CT is a method that allows imaging of bone and soft tissue elements in the spinal region and is quite successful in evaluating bones compared with other imaging methods. An important advantage of MRI is that radio waves are used, and images can be captured in any plane without changing the patient's position. At the same time, it is especially preferred because it has the highest soft tissue contrast resolution.

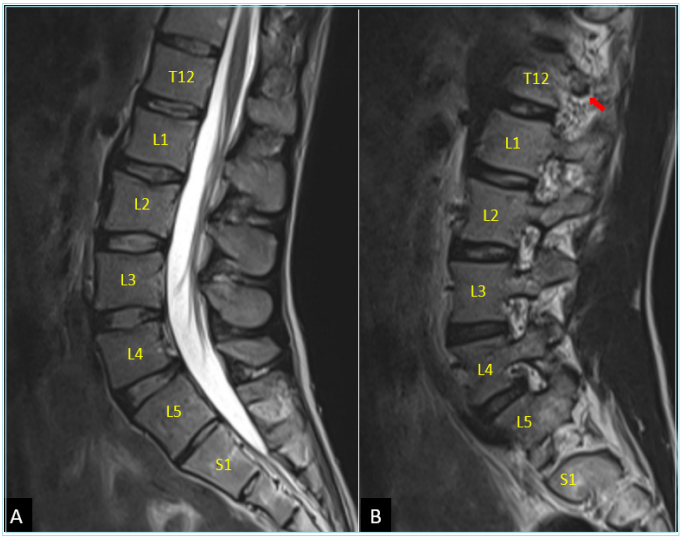


Figure 1. Sacralization of L5. Sagittal plane T2W lumbar magnetic resonance images (MRI) (A, B) showing the sacralized 5th lumbar vertebra. The 12th thoracic vertebra was confirmed by observing the 12th rib (red arrow) on sagittal T2W MRIs

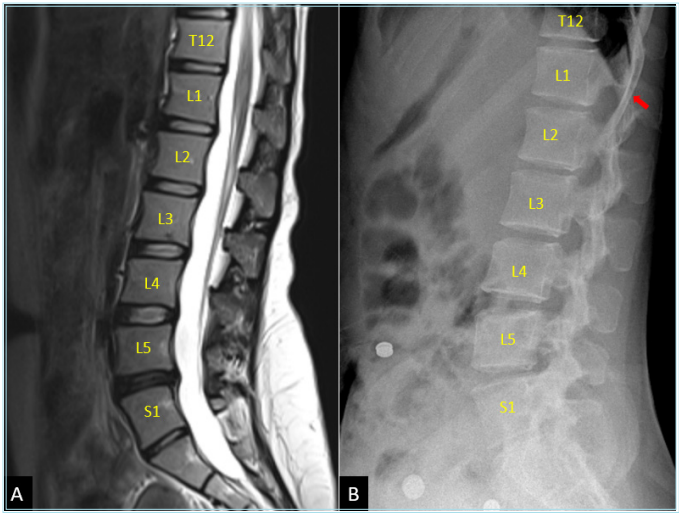


Figure 2. Lumbarization of S1. In the sagittal plane, T2-weighted lumbar magnetic resonance imaging (A) and lateral lumbar radiograph (B) show the summarized 1st sacral vertebra. The 12th thoracic vertebra was confirmed by observing the 12th rib (red arrow) on the lateral lumbar radiograph

In our study, we aimed to compare age, sex, and lumbalization/sacrosanctation values in patients from the Erzincan region who visited the clinic for various reasons and were diagnosed with LSTV.

Methods

Patient Population and Demographic Data

In this study, images taken at Erzincan Binali Yıldırım University Mengücek Gazi Training and Research Hospital Radiodiagnostic Department between 01.01.2020 and 21.07.2022 were used. Approval for the study was obtained from Erzincan Binali Yıldırım University Clinical Research Ethics Committee (ethics committee decision date: March 30, 2023; decision number: 2023-07/4). MRI of the lumbosacral region of 1,164 patients, which were obtained from the department of radiodiagnostics between these dates, were retrospectively analyzed. Patients aged >65 years, those with scoliosis, spondylolisthesis, pelvic or spinal region trauma, and those who had previously undergone lumbar region surgery were excluded from the study on the grounds that their normal anatomy may be disrupted. Finally, 274 patients (119 men, 155 women) who were eligible for the study were identified, and their gender and age were recorded.

Acquisition and Processing of Images

All MRI images were obtained using a 1.5T MRI machine with a 32-channel lumbar coil (Magnetom Aera, Siemens, Erlangen, Germany). Images were taken with the patient in the supine position: sagittal plane T2-weighted images TR (time of repetition): 4120 ms, TE (time of echo): 104 ms, average: 2, field of view: 280 mm, slice thickness: 4 mm, voxel size: 0.9*0.9*4 mm; sagittal plane T1 images TR: 646 ms, TE: 9 ms, average: 2, field of view: 280 mm, slice thickness: 4 mm, voxel size: 0.9*0.9*4 mm; and axial plane T2-weighted images TR: 5070 ms, TE: 88 ms, average: 1, field of view: 190 mm, slice thickness: 4 mm, voxel size: 0.7*0.7*4 mm.

All MRI images were re-evaluated by a radiologist with 10 years of experience. The MRIs were transferred to an image archiving and transmission system workstation (Akgün PACS Viewer v7.5, Akgün Software, Ankara, Turkey) for analysis and measurement in standard digital imaging and medical formats.

Evaluation of Images

The presence of the LSTV, which constitutes the morphological data, was obtained from the coronal and sagittal reformate images and recorded. This was considered as lumbarization and sacralization.

Statistical Analysis

IBM Statistical Package for the Social Sciences 22 (IBM Corp., Armonk, N.Y., USA) software was used for statistical analysis. The results are summarized as numbers (n) and percentages (%) for categorical variables and as mean±standard deviation and median and minimum-maximum values for continuous variables. The Fisher's exact test was used to analyze categorical variables. The assumption of normality for continuous variables was confirmed by the Kolmogorov-Smirnov test. When comparing continuous variables between two groups, Student's t-test was used when statistical assumptions were met, and Mann-Whitney U test was used when statistical assumptions were not met. The statistical significance level was set at 0.05 for all tests.

Results

As a result of retrospective screening, it was found that 121 (44.2%) of the 274 patients included in the study were male and 153 (55.8%) were female. The gender distribution of patients is presented in Figure 3 as percentages and numbers. The overall average age of the patients was found to be 41.6±13.0 (12-64) years, and the frequency distribution according to the age ranges is shown in Figure 3.

When age was examined by sex, the average age of the women was calculated as 42.2±13.1 (13-64) years and that of the men was calculated as 41.8±13.0 (12-64) years. The results are presented in Table 1. Age was statistically similar across the gender groups (p=0.386).

When LSTV positivity was examined, LSTV was observed in the form of lumbarization in 264 (96.4%) of the 274 patients included in the study.

Age distribution in groups with LSTV (lumbalization and sacralization) was examined, and descriptive statistics of age are presented in Table 1. The median age was similar between the LSTV (S) and LSTV (L) groups (p=0.984).

Discussion

LSTV is an anatomical anomaly observed between the 5th lumbar vertebra and the *os sacrum*.[8] LSTV are characterized by lumbarization and sacralization.[3] Sacralization is related to the extension of the *processus transversus* of the 5th lumbar vertebra and its fusion with the first sacral vertebra to varying degrees. Lumbalization is the development of the first sacral vertebra partially or completely in the lumbar-type morphology. When complete, six lumbar vertebrae are observed.[9] The incidence of sacralization is higher than that of lumbarization.[10]

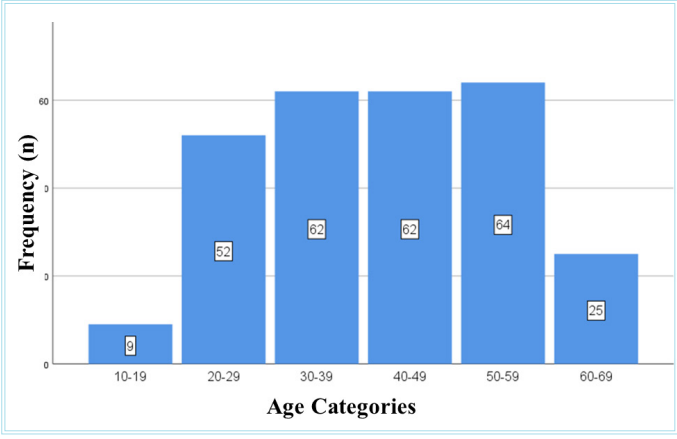


Figure 3. Age distribution of patients

The *ligamentum iliolumbale* is accepted as the reference point for determining the LSTV. In a study using MRI, Carrino et al.[11] found that the *ligamentum iliolumbale* originates from the 5th lumbar vertebra in 96.8 % of cases. Castellvi et al.[12] developed a radiological classification system that defines four types of LSTV. Type 1 includes unilateral (1a) or bilateral (1b) dysplastic *processus transversus*. In type 2, incomplete unilateral (2a) or bilateral (2b) lumbarization/sacralization is observed; there is a diarthrodial joint between the enlarged *processus transversus* and the *os sacrum*. Type 3 is defined by complete osseous fusion of the *processus transversus* to the *os sacrum*. It includes unilateral (3a) or bilateral (3b) lumbalization/sacralization. Type 4 has a type 3 LSTV on one side and a type 2 LSTV on the other side.

O'Driscoll et al.[13] developed four types of classification systems according to the presence or absence of the *discus intervertebralis* and anteroposterior length of S1-2 disc morphology using MRI. According to this classification, between the *os sacrum* and the 1st sacral vertebra; type 1 has no disc and is observed in those without LSTV. In type 2, there is a residual disc. The AP diameter is lower than the AP diameter of the *os sacrum*, and this type is most common in patients without LSTV. In type 3, a normal disc has an AP diameter equal to the AP diameter of the *os sacrum*. Type 3 is observed in the normal *columna vertebralis* and LSTV. Type 4 is similar to type 3, with the difference being that squareness is observed in the first sacral vertebra. There was a good correlation between the type 4 disc and the summarized sacral vertebra.

In patients with LSTV abnormalities, the joint limitation of this region increases as a result of the bilateral fusion of the *processus transversus* of the lowest lumbar vertebra and the *os sacrum*, and this affects the biomechanics of the lumbar region.[14] Because this condition increases the stabilization of this region, *discus intervertebralis* pathology is less common below the LSTV level, whereas disc degeneration is more common because the *discus vertebralis* at the upper level will carry the load.[15] The relationship between low back pain and LSTV was first described by Bertolotti[3] in 1917 and was named Bertolotti syndrome.[16]

There are cases in the literature of surgical procedures performed at the wrong lumbar level if there is a LSTV in both surgical interventions and injections, as it is not known which level the nerve root corresponds to. Therefore, the LSTV can have important clinical consequences.[14]

Although LSTV is a congenital anatomical variation frequently encountered in the lumbosacral region, its pathophysiology and biomechanical effects are not fully understood.[17] In various studies, the incidence of LSTV varies between 4% and 37%.[17] This difference between rates can be explained by assessment errors, differences in individual diagnosis and classification criteria, and factors that create confusion among the population samples investigated.[18,19]

Table 1. Age distribution of LSTV (lumbalization and sacralization) patients and by gender

LSTV	Mean	SD	Median	Minimum	Maximum	p
Sacralization	41.80	15.519	41	23	64	0.984
Lumbalization	41.55	12.965	42	12	64	
Women	42.2	13.1	43	13	64	0.386
Men	40.8	13.0	42	12	64	
Total	41.6	13.0	42	12	64	

The Mann-Whitney U test was applied.
SD: Standard deviation, LSTV: Lumbosacral transitional vertebra

In the 28 studies conducted between 2000 and 2017 that we reviewed regarding LSTV, radiological images of 47,586 patients were examined, and LSTV variations were detected in 6,353 patients (13.3%). In 15 of these studies, researchers stated that LSGV was associated with lumbarization and sacralization. These studies were conducted with a total of 30,053 patients, and the average LSTV rate was 12.45%. Of these, the lumbarization rate was 3.76%, and the sacralization rate was 8.69%. In our study, the incidence of LSTV was higher than the average of 28 studies. According to the averages of 15 studies on sacralization and lumbarization rates, these rates were quite different. In our study, the incidence of LSTV was 23.53%, of which lumbarization was 22.68% and sacralization was 0.85%.[20]

Study Limitations

Although our study was a comprehensive retrospective study, a majority suitable for typing could not be achieved because of the large number of patients who were excluded from the study. In the future, the scope of this study can be expanded to include various morphometric measurements to correlate LSTV with pain in patients with LSTV. Our lumbar MRIs cover T12. The detection was performed on the t12 vertebra.

Conclusion

In our study, we aimed to compare age, sex, and lumbarization/sacralization values in patients from the Erzincan region who came to the clinic for various reasons and were diagnosed with LSTV. Currently, MRI is a method used by radiologists in radiodiagnostic departments in medicine, both for accurate diagnosis and for diagnosis and morphometric measurements of congenital variations, such as LSTV. In addition, the variability in lumbalization/sacralization rates observed according to regional patient profiles indicates the need for screening in larger patient populations.

Ethics

Ethics Committee Approval: Erzincan Binali Yıldırım University Clinical Research Ethics Committee (decision date: 30.03.2023, decision number: 2023-07/4).

Informed Consent: Because this was a retrospective study, informed consent was not required by the ethics committee.

Footnotes

Author Contributions

Concept: K.B., Design: K.B., Data Collection or Processing: K.B., M.K.A., K.B.M., Analysis or Interpretation: K.B., M.K.A., M.S., Literature Search: K.B., M.K.A., K.B.M., Writing: K.B., M.S.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Daniel P, Jerry JJ, Parminder KR. Lumbosacral transitional vertebrae in patients with low back pain: Radiological classification and morphometric analysis. J of Anat Soc. 2019;68:123-8.
2. Standring S, Ellis H, Healy JC, et al. Back and Macroscopic Anatomy of Spinal Cord Gray's Anatomy. 39th ed. Spain Elsevier Livingstone Churchill. 2005;725-98.
3. Bertolotti M. Cotributo alla conoscenza dei vizi di differenzazione regionale del rachide con speciale reguardo all assimilazione sacrale della V. lombare. Radiologia Medica. 1917;4:113-44.
4. Quinlan JF, Duke D, Eustace S. Bertolotti's syndrome. A cause of back pain in young people. J Bone Joint Surg Br. 2006;88:1183-6.
5. Konin GP, Walz DM. Lumbosacral transitional vertebrae: classification, imaging findings, and clinical relevance. AJNR Am J Neuroradiol. 2010;31:1778-86.
6. Hughes RJ, Saifuddin A. Imaging of lumbosacral transitional vertebrae. Clin Radiol. 2004;59:984-91.
7. McGrath K, Schmidt E, Rabah N, Abubakr M, Steinmetz M. Clinical assessment and management of Bertolotti Syndrome: a review of the literature. Spine J. 2021;21:1286-96.
8. Apazidis A, Ricart PA, Diefenbach CM, Spivak JM. The prevalence of transitional vertebrae in the lumbar spine. Spine J. 2011;11:858-62.
9. Sezgin S. Lumbosakral transizyonel vertebra sıklığı; transizyonel vertebraların numaralandırılmasında sagittal sayma ve iliolumbal ligamanın katkısı. Abant İzzet Baysal Üniversitesi İzzet Baysal Tıp Fakültesi Radyodiagnostik Anabilim Dalı, Uzmanlık Tezi, Bolu, (2010). Erişim Adresi: https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=wSLvdAug58-z3NNp4vjaGg&no=q2v-2PlhDkGqShv3jg29bQ
10. Erkoç MF, Balbaloglu Ö, Korkmaz M, et al. The Relationship Between Low Back Pain and Transitional Vertebra Anomaly. Bozok Med J. 2014;4:24-8.
11. Carrino JA, Campbell PD, Lin DC, Morrison WB, Schweitzer ME, Flanders AE, Eng J, Vaccaro AR. Effect of spinal segment variants on numbering vertebral levels at lumbar MR imaging. Radiology. 2011;259:169-202.
12. Castellvi AE, Goldstein LA, Chan DP. Lumbosacral transitional vertebrae and their relationship with lumbar extradural defects. Spine. 1984;9:493-5.
13. O'Driscoll CM, Irwin A, Saifuddin A. Variations in morphology of the lumbosacral junction on sagittal MRI: correlation with plain radiography. Skeletal Radiol. 1996;25:225-30.
14. Delport EG, Cucuzzella TR, Kim N, et al. Lumbosacral transitional vertebrae: incidence in a consecutive patient series. Pain Physician. 2006;9:53-6.
15. Luoma K, Vehmas T, Raininko R, et al. Lumbosacral transitional vertebra: relation to disc degeneration and low back pain. Spine. 2004;29:200-5.
16. Otani K, Konno S, Kikuchi S. Lumbosacral transitional vertebrae and nerve-root symptoms. J Bone Joint Surg Br. 2001;83:1137-40.
17. Elster AD. Bertolotti's syndrome revisited. Transitional vertebrae of the lumbar spine. Spine (Phila Pa 1976). 1989;14:1373-7.
18. Olofin MU, Noronha C, Okanlawon A. Incidence of lumbosacral transitional vertebrae in low back pain patients. West Afr J Radiol. 2001;8:1-6.
19. Bron JL, Van Royen BJ, Wuisman PI. The clinical significance of lumbosacral transitional anomalies. Acta Orthop Belg. 2007;73:687-95.
20. Gökçe C. Multidedektör compüterize tomografi (MDCT) ile basis cranii üzerindeki önemli kemik oluşumlarının morfometrik analizi. Selçuk Üniversitesi Sağlık Bilimleri Enstitüsü. Yüksek lisans tezi, Konya, (2010). Erişim Adresi: https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=8WbBi2KymVrNaoHFY2Z7UA&no=d2AQlE-qb29AbL5iTYSbWA

RESEARCH ARTICLE

DOI: 10.4274/AdvRadiolImaging.galenos.2024.76486
Adv Radiol Imaging 2024;1(3):55-62

Correlations Between Different Types of Posterior Superior Rotator Cuff Tears and Myoarchitecture: Insights from Magnetic Resonance Imaging

Zahra S. M. Husain, Sarah Makki Al Salam, Abdullah Saad Al Driweesh

Dammam Medical Complex, Department of Diagnostic Radiology, Dammam, Saudi Arabia

Abstract

Objectives: Posterior rotator cuff (RC) tears (RCTs) are common and cause adverse structural and functional changes within the associated musculature. Despite our existing knowledge of the architectural features of normal RC muscles, their specific characteristics remain insufficiently understood in the context of RCTs. The aim of the study is to investigate the association between muscle and tendon architectural alterations in posterior superior RCTs and their correlation with the Goutallier grade of the supraspinatus and infraspinatus muscles.

Methods: The study cohort comprised 150 patients with distinct subtypes of posterior superior RCTs, specifically L-shaped, C/U-shaped, and complete tears. Two experienced musculoskeletal radiologists conducted a blinded analysis of the magnetic resonance imaging (MRI) images obtained using a 3.0 Tesla MRI machine to quantify the Goutallier grade for both the supraspinatus and infraspinatus muscles. Furthermore, the authors assessed the muscle architectural parameters of the supraspinatus, including the central tendon angle (CTA), anterior pennation angle (PA), and posterior PA, for each individual in the cohort.

Results: The Goutallier grade was significantly higher in the infraspinatus muscle than in the supraspinatus muscle ($p<0.001$). CTA demonstrated a moderate positive correlation with the Goutallier grade in L-shaped ($p=0.002$) and C/U-shaped tears ($p=0.004$), but no significant correlation was observed in complete tears ($p=0.183$). Specifically, the anterior PA showed a moderate positive correlation with the Goutallier grade in L-shaped tears only ($p=0.02$), whereas the posterior PA exhibited a strong positive correlation across all tear types ($p<0.05$).

Conclusion: In cases of posterior superior RCTs, changes in the posterior PA exhibit a robust correlation with the Goutallier grade of the supraspinatus and infraspinatus muscles. Consequently, the posterior PA can serve as a surrogate marker for evaluating early, irreversible morphological alterations in the RC muscles, thereby prompting timely consideration of surgical interventions.

Keywords: Rotator cuff, muscle atrophy, tendon, MRI, shoulder

Introduction

The supraspinatus muscle and tendon exhibit a complex architecture. The muscle is anatomically divided into two primary regions: anterior and posterior, each exhibiting distinct functional characteristics. The anterior region comprises 75-86% of the muscle volume, with its pennate fiber bundles inserted laterally into the anterior tendon, thereby generating the predominant force output of the muscle. Conversely, the posterior region is considerably smaller in volume and partially situated deep into the anterior region, with parallel fiber bundles inserted laterally into the posterior tendon.[1-5] The functional capacity of a muscle is intrinsically linked to its architectural configuration. Among the architectural parameters, fiber bundle length (FBL) is of paramount importance because it is directly proportional to muscle excursion and contraction velocity.[6,7] A direct linear relationship exists between muscle length and the force of isometric contraction.[8] Consequently, variations in FBL can significantly influence the optimal range and velocity of muscle contraction.[9] In the pennate muscles, only a component of the force of the muscle fibers is aligned with the line of action; thus, alterations in the pennation angle (PA) will also impact the muscle's force-generating capacity.[10] Given that FBL and PA are critical determinants of skeletal muscle function,[11] quantifying these parameters in the pathological supraspinatus is imperative. Existing literature has examined the myoarchitecture of anterior and posterior rotator cuff (RC) tears (RCTs) and related them to one another. However, no previous studies have specifically investigated the subtypes of posterior superior RCT.

The pattern of posterior superior RCT affects the development of surgical planning. C-shaped tears are typically repaired with direct

Cite this article as: Husain ZSM, Al Salam SM, Al Driweesh AS. Correlations Between Different Types of Posterior Superior Rotator Cuff Tears and Myoarchitecture: Insights from Magnetic Resonance Imaging. Adv Radiol Imaging. 2024;1(3):55-62

Address for Correspondence: Zahra S. M. Husain MD, Dammam Medical Complex, Department of Diagnostic Radiology, Dammam, Saudi Arabia
E-mail: Zahra.4@live.com ORCID ID: orcid.org/0000-0003-0867-6702
Received: 05.10.2024 Accepted: 07.10.2024 Epub: 09.10.2024 Published: 18.12.2024

tendons at the greater nodules of the humerus, whereas U-shaped and smaller L-shaped tears require tendon edge convergence and side-to-side tendon repair before the broken tendon can be directly anchored to the bone insertion.[12] Therefore, studying the myoarchitecture of each tear pattern and specifying the tear pattern in radiology reports will help orthopedists in their per-operative planning and guide the management options.

The aim of this study is to investigate the association between muscle and tendon architectural alterations in posterior superior RCTs and their correlation with the Goutallier grade of the supraspinatus and infraspinatus muscles.

Methods

Study Design and Grouping

The study population of this retrospective study comprised adult men and women aged less than 60 years who underwent shoulder magnetic resonance imaging (MRI) between January 2019 and December 2023 at our hospital. All cases meeting the inclusion and exclusion criteria were included in this study, and data were collected by searching the Picture Archiving and Communication System (PACS) of the medical institution. We divided the study population into three groups: 1) those involving L-shaped tears, i.e., tear involving the anterior part of the supraspinatus tendon with a tear gap wider in oblique coronal images and shorter in sagittal oblique images (n=50); 2) those with crescent/U-shaped tears, i.e., a tear that did not affect the anterior part of the supraspinatus or the posterior part of the infraspinatus tendon with a tear gap wider in the oblique-sagittal plane than in the oblique coronal images (n=50); 3) those with a complete tear of the supraspinatus and infraspinatus tendons (n=50).

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: 1) Adult men and women aged less than 60 years old 2) radiological final report with a diagnosis of full-thickness posterior superior RCT. 3) MRI report was reviewed twice by two senior musculoskeletal imaging radiologists, and the diagnosis was confirmed as a full-thickness posterior superior RCT. 3) full-thickness posterior superior RCT presenting as L-shaped, U/crescent-shaped, or a complete tear of the supraspinatus and infraspinatus tendons.

The exclusion criteria were as follows: 1) full-thickness not conforming to L-shaped, U-shaped, crescent-shaped, or complete tear of the supraspinatus and infraspinatus tendons. 2) Concurrent abnormal disease process of the supraspinatus or infraspinatus muscle. 3) Tears to the RC muscles other than the supraspinatus and infraspinatus. 4) Other pathological shoulder processes such as metastatic lesions, Bankart, Hill-Sachs deformity, osteoarthritis or osteonecrosis. 5) Prior RC repair surgery or joint replacement. 6) Absent or poor quality oblique sagittal T1-weighted MRI sequence.

Magnetic Resonance Imaging and Image Analysis

In this study, shoulder MRI examinations were conducted using a 3.0 Tesla MRI machine equipped with a specialized shoulder coil. The imaging protocol included several sequences: 1) an oblique sagittal and oblique coronal T1-weighted fat-sensitive sequence with repetition time (TR) of 600 milliseconds (ms) and time to echo (TE) measuring 15 ms; 2) an oblique sagittal, oblique coronal, and axial proton density fat suppression sequence (TE=40 ms, TR=3000 ms), and 3) an axial T2* gradient inversion recovery sequence (TE=16 ms, TR=1039). The slice thickness for all sequences was 3 mm.

Two senior musculoskeletal imaging radiologists performed a blind analysis of the MRI images. These images were taken from the PACS. They measured the medial-lateral and anterior-posterior tear range data for full-thickness posterior upper RCTs. These tears were recorded based on the RCT shape defined by Davidson and Burkhart[13], which included L-shaped or U-shaped/crescent-shaped tears. A complete tear was defined as a full-thickness tear involving the entire supraspinatus and infraspinatus tendons.

Additionally, diagnostic radiologists retrospectively analyzed the MRI images of each shoulder in the study population and measured the central tendon angle (CTA) and anterior and posterior PA of the supraspinatus muscle (Figures 1, 2). The degree of intramuscular fat infiltration (FI) in the supraspinatus and infraspinatus muscles was independently evaluated using the blind Goutallier grading method utilizing imaging sequences corresponding to a Y-shaped view of each study object. The Goutallier grades used in this study were as follows: grade 0 (no fat), grade 1 (fat stripe), grade 2 (muscle > fat), grade 3 (muscle = fat), and grade 4 (muscle < fat).

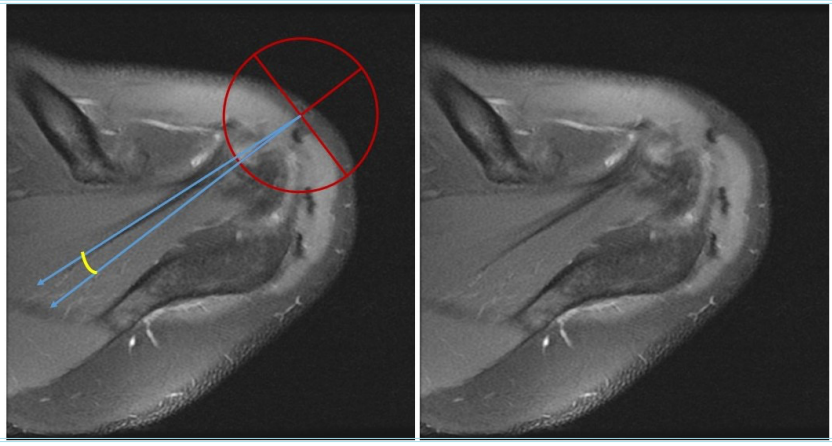


Figure 1. Magnetic resonance imaging axial proton density fat saturation sequence. The red circle demonstrates the humeral head with its transaxial axis. The central tendon angle (yellow arc) was measured between the supraspinatus tendon and the line paralleling the transverse humeral head axis

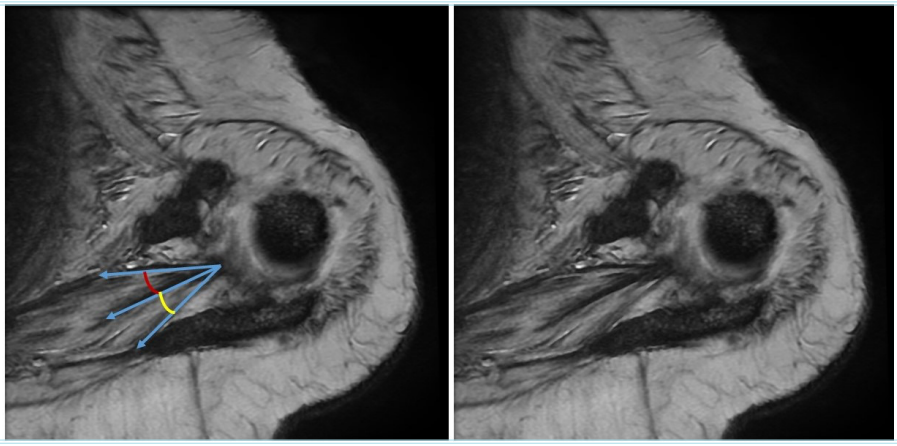


Figure 2. Magnetic resonance imaging axial gradient inversion recovery sequence of the left shoulder joint showing the anterior pennation angle (red arc) and posterior pennation angle (yellow arc)

Statistical Analysis

The data were analyzed using Stata 15.0 statistical software. The chi-square test was used to compare age, male-to-female ratio, tear range, trauma history, and symptom duration (below or above 4 weeks). Additionally, the mean Goutallier grades of the supraspinatus and infraspinatus muscles were compared between the groups using an unpaired t-test after examining the data using the Kolmogorov-Smirnov test. Associations among age, male percentage, tear range, trauma history, and Goutallier grade were evaluated using Spearman's rank correlation coefficient within each group. Additionally, the correlation between CTA, anterior and posterior PA, tear range and subtype, and Goutallier grade was examined using the same statistical method. The reliability between the two assessors was determined by calculating the kappa value, with a significance level of $p<0.05$.

Results

Assessment of the Goutallier Grade of the Supraspinatus and Infraspinatus Muscles

The intraclass correlation coefficients (ICC) for the Goutallier grade measurements provide important insights into the reliability of these assessments. For the supraspinatus muscle, the ICC was 0.500, indicating moderate inter- and intraobserver agreement. Similarly, the infraspinatus muscle had an ICC of 0.480, which also reflects moderate inter- and intraobserver agreement. These results suggest that although there is a reasonable level of consistency between different observers and across repeated measurements, room remains for improvement in the reliability of these measurements.

Analysis and Summary of the Clinical Data of All Subjects in Each Group

The analysis of various factors related to different tear types (Table 1) revealed that the mean ages of the L-shaped, C/U-shaped, and complete tear groups were approximately 51.58, 52.44, and 56.72 years, respectively. The P-value for age differences across these groups is $p<0.001$, indicating a statistically significant difference in age distribution, with the complete tear group being older on average. The percentage of males was fairly consistent across the groups, with 50% in the L-shaped group, 54% in the C/U-shaped group, and 48% in the complete tear group ($p=0.830$). The distribution of right and left side involvement was similar across the groups, with approximately 60-62% of tears occurring on the right side ($p=0.972$). There was significant variation in tear size distribution among the groups, particularly in the complete tear group, which had a higher proportion of larger tears [32% falling within the 3-5 cm range ($p<0.001$)]. Trauma history was relatively uncommon across all groups, with the complete tear group reporting no history of trauma history ($p=0.143$). Most patients in the L-shaped and C/U-shaped tear groups experienced symptoms lasting more than four weeks (86%), whereas all patients in the complete tear group experienced symptoms lasting over four weeks ($p=0.021$).

The analysis suggests that there were statistically significant differences in age, tear size distribution, and symptom duration among the different tear types, whereas gender, side involvement, and trauma history did not show significant differences.

Analysis of Myoarchitecture in Each Group

Analysis of muscle and tendon architecture (Table 2) revealed significant differences among tear types. The comparison of L-shaped and C/U-shaped tears yielded a p value of 0.233 for CTA, indicating no statistically significant difference. However, significant differences were observed between L-shaped and complete tears ($p<0.001$) and C/U-shaped tears ($p<0.001$). Similarly, the anterior PA showed significant differences between the complete tear group and both L-shaped ($p<0.001$) and C/U-shaped tears ($p<0.001$). The posterior PA exhibited statistically significant differences across all comparisons, with particularly pronounced differences between L-shaped and complete tears ($p<0.001$) and a p value of 0.002 when comparing C/U-shaped to complete tears. The findings underscore that the posterior PA is significantly altered in C/U-shaped tears compared with L-shaped tears.

Comparison of Goutallier Grades of the Supraspinatus and Infraspinatus Muscles

The analysis of Goutallier grades for the supraspinatus and infraspinatus muscles (Table 3) revealed that the complete tear group exhibits significantly higher grades. The p values between both groups were extremely low, demonstrating statistically significant differences in Goutallier grade severity among the various types of RCTs. Within each group, the differences between the supraspinatus and infraspinatus muscles were generally not statistically significant; however, the Goutallier grade was notably higher in the infraspinatus muscle than in the supraspinatus muscle for all types of RCT. These findings suggest

Table 1. Analysis and summary of the clinical data of all subjects in each group were performed using the chi-square test

Items	L-shaped tear (n=50)	C/U-shaped tear (n=50)	Complete tear (n=50)	p value
Age (years)	51.58±5.87	52.44±5.00	56.72±2.48	<0.001
Male %	50%	54%	48%	0.830
Side, n (%)				0.972
Right	31 (62%)	30 (60%)	31 (62%)	
Left	19 (38%)	20 (40%)	19 (38%)	
Tear range, n (%)				<0.001
<1 cm	14 (28%)	14 (28%)	0	
1-3 cm	36 (72%)	36 (72%)	34 (68%)	
3-5 cm	0	0	16 (32%)	
>5 cm	0	0	0	
Trauma history, n (%)				0.143
Yes	4 (8%)	3 (6%)	0	
No	46 (92%)	47 (94%)	50 (100%)	
Duration of symptoms >4 weeks, n (%)				0.021
Yes	43 (14%)	43 (14%)	100%	
No	7 (86%)	7 (86%)	0	

Table 2. Comparison of myoarchitecture among the groups using the chi-square test

Item	Normal subjects (n=30)	L-shaped tear (n=50)	C/U-shaped tear (n=50)	Complete tear (n=50)	p value
CTA	6.35±0.67	7.02±1.35	7.31±1.07	9.14±1.56	0.233 <0.001 <0.001
Anterior PA	17.83±1.47	18.47±1.84	18.40±1.59	21.16±2.99	0.857 <0.001 <0.001
Posterior PA	17.86±1.54	19.73±2.38	23.56±3.09	25.53±3.06	<0.001 <0.001 0.0012

CTA: Central tendon angle, PA: Pennation angle

Table 3. Comparison of Goutallier grades of the supraspinatus and infraspinatus muscles using the unpaired t-test after examining the data with a Kolmogorov-Smirnov test

Goutallier grade	L-shaped tear (n=50)	C/U-shaped tear (n=50)	Complete tear (n=50)	p value (between groups)
Supraspinatus	1.88±0.92	1.60±1.20	3.50±0.51	<0.001
Infraspinatus	2.44±1.19	2.54±1.20	3.63±0.76	<0.001
p value (within groups)	0.638	0.114	0.022	

that the severity of Goutallier grade varies markedly among patients with different types of RCTs, particularly highlighting the differential involvement of the infraspinatus muscle.

Correlation Analysis Between Goutallier Grade, Myoarchitecture, and Other Clinical Data

1. L-shaped Tear

Both age and tear size were strongly positively correlated with Goutallier grade in the supraspinatus and infraspinatus muscles, suggesting that older age and larger tears were associated with greater fatty infiltration of the muscles. The duration of symptoms showed a moderate positive correlation, indicating that longer symptoms duration is associated with an increased Goutallier grade. In contrast, trauma history displayed a negative correlation, suggesting that patients with a history of trauma tend to have a lower Goutallier grade than those without such a history. This is likely because the majority of patients with a history of trauma have symptoms lasting less than four weeks (Table 4).

All architectural parameters showed moderate positive correlations with Goutallier grades of the supraspinatus and infraspinatus muscles, with the strongest correlation noted in the posterior PA. The CTA and posterior PA showed moderate positive correlations with duration of symptoms, with no significant correlation found with anterior PA. The tear range exhibited weak positive correlations with the anterior and marginal PAs, indicating that larger tears may contribute to increases in these angles. Conversely, age generally did not show significant correlations with cytoarchitectural angles, suggesting that age may not

directly influence the morphological alteration of muscle architecture in the context of L-shaped tears (Table 5).

2. C/U-shaped Tear

Both age and tear range were strongly positively correlated with Goutallier grade in the supraspinatus and infraspinatus muscles, mirroring the findings of the L-shaped tear group. Trauma history consistently displayed a moderate negative correlation in both muscles. Unlike the L-shaped tear, the duration of symptoms showed no significant correlation with the supraspinatus grade and a weak, borderline significant correlation with the infraspinatus grade. These findings underscore the importance of tear size as a significant factor associated with the severity of muscle fatty infiltration regardless of the duration of symptoms (Table 6).

Age demonstrates a strong correlation with posterior PA, indicating that as age increases, there is a significant increase in posterior PA. Additionally, tear size is consistently correlated with all three cytoarchitectural features, suggesting that larger tears are associated with notable changes in tendon and muscle architecture. The duration of symptoms exhibits moderate correlations with the CTA, posterior PA, and posterior PA, implying that longer symptom duration is linked to structural changes in these areas. Furthermore, the supraspinatus and infraspinatus Goutallier grades were significantly correlated with posterior PA, indicating that higher levels of Goutallier grade in the supraspinatus and infraspinatus muscles are associated with alterations in tendon and muscle architecture (Table 7).

Table 4. Correlation analysis of the average Goutallier grade in the L-shaped tear group

	Supraspinatus muscle		Infraspinatus muscle	
	rs	p value	rs	p value
Age (years)	0.611	<0.001	0.624	<0.001
Duration of symptoms	0.408	0.003	0.326	0.021
Trauma history	-0.366	0.01	-0.398	0.004
Tear range	0.631	<0.001	0.605	<0.001

rs: Spearman's rank correlation coefficient

Table 5. Correlation analysis of myoarchitecture in the L-shaped tear group

	CTA		Anterior PA		Posterior PA	
	rs	p value	rs	p value	rs	p value
Age (years)	-0.117	0.418	-0.223	0.12	-0.129	0.372
Tear range	0.066	0.647	0.309	0.029	0.272	0.056
Duration of symptoms	0.380	0.007	0.232	0.105	0.418	0.003
Supraspinatus Goutallier grade	0.413	0.003	0.366	0.024	0.580	0.006
Infraspinatus Goutallier grade	0.335	0.008	0.269	0.022	0.595	0.002

CTA: Central tendon angle, PA: Pennation angle, rs: Spearman's rank correlation coefficient

Table 6. Correlation analysis of average Goutallier grade in the C/U-shaped tear group

	Supraspinatus muscle		Infraspinatus muscle	
	rs	p value	rs	p value
Age (years)	0.539	<0.001	0.607	<0.001
Duration of symptoms	0.045	0.754	0.277	0.052
Trauma history	-0.293	0.039	-0.405	0.004
Tear range	0.538	<0.001	0.582	<0.001

rs: Spearman's rank correlation coefficient

Table 7. Correlation analysis of myoarchitecture in C/U-shaped tear group

	CTA		Anterior PA		Posterior PA	
	rs	p value	rs	p value	rs	p value
Age (years)	0.47	0.013	0.27	0.1683	0.62	<0.001
Tear range	0.47	0.001	0.48	<0.001	0.36	0.011
Duration of symptoms	0.28	0.046	0.37	0.01	0.41	0.003
Supraspinatus Goutallier grade	0.32	0.025	0.23	0.116	0.22	<0.001
Infraspinatus Goutallier grade	0.40	0.004	0.37	0.088	0.47	<0.001

CTA: Central tendon angle, PA: Pennation angle, rs: Spearman's rank correlation coefficient

3. Complete Tear

The analysis indicates that age has weak or no significant correlation with Goutallier grade in both muscles, whereas tendon retraction has a moderate positive correlation with Goutallier grade in both the supraspinatus and infraspinatus muscles. This finding is likely attributed to the exclusion of elderly patients aged >60 years from the study population to eliminate false-positive results secondary to senile fatty infiltration of the muscles. No significant correlations were found between tear range and trauma history, with some variables being incalculable due to a lack of variability in the data. These findings suggest that tendon retraction is a more influential factor in determining Goutallier grade in the complete tear group, whereas age and tear size play a less significant role (Table 8).

The posterior PA demonstrates the most significant correlations with both Goutallier grade and tendon retraction, indicating that changes in muscle architecture are closely linked to the severity of Goutallier grade and tendon retraction. Tear range was moderately correlated with anterior palmar arch, highlighting a relationship between tear size and anterior muscle architecture. Age was significantly correlated only with posterior PA, suggesting that older patients may exhibit more pronounced changes in this particular aspect of muscle architecture (Table 9).

Discussion

This is the first study to investigate and model both the muscle and tendon architecture of the pathologic supraspinatus. The findings revealed substantial architectural alterations associated with RC tendon pathology, with variations observed among different subtypes of posterior superior RCTs.

The RC forms a crucial structural complex with the anterior edge of the supraspinatus tendon, facilitating force transfer from the tendon to the proximal humerus. This complex provides stress-shielding protection to the posterior upper RC crescent region. In comparison with anterior supraspinatus tendon tears, full-thickness tears involving the RC-anterior supraspinatus tendon complex are closely linked to RC dysfunction.[14] Mesiha et al.[15] emphasized that the integrity of this complex ensures normal biomechanical load distribution from the scapula to the proximal humerus. Notably, full-thickness tears involving the anterior supraspinatus tendon result in larger tendon tears, displacement, and mechanical changes in the stress area. These tears may lead to serious clinical symptoms, joint damage, and propensity for RCT progression.

The posterior region, which exhibits a significantly smaller volume than the anterior region in normal muscle, is highly susceptible to even minor atrophy.[3] Chronic tears may lead to atrophy or complete loss, highlighting the critical importance of early tear detection and prompt tendon repair. Delayed detection is associated with surgical complications and suboptimal outcomes, and substantial alterations in the posterior region may contribute to these challenges.[11,12]

The precise origin of the posterior upper RCT remains a subject of ongoing debate. Some theories propose that it initiates at the center of the crescent area, involving the anterior supraspinatus tendon.[3-5] Researchers speculate that age plays a crucial role in the mechanical load transfer from the scapula to the humerus through the RC-anterior supraspinatus tendon complex. Podgórski et al.[14] identified two distinct age-related RCT patterns: 1) Young patients exhibit a robust RC crescent part (the crescent dominant mode), while 2) Elderly patients experience a weakened RC crescent part due to age-related tendon degeneration (the RC dominant mode). Additionally, RC hypertrophy may serve as an adaptation to age-related crescent thinning. Notably, the present study found a positive correlation between age and average Goutallier grade in the L-shaped and C/U-shaped tear groups, supporting the hypothesis.

Previous research indicates that anterior supraspinatus tendon tears are associated with higher fatty infiltration of the supraspinatus than RCTs in other regions. Researchers have speculated that the histology and function of the anterior supraspinatus tendon differ from those of the RC.[5] Additionally, Kim et al.[16] found that full-thickness RCTs, even small-scale tear, result in more severe supraspinatus fatty infiltration when the anterior supraspinatus tendon is involved and less fatty infiltration when it is not. Our investigation revealed a noteworthy association between the degree of fatty infiltration in the supraspinatus muscle and a specific RCT. This phenomenon is particularly pronounced in L-shaped posterior superior RCTs that partially extend into the anterior portion

Table 8. Correlation analysis of the average Goutallier grade in complete tear group

	Supraspinatus muscle		Infraspinatus muscle	
	rs	p value	rs	p value
Age (years)	0.157	0.276	0.297	0.036
Tear range	-0.171	0.234	-0.210	0.143
Tendon retraction	0.435	0.002	0.497	<0.001

rs: Spearman's rank correlation coefficient

Table 9. Correlation analysis of myoarchitecture in complete tear group

	CTA		Anterior PA		Posterior PA	
	rs	p value	rs	p value	rs	p value
Age (years)	-0.248	0.083	-0.135	0.35	0.315	0.026
Tear range	-0.036	0.806	0.413	0.003	0.106	0.466
Supraspinatus Goutallier grade	0.247	0.084	0.039	0.789	0.638	<0.001
Infraspinatus Goutallier grade	0.192	0.183	0.106	0.466	0.648	<0.001
Tendon retraction	-0.022	0.881	0.076	0.602	0.539	<0.001

CTA: Central tendon angle, PA: Pennation angle, rs: Spearman's rank correlation coefficient

of the supraspinatus tendon. In contrast, C/U-shaped tears that do not involve the anterior supraspinatus tendon exhibit lower degrees of fatty infiltration.

Infraspinatus fatty infiltration is not proportionally correlated with the extent of full-thickness tears observed on MRI. Mochizuki et al.[17] conducted an autopsy study and revealed that the footprint of the infraspinatus tendon insertion was larger than previously assumed. Furthermore, the insertion extended further forward into the articular surface of the upper part of the greater tuberosity of the humerus. Consequently, the insertion range of the greater tuberosity of the humerus in the supraspinatus tendon was much smaller than previously believed. This information highlights the importance of considering anatomical variations when assessing RCT and its impact on muscle function. In our investigation, we observed that the Goutallier grade for fatty infiltration was consistently higher in the infraspinatus muscle than in the supraspinatus muscle across all subtypes of superior posterior RCTs. Notably, the most pronounced difference was observed in complete tear cases.

In the evaluation of tendon architecture, previous research has demonstrated notable changes in the posterior PA in cases of tears affecting the posterior superior RC. Conversely, alterations in the anterior PA are minimal and do not significantly differ.[18,19] Our study corroborates these findings, as we observed significant deviations from the mean normal posterior PA in healthy subjects, particularly in C/U-shaped and complete tears, while the anterior PA exhibited minor deviations with less significant statistical relevance.

In their study, Thompson et al.[4] investigated the CTA of the supraspinatus muscle in both normal subjects and individuals with full-thickness RCTs. The researchers found a statistically significant reduction in supraspinatus CTA among those with full-thickness tears compared with the normal group (17.7 degrees vs. 7.3 degrees; $p<0.001$). Interestingly, our study showed that the mean CTA in normal subjects was much lower than that observed in the literature, and across all tear subtypes, there was a consistent positive trend in CTA. Notably, the most pronounced difference in CTA was observed in complete tears. Furthermore, the study revealed a moderate correlation between CTA and Goutallier grade L-shaped and C/U-shaped tears. These findings highlight the clinical relevance of CTA measurements in assessing the pathology of RC.

Study Limitations

This study has several limitations that warrant consideration. First, its retrospective nature restricted data collection to relevant clinical information available within our institution's PACS. Consequently, only data from this specific source were retrieved. Second, certain factors remained unclear due to the study design. Specifically, information regarding the dominant hand and the range and intensity of daily shoulder activities were not available for the study participants. Third, caution should be exercised when generalizing the findings. The conclusions may not apply to RCTs that were not included in this specific investigation. Additionally, the lack of surgical confirmation in RCTs introduces an element of uncertainty. Although our study demonstrated moderate inter- and intraobserver agreement for the Goutallier grade measurements, this level of consistency highlights the need for further standardization and training to enhance the reliability of this observational assessment. Furthermore, the study sample size was relatively small, which could have affected the statistical power and generalizability of the results. Moving forward, large-scale studies are essential to validate the current findings and explore potential differences among various full-thickness RCTs. Additionally, leveraging big data research projects could shed light on the clinical correlations between different RCT patterns, CTA, anterior and posterior PA, FI, and postoperative outcomes.

Conclusion

In summary, our study revealed a strong association between alterations in muscle architecture and Goutallier grade of the supraspinatus and infraspinatus muscles in posterior superior RCT cases. Notably, the posterior PA is a valuable surrogate marker for detecting early, irreversible morphological changes in the RC muscles, prompting timely consideration of surgical intervention. These findings underscore the clinical significance of assessing the posterior PA in managing patients with RC pathology.

Ethics

Ethics Committee Approval: The study was approved by the Research and Ethics Committee of Dammam Medical Complex under the Trainee Research Category (EXT0409) on March 4, 2024.

Informed Consent: Since the study was a retrospective study, informed consent was not required by the ethics committee.

Footnotes

Authorship Contributions

Concept: Z.S.M.H., S.M.A.S., A.S.A.D., Design: Z.S.M.H., Data Collection or Processing: S.M.A.S., A.S.A.D., Analysis or Interpretation: Z.S.M.H., S.M.A.S., A.S.A.D., Literature Search: Z.S.M.H., Writing: Z.S.M.H.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Roh MS, Wang VM, April EW, Pollock RG, Bigliani LU, Flatow EL. Anterior and posterior musculotendinous anatomy of the supraspinatus. J Shoulder Elbow Surg. 2000;9:436-40.
2. Ward AD, Hamarneh G, Ashry R, Schweitzer ME. 3D shape analysis of the supraspinatus muscle: a clinical study of the relationship between shape and pathology. Acad Radiol. 2007;14:1229-41.
3. Kim SY, Boynton EL, Ravichandiran K, Fung LY, Bleakney R, Agur AM. Three-dimensional study of the musculotendinous architecture of supraspinatus and its functional correlations. Clin Anat. 2007;20:648-55.
4. Thompson SM, Reilly P, Emery RJ, Bull AM. An anatomical description of the pennation angles and central tendon angle of the supraspinatus both in its normal configuration and with full thickness tears. J Shoulder Elbow Surg. 2011;20:899-903.
5. Karas V, Wang VM, Dhawan A, Cole BJ. Biomechanical factors in rotator cuff pathology. Sports Med Arthrosc Rev. 2011;19:202-6.
6. Lieber RL, Ward SR. Skeletal muscle design to meet functional demands. Philos Trans R Soc Lond B Biol Sci. 2011;366:1466-76.
7. Lieber RL, Fridén J. Clinical significance of skeletal muscle architecture. Clin Orthop Relat Res. 2001:140-51.
8. Morrison JB. The mechanics of muscle function in locomotion. J Biomech. 1970;3:431-51.

9. Lieber RL, Bodine-Fowler SC. Skeletal muscle mechanics: implications for rehabilitation. Phys Ther. 1993;73:844-56.
10. Gans C, Gaunt AS. Muscle architecture in relation to function. J Biomech. 1991;24(Suppl 1):53-65.
11. Powell PL, Roy RR, Kanim P, Bello MA, Edgerton VR. Predictability of skeletal muscle tension from architectural determinations in guinea pig hindlimbs. J Appl Physiol Respir Environ Exerc Physiol. 1984;57:1715-21.
12. Mihata T, McGarry MH, Ishihara Y, et al. Biomechanical analysis of articular-sided partial-thickness rotator cuff tear and repair. Am J Sports Med. 2015;43:439-46.
13. Davidson J, Burkhart SS. The geometric classification of rotator cuff tears: a system linking tear pattern to treatment and prognosis. Arthroscopy. 2010;26:417-24.
14. Podgórski MT, Olewnik Ł, Grzelak P, Polguj M, Topol M. Rotator cable in pathological shoulders: comparison with normal anatomy in a cadaveric study. Anat Sci Int. 209;94:53-7.
15. Mesiha MM, Derwin KA, Sibole SC, Erdemir A, McCarron JA. The biomechanical relevance of anterior rotator cuff cable tears in a cadaveric shoulder model. J Bone Joint Surg Am. 2013;95:1817-24.
16. Kim HM, Dahiya N, Teefey SA, Keener JD, Galatz LM, Yamaguchi K. Relationship of tear size and location to fatty degeneration of the rotator cuff. J Bone Joint Surg Am. 2010;92:829-39.
17. Mochizuki T, Sugaya H, Uomizu M, et al. Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. J Bone Joint Surg Am. 2008;90:962-9.
18. Nakajima T, Hughes RE, An KN. Effects of glenohumeral rotations and translations on supraspinatus tendon morphology. Clin Biomech (Bristol, Avon). 2004;19:579-85.
19. Neumann CH, Holt RG, Steinbach LS, Jahnke AH Jr, Petersen SA. MR imaging of the shoulder: appearance of the supraspinatus tendon in asymptomatic volunteers. AJR Am J Roentgenol. 1992;158:1281-7.

RESEARCH ARTICLE
Out of Context

DOI: 10.4274/AdvRadiolImaging.galenos.2024.28863
Adv Radiol Imaging 2024;1(3):63-7

Retrospective Evaluation of Patients with Acute Cholecystitis Who Undergoing Percutaneous Cholestostomy with All Treatment Aspects: Single Center Results

Türkhun Çetin

Erzincan Binali Yıldırım University Faculty of Medicine, Department of Radiology, Erzincan, Turkey

Abstract

Objectives: Percutaneous cholecystostomy (PC) is an important procedure for the treatment of acute calculous cholecystitis (ACC). The main purpose of this research study was to retrospectively analyze all data of patients who underwent PC placement via the transperitoneal (TP) or transhepatic (TH) approach in patients with ACC.

Methods: The datasets of the 59 patients included in the research study included cases who underwent PC in the interventional radiology clinic after ACC diagnosis between January 1, 2022 and September 1, 2024. The data included all six-month follow-up results recorded following the placement of permanent tube catheters with TP or TH percutaneous cholecystostomy procedural techniques after the clinical and radiological imaging diagnoses of ACC.

Results: A total of 59 patients diagnosed with ACC underwent PC placement in 41 cases with TP and 18 cases with TH approach; In patients using the TH procedural technique, there was a slight increase in the bleeding rate (1.8% vs. 0.6%, p=0.01), but there was no significant difference between the two groups in terms of other post-procedural complications (tube dislocation, bile leakage and bile leakage hemorrhage, tube occlusion, peritonitis, organ perforation, etc.).

Conclusion: PC has become an important procedure for the treatment of acute cholecystitis. PC is mostly performed in patients who cannot undergo emergency laparoscopic cholecystectomy, and PC-related complications are much rarer compared with other invasive biliary procedures. The following resolution of the clinical presentation of ACC, cholecystectomy should be performed in patients who can tolerate anesthesia and surgical risks to prevent biliary event recurrence. PC is an effective and reliable intervention to decompress the gallbladder and prevent widespread sepsis.

Keywords: Percutaneous cholecystostomy, percutaneous transhepatic gallbladder drainage, percutaneous transperitoneal gallbladder drainage, calculous cholecystitis, cholecystectomy, percutaneous cholangiography

Introduction

Percutaneous cholecystostomy (PC) is increasingly preferred for acute sepsis control and gallbladder decompression in patients with acute calculous cholecystitis (ACC) and is considered an effective treatment procedure performed by interventional radiologists. Although laparoscopic cholecystectomy (LC) is the current standard treatment for ACC for patients who can tolerate surgery; it has been clearly proven in the last decade that PC is an alternative safe procedure for the emergency treatment of ACC, especially in cases with multiple comorbidities and in patients considered to be at high risk for surgery or anesthesia.[1,2] The developmental stages of PC date back to the 1970s, when PC was first applied to patients with obstructive jaundice. In the 1980s, PC was gradually performed in acute cholecystitis (AC) patients. Currently, according to the World Society for Emergency Surgery guidelines, PC is widely indicated as an alternative treatment for ACC patients who are not suitable for emergency LC, such as those with severe sepsis, shock, or multiple comorbidities.[3-5]

Although there are different techniques for PC, PC is typically performed under local anesthesia using the Seldinger technique and usually under ultrasound systems or scopy guidance for direct visualization of the needle. However, trocar techniques have also been described for applications guided by computed tomography. There is an ongoing debate about the best access route to the gallbladder; the two main techniques involve crossing a segment of the liver to access the gallbladder [transhepatic (TH) approach] or directly entering the lumen of the gallbladder with a puncture [transperitoneal (TP) approach].[1,6-8]

Cite this article as: Çetin T. Retrospective Evaluation of Patients with Acute Cholecystitis Who Undergoing Percutaneous Cholestostomy with All Treatment Aspects: Single Center Results. Adv Radiol Imaging. 2024;1(3):63-7

Address for Correspondence: Türkhun Çetin MD, Erzincan Binali Yıldırım University Faculty of Medicine, Department of Radiology, Erzincan, Turkey
E-mail: turkhuncetinmd@gmail.com ORCID ID: orcid.org/0000-0003-0209-4218
Received: 27.10.2024 Accepted: 29.10.2024 Epub: 31.10.2024 Published: 18.12.2024

The TH approach is recommended to provide stable access to a potentially mobile gallbladder, provide a good ultrasonographic acoustic window, and reduce the risk of iatrogenic perforation of the intestines. In addition, the possibility of bile leakage and subsequent peritonitis decreases when the gallbladder perforation is contained by the liver parenchyma.[4,7,8] In contrast, TP approaches can be considered a simpler procedure with a reduced risk of liver parenchymal injury and hemorrhage. Anatomical considerations, including the patient's body structure and mobility, can determine the approach technique and treatment procedures.[9,10]

Methods

The datasets of the 59 patients included in this research study include patients who underwent PC in the interventional radiology clinic of Erzincan Binali Yıldırım University Faculty of Medicine Training and Research Hospital after the diagnosis of ACC between January 1, 2022 and September 1, 2024. For this retrospective research study, scientific approval and permission was obtained from the Ethics Committee of Erzincan Binali Yıldırım University Faculty of Medicine (approval number: 2023.12/003-128.6, decision date: 12.12.2023). The data included detailed evaluations of all six-month follow-up results recorded following the placement of permanent tube catheters with TP or TH PC procedural techniques after the diagnosis of ACC as clinical and radiological imaging. Case data were collected by obtaining follow-up data on catheter placement techniques together with short-term and medium-term results (including post-procedural complications and re-application).

Data Collection

The obtained data included preprocedural demographic information, biochemical analyses, radiological imaging results, complicated or uncomplicated cholecystitis, and factors associated with the technical PC procedure. The patient group defined as complicated cholecystitis included cases associated with emphysematous cholecystitis, gangrenous cholecystitis, abscess formation and collection, gallbladder perforation, or biloma.

Statistical Analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences version 27 (IBM Corp. Armonk, NY). Categorical data points were analyzed using Fisher's exact test or χ^2 test. Mann-Whitney U test was used for ordinal or nonparametric continuous variables, and the independent sample t-test was used for other variables. Data were evaluated using multivariate logistic regression modeling to account for potential confounders, such as age, gender, and ACC severity. Throughout the data analysis, p values <0.05 were consistently considered significant.

Results

A total of 59 patients (33 female, 26 male) diagnosed with ACC underwent PC placement in 41 cases via TP and 18 via TH approach; there was a slight increase in the bleeding rate in patients using TH procedural technique (1.8% vs. 0.6%, p=0.01), but there was no significant difference between the two groups in terms of other post-procedural complications (cholecystostomy tube dislocation, bile leakage and bile leakage hemorrhage, tube obstruction, tunnel infection, peritonitis, organ perforation, etc.). The frequency of primary complications associated with PC was recorded as only 11 cases (18.6%) in the entire series. No significant difference was observed in mortality rates within the first 3 months after PC application (TH vs. TP, 5.3%, p=0.64 and 7.9%, p=0.52, respectively). Rehospitalization rates in patients with recurrent calculous cholecystitis were significantly higher in the TH group than in the TP procedural approach (13.2% vs. 8.9%, respectively, p=0.01).[3,11,12]

There was no significant difference in the size of the cholecystostomy tube between the 8- and 10-Fr catheter tube groups. More patients in the TP group had complicated cholecystitis than in the TH group (54.9% vs. 38.7%, p=0.02). No statistically significant difference was found in median C-reactive protein (CRP) (274 TH vs. 281 TP, mg/L) in the biochemical analysis, which is considered an indicator of sepsis burden. No significant difference in morbidity associated with other PC procedures, including biloma formation or abscess formation, was observed. There was no relationship between tube size and periprocedural bleeding rates (Table 1).[3,13-15]

Discussion

PC is a technically feasible and safe alternative to emergency cholecystectomy in patients with AC who have multiple comorbidities or severe inflammation and infection. PC is also considered an effective procedure that can drain infectious bile and relax the gallbladder; moreover, PC reduces the severity of systemic infection in a short time. Regarding the time from PC placement to disease resolution, Horn et al.[16] reported that most patients showed clinical improvement on an average of 3-4 days after PC placement. They demonstrated significant decreases in white blood cell and CRP levels after PC; in particular, the latter study focused mainly on patients with acute acalculous cholecystitis.[3,14,17,18]

The TP approach was not associated with increased bile leakage, which is an important rationale for preferring a TH approach in the literature and popular discourse. This may be due to limited bile leakage from the site at the time of placement or in the context of acute sepsis and severe inflammation, where a small bile leak may not cause significant additional irritation to the peritoneum (Table 2).[1,9,13]

For patients with complete PC tube displacement, complete evaluation is necessary. Once the patient is confirmed to be asymptomatic, he or she can be discharged without repeat PC. For patients with suspected partial PC tube displacement, cholangiography can be performed to confirm the position of the drainage tube. The decision to keep or remove the drainage tube is made by the physician or radiologists based on the general condition of the patient. Among patients complicated by bile leakage, which is usually symptomatic, antibiotics and image-guided

Table 1. High-risk and critical patient groups for cholecystectomy operation

1. Advanced age
2. Leukocytosis
3. Hypoalbuminemia
4. Pericholecystic fluid
5. Diabetes mellitus
6. Elevated total bilirubin content
7. Male sex
8. History of abdominal surgery
9. History of pulmonary disease
10. Serum hemoglobin <9 mg/dL
11. Gallbladder wall diameter (gallbladder wall thickness is over >6.5 mm)

Table 2. Classification of acute cholecystitis severity according to the 2018 Tokyo guidlines[1]

Grade 1 (mild)	Grade 2 (moderate)	Grade 3 (severe)
- No criteria for grade 2 or 3 - Acute cholecystitis in a previously healed patient with no organ dysfunction and mild inflammation of the gallbladder	Any of the following conditions: - Leukocytosis >18,000/mm^3 - Palpable tumor in the right upper quadrant - Symptom duration >72 h - Marked local inflammation (gangrenous cholecystitis, pericholecystic abscess, bile peritonitis, emphysematous cholecystitis)	Any of the following organ dysfunctions: - Cardiovascular: low blood pressure with need for 5 µg/kg/min of dopamine or norepinephrine - Neurological: decline in alertness - Respiratory: PaO_2/FiO_2>300 - Kidney function: oliguria or creatinine >2.0 mg/dL - Liver: INR >1.5 - Hematologic: plateletes >100,000/mm^3

INR: International normalized ratio

drainage should be considered.[8,17] Most patients complicated by minor bleeding can be managed conservatively. If the examination shows tube obstruction, subsequent treatment, including PC tube reinsertion or emergency cholecystectomy, should be based on the patient's clinical condition. Cholecystectomy is recommended for patients who are physically fit for surgery. However, if the patient refuses surgery or has multiple comorbidities, PC tube replacement is recommended. In studies that have compared PC versus open cholecystectomy in critically ill patients with acalculous cholecystitis, less morbidity, fewer days of hospital stay, and lower associated costs have been observed in patients who have undergone PC placement.[15,16,18]

The primary function of PC is to reduce inflammation or infection in patients with AC who cannot tolerate the risk of surgery or anesthesia and not to limit the possibility of definitive surgery. It is important to identify patients who are not suitable for surgery or who are suitable for PC after surgery. In addition, the latest Tokyo Guidelines 2018 revised the algorithm for severe cholecystitis and suggested that patients with Charlson Comorbidity Index 4 and American Society of Anesthesiologists Physical Status 3 should receive expectant management; however, the effectiveness of this classification has not been studied.[10] Future research is needed on the effectiveness of the latest classification and new objective factors that can distinguish patients who are suitable for surgery from those who are not (Figure 1).[3,10,17,19,20]

Despite the lack of clear evidence, the initial puncture of the PC biliary system drainage under ultrasound guidance has been accepted as the standard in many international guidelines. LC is the gold standard treatment procedure for AC and is superior to PC. PC is a valuable option for high-risk and critically ill patients in intensive care who are not suitable for LC and may even be the definitive treatment option. Ultrasonographically guided PC can be performed at the bedside in critically ill patients without fluoroscopy. Recent studies have reported that contrast-enhanced USG can be used in PC for the selection of the correct placement technique and appropriate catheter needle and for confirming the sealing of the gallbladder (Figure 2).[10,13,19,21]

The biggest and most important limitation of this study is that we could not make a comparison with high-risk and critically ill patients who underwent cholecystectomy in the same period. Whether cholecystectomy would be advantageous for this patient group remains unclear.[21,26] In addition, urgent PL may be superior to PC as a definitive treatment method because of the high rate of recurrent ACC symptoms after PC.[22] The results of our study have proven that PC is a safe and effective way to manage AC, especially in high-risk critically ill patients who are followed in the intensive care unit, compared with conservative treatments; we recommend PC as the first treatment option for this particular patient group. We also suggest that PC is an effective and definitive treatment option for stone-free AC in this patient group. In addition, we primarily recommend the TP approach for PC procedures because it is easily applicable, safe, and effective.[7,8,15,22]

Although many meta-analyses have clearly demonstrated that PC is an effective and reliable treatment alternative in high-risk and critically ill patients in whom LC surgery is contraindicated; it is clear that a standard definition is needed for the criteria considered contraindicated for the operation procedure in the future. The primary function of PC is to reduce the inflammation or infection status of patients with AC who

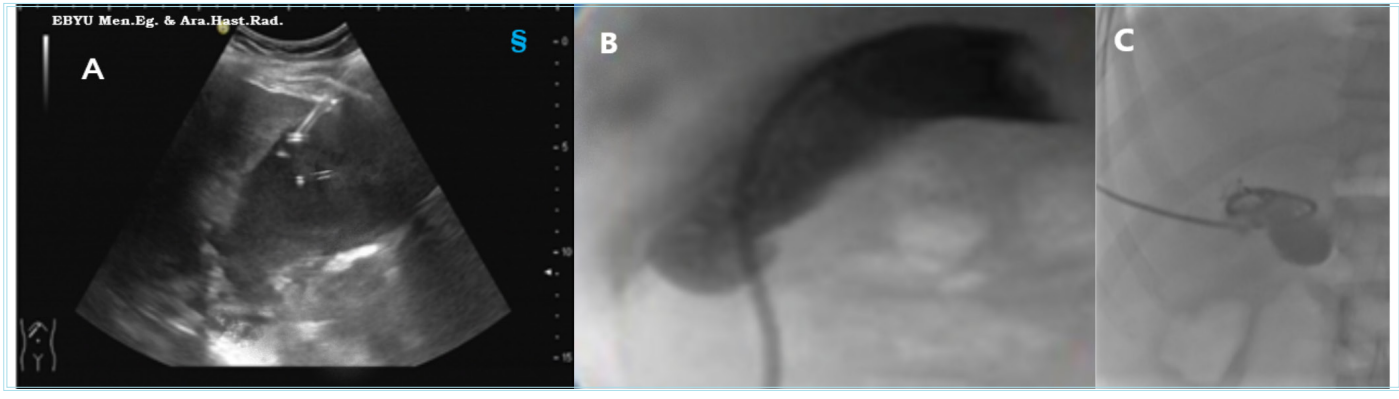


Figure 1. Techniques used for TP or TH percutaneous cholecystostomy. Application of TP or TH percutaneous cholecystostomy under ultrasonography (A) and fluoroscopic guidance (B, C). Placement of 8- and 10-Fr multihole pigtail indwelling drainage catheters after successful confirmation of gallbladder lumen by percutaneous puncture and contrast injection

TP: Transperitoneal, TH: Transhepatic

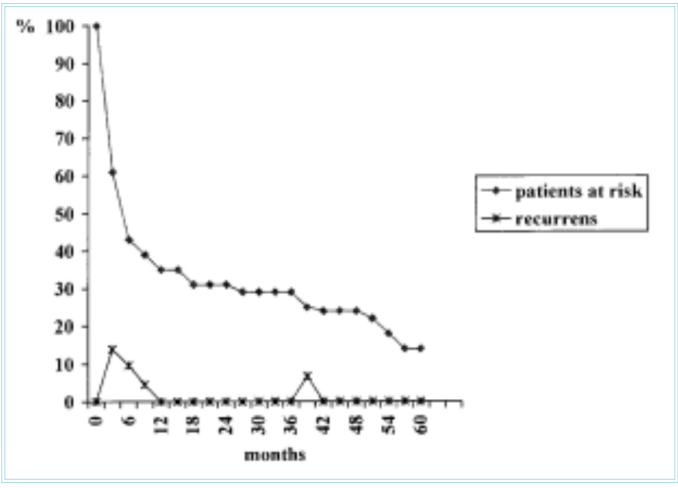


Figure 2. Risk and recurrence of acute cholecystitis in the period following imaging-guided percutaneous cholecystostomy procedures[10]

cannot tolerate the risk of surgery or anesthesia and not limit or prevent the possibility of definitive surgical treatment. Expertise, experience, and clinical experience in interventional interventions directed at the biliary system under ultrasound guidance are increasing, and we believe that they will become more widely applied in the future.[11,22,23] However, it seems certain that all types of interventional radiological procedures will play an increasing role in treatment planning and applications in developed countries with better-equipped health systems and high-technology radiological modalities in the future.[5,11,19,18,24,25]

Conclusion

In recent years, PC has become an important procedure for the treatment of AC. PC is mostly performed in patients who cannot undergo emergency LC, and PC-related complications are much rarer compared with other invasive biliary procedures. The following resolution of the clinical presentation of ACC, cholecystectomy should be performed in patients who can tolerate anesthesia and surgical risks to prevent biliary event recurrence. PC is an effective and reliable intervention to decompress the gallbladder and prevent widespread sepsis until definitive surgical operations.[1,19,26] The placement of the PC catheter tube, procedural techniques, and management should be evaluated individually for each patient, and a personalized decision should be made. Although drainage can be provided with PC as a palliative procedure until the patient is ready for surgery; the presence of gallbladder stones in these patients is a definitive indication for cholecystectomy. Although a time period of 6-8 weeks is generally recommended between PC and cholecystectomy by general surgery authorities; there is no consensus yet on the optimum timing. In selected patients, the strategy of performing cholangiography before removing the PC catheter tube is generally applied. The TP PC approach may be safer than TH, with a lower bleeding complication rate and fewer readmissions.[7,8,15,19]

Ethics

Ethics Committee Approval: All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Committee of Erzincan Binali Yıldırım University Faculty of Medicine (approval number: 2023.12/003-128.6, decision date: 12.12.2023).

Informed Consent: Since the study was a retrospective study, informed consent was not required by the ethics committee. No animal or human studies were conducted by the author for this article.

Footnotes

Financial Disclosure: The author declared that this study received no financial support.

References

1. Aroori S, Mangan C, Reza L, Gafoor N. Percutaneous Cholecystostomy for Severe Acute Cholecystitis: A Useful Procedure in High-Risk Patients for Surgery. Scand J Surg. 2019;108:124-9.
2. Hung YL, Sung CM, Fu CY, et al. Management of Patients With Acute Cholecystitis After Percutaneous Cholecystostomy: From the Acute Stage to Definitive Surgical Treatment. Front Surg. 2021;8:616320.
3. Fleming CA, Ismail M, Kavanagh RG, et al. Clinical and Survival Outcomes Using Percutaneous Cholecystostomy Tube Alone or Subsequent Interval Cholecystectomy to Treat Acute Cholecystitis. J Gastrointest Surg. 2020;24:627-32.
4. Ansaloni L, Pisano M, Coccolini F, et al. 2016 WSES guidelines on acute calculous cholecystitis. World J Emerg Surg. 2016;11:25.
5. Okamoto K, Suzuki K, Takada T, et al. Tokyo Guidelines 2018: flowchart for the management of acute cholecystitis. J Hepatobiliary Pancreat Sci. 2018;25:55-72.
6. Sanjay P, Mittapalli D, Marioud A, White RD, Ram R, Alijani A. Clinical outcomes of a percutaneous cholecystostomy for acute cholecystitis: a multicentre analysis. HPB (Oxford). 2013;15:511-6.
7. Hung YL, Sung CM, Fu CY, et al. Management of Patients With Acute Cholecystitis After Percutaneous Cholecystostomy: From the Acute Stage to Definitive Surgical Treatment. Front Surg. 2021;8:616320.
8. Granlund A, Karlson BM, Elvin A, Rasmussen I. Ultrasound-guided percutaneous cholecystostomy in high-risk surgical patients. Langenbecks Arch Surg. 2001;386:212-7.
9. Chang YR, Ahn YJ, Jang JY, et al. Percutaneous cholecystostomy for acute cholecystitis in patients with high comorbidity and re-evaluation of treatment efficacy. Surgery. 2014; 155:615-22.
10. Kallini JR, Patel DC, Linaval N, Phillips EH, Van Allan RJ. Comparing clinical outcomes of image-guided percutaneous transperitoneal and transhepatic cholecystostomy for acute cholecystitis. Acta Radiol. 2021;62:1142-7.
11. Liu P, Liu C, Wu YT, et al. Impact of B-mode-ultrasound-guided transhepatic and transperitoneal cholecystostomy tube placement on laparoscopic cholecystectomy. World J Gastroenterol. 2020;26:5498-507.
12. Loberant N, Notes Y, Eitan A, Yakir O, Bickel A. Comparison of early outcome from transperitoneal versus transhepatic percutaneous cholecystostomy. Hepatogastroenterology. 2010;57:12-7.
13. Masrani A, Young D, Karageorgiou JP, Mani NB, Picus DD, Kim SK. Management algorithm of acute cholecystitis after percutaneous cholecystostomy catheter placement based on outcomes from 377 patients. Abdom Radiol (NY). 2020;45:1193-7.
14. Polistina F, Mazzucco C, Coco D, Frego M. Percutaneous cholecystostomy for severe (Tokyo 2013 stage III) acute cholecystitis. Eur J Trauma Emerg Surg. 2019;45:329-36.

15. Wang CC, Tseng MH, Wu SW, Yet al. The Role of Series Cholecystectomy in High Risk Acute Cholecystitis Patients Who Underwent Gallbladder Drainage. Front Surg. 2021;8:630916.
16. Horn T, Christensen SD, Kirkegård J, Larsen LP, Knudsen AR, Mortensen FV. Percutaneous cholecystostomy is an effective treatment option for acute calculous cholecystitis: a 10-year experience. HPB (Oxford). 2015;17:326-31.
17. Müller T, Braden B. Ultrasound-Guided Interventions in the Biliary System. Diagnostics (Basel). 2024;14:403.
18. MacCormick A, Jenkins P, Gafoor N, Chan D. Percutaneous transcystic removal of gallbladder and common bile duct stones: a narrative review. Acta Radiol. 2022;63:571-6.
19. Yun SS, Hwang DW, Kim SW, et al. Better treatment strategies for patients with acute cholecystitis and American Society of Anesthesiologists classification 3 or greater. Yonsei Med J. 2010;51:540-5.
20. Hung YL, Chen HW, Fu CY, et al. Surgical outcomes of patients with maintained or removed percutaneous cholecystostomy before intended laparoscopic cholecystectomy. J Hepatobiliary Pancreat Sci. 2020;27:461-9.
21. Chen SY, Huang R, Kallini J, et al. Outcomes of percutaneous cholecystostomy tube placement in patients with acalculous versus calculous cholecystitis. World J Surg. 2022;46:1886-95.
22. Noh SY, Gwon DI, Ko GY, Yoon HK, Sung KB. Role of percutaneous cholecystostomy for acute acalculous cholecystitis: clinical outcomes of 271 patients. Eur Radiol. 2018;28:1449-55.
23. Bundy J, Srinivasa RN, Gemmete JJ, Shields JJ, Chick JFB. Percutaneous Cholecystostomy: Long-Term Outcomes in 324 Patients. Cardiovasc Intervent Radiol. 2018;41:928-34.
24. Yun SS, Hwang DW, Kim SW, et al. Better treatment strategies for patients with acute cholecystitis and American Society of Anesthesiologists classification 3 or greater. Yonsei Med J. 2010;51:540-5.
25. Morse BC, Smith JB, Lawdahl RB, Roettger RH. Management of acute cholecystitis in critically ill patients: contemporary role for cholecystostomy and subsequent cholecystectomy. Am Surg. 2010;76:708-12.
26. McKay A, Abulfaraj M, Lipschitz J. Short- and long-term outcomes following percutaneous cholecystostomy for acute cholecystitis in high-risk patients. Surg Endosc. 2012;26:1343-51.

RESEARCH ARTICLE

DOI: 10.4274/AdvRadiolImaging.galenos.2024.47966
Adv Radiol Imaging 2024;1(3):68-73

Thoracic Endovascular Stent Graft Implantation Efficacy

Şükriye Yılmaz[1], Fatih Boyvat[2], Cüneyt Aytekin[3], Ahmet Muhteşem Ağıldere[2]

[1]*Ankara Etlik City Hospital, Clinic of Radiology, Ankara, Turkey*
[2]*Başkent University Faculty of Medicine, Department of Radiology, Ankara, Turkey*
[3]*Klinikum Bielefeld, Institut Für Radiologie, Department of Radiology, Bielefeld, Germany*

Abstract

Objectives: Thoracic aortic aneurysm (TAA) is an uncommon disease with an incidence of 10.4 per 100,000 and dissection is the major complication of TAA. The treatment of aortic diseases is surgery. In recent years, endovascular stent graft (EVSG) application has been performed for many reasons, especially due to its low complications in the treatment of aortic aneurysm and dissection. The aim of this study is to evaluate the efficacy, treatment results, and complications EVSG implantation.

Methods: A total of 34 patients with thoracic aortic disease who underwent stent grafting between August 2004 and January 2011 were included in the study. The patients' diagnoses and risk factors were recorded. Complications of the procedure and the presence of postprocedural leakage were evaluated. The patients were followed up with computed tomography angiography.

Results: Of the 34 patients who underwent the procedure, 16 had no early, late complications and no leakage, whereas eight required additional stenting and other intervention. During follow up three patients showed acute cerebral infarction and four patients have hospital infections. A total of 7 patients had endoleaks occurred and repair with additional interventions. The average hospital stay is 5.8 days. The mortality rate in the hospital is 11.7%.

Conclusion: The EVSG treatments of acute and chronic thoracic aortic diseases in appropriate patients is an alternative and safe method to surgery with high technical success, low complication rates.

Keywords: Endovascular stent-graft, thoracic aortic aneurysm, computed tomography, anjiography

Introduction

Thoracic endovascular stent graft (EVSG) is the preferred treatment option for thoracic aortic pathologies and consists of placing a stent-graft in the pathological area to restore the lumen. In the last thirty years, the effectiveness of EVSG, especially in type B aortic dissection and aneurysms, has been proven by numerous studies.[1-12] In recent years, studies have been conducted to evaluate the effectiveness of different types and brands of stent grafts.[13-15] Additionally, studies by teams performing EVSG with new and different techniques are of interest.[16,17]

In this study, we tried to present the treatment effectiveness and results of EVSG implantation using different stent-grafts in 34 patients with type B aortic dissection and aneurysm, and especially to emphasize the importance of the complication profile and management.

Methods

Study Population

A total of 34 patients with thoracic aortic disease underwent stent graft implantation. Twenty-six of these patients were male and 8 were female, and their ages ranged from 27 to 81 years (mean age: 64.91 years). The patients' comorbidities, risk factors, post-procedure follow-up, early and late results of the procedure, early and late complications of the procedure, and treatment of complications were evaluated retrospectively. Additionally, the necessity of emergency surgery or additional interventions was investigated. The study inclusion and exclusion criteria are defined below. Criteria for inclusion in the study;

- Patients with complicated and uncomplicated type B aortic dissection, rupture, penetrating ulcer and intramural hematoma
- Degenerative or traumatic type B aneurysms.

Exclusion criteria from the study;

- Patients with Stanford type A aortic dissection, rupture, penetrating ulcer and intramural hematoma
- Patients with chronic dissection associated with connective tissue disease

Ethical approval for the study was granted by the Ethics Committee of Başkent University Faculty of Medicine (code: KA 12-04, date: 16.02.2012).

Cite this article as: Yılmaz Ş, Boyvat F, Aytekin C, Ağıldere AM. Thoracic Endovascular Stent Graft Implantation Efficacy. Adv Radiol Imaging. 2024;1(3):68-73

Address for Correspondence: Şükriye Yılmaz MD, Ankara Etlik City Hospital, Clinic of Radiology, Ankara, Turkey
E-mail: dryavuzer@gmail.com **ORCID ID:** orcid.org/0000-0002-5777-6147
Received: 11.11.2024 **Accepted:** 04.12.2024 **Epub:** 12.12.2024 **Published:** 18.12.2024

Evaluation Before Endovascular Prosedure

All procedures were performed in the angiography unit, under appropriate sterile conditions, by a multidisciplinary team consisting of an interventional radiologist, cardiovascular surgeon and anesthesiologist. All patients were administered local anesthesia and sedation. Before the procedure, patients were evaluated for suitability for aneurysm and dissection repair by computed tomography (CT) angiography (CTA) (Sensation 16, Siemens, Germany) and digital subtraction angiography (Siemens Multistar TOP). Detailed measurements were obtained to determine graft type and dimensions. Iliac and femoral arteries were evaluated for compatibility. Parameters such as the diameters of the false and true lumens of the aorta, vascular calcification, the presence of intraluminal thrombus, and the length of the aneurysmal segment were measured. Informed consent was obtained from all patients after discussion of potential complications.

Endovascular Procedure

After the patient was placed on the angiography table, vascular sheaths were applied to appropriate anatomical areas to facilitate thorax angiography (Table 1). During angiography, segment length and iliac arteries requiring repair (especially if there was potential iliac artery stenosis or angulation on preprocedural CT) were evaluated according to predefined criteria. For aneurysm repair, measurements were made to ensure that the proximal and distal graft implantation sites adhere to intact vessel segments, and the graft diameter was selected to be 20% larger than the measured vessel diameter. After selecting the appropriate stent graft material and confirming vascular access, the patency of the left subclavian artery was assessed. The right common femoral artery was then exposed and accessed via incision. The left femoral artery was incised in five patients (15%) (Table 1). A guidewire was advanced into the aortic arch through an appropriately sized vascular sheath, followed by proper positioning of the sheath for stent graft placement. The stent was directed to the targeted location with the graft delivery system and the graft was positioned correctly. A follow-up angiography was performed to confirm stent placement and assess for any endoleak.

For aneurysm repair, measurements were made to ensure that the proximal and distal graft implantation sites adhere to intact vessel segments, and the graft diameter was selected to be 20% larger than the measured vessel diameter. After selecting the appropriate stent graft material and confirming vascular access, the patency of the left subclavian artery was assessed. The common femoral artery was then exposed and accessed via incision. A guidewire was advanced into the aortic arch through an appropriately sized vascular sheath, then the appropriate sheath for the stent graft was positioned. The stent was directed to the targeted location with the graft delivery system and the graft was positioned correctly. A follow-up angiography was performed to confirm stent placement and assess for any endoleak. Once completed, the vascular sheath was removed and the femoral artery was repaired and closed.

Table 1. The vascular structures used for the access of stent graft for angiography in the endovascular stent graft procedure

	Angiography access	Stent graft access (surgical cutdown)
Right axillary artery	18	-
Left axillary artery	7	-
Right main femoral artery	5	29
Left main femoral artery	4	5

Endovascular Prosthesis

A total of 50 stent grafts were placed in the patient cohort. Stent graft systems used included Medtronic Valiant Captiva, Gore TAG, Jotec E-vita® Thoracic Stent Graft System, and Medtronic [R] Talent stents.

In cases where lesion extension was necessary, the left subclavian artery was occluded in 2 patients with thoracic aneurysms and in 7 patients who underwent dissection. In 1 patient with chronic aortic dissection, planned occlusion of the left subclavian artery was postponed after angiography detected insufficient flow in the right vertebral artery due to atherosclerotic changes. In this case, the left subclavian artery patency was preserved initially, and the occlusion was completed in the next session after the left carotid-left subclavian artery transposition.

Statistical Analysis

Normally distributed continuous variables such as age and gender, were expressed as median, standard deviation, and range values. Imaging findings were summarized descriptively using absolute counts and percentages based on the final consensus interpretations. Statistical analysis was performed with Microsoft Excel.

Results

Seventeen type B aneurysms and 17 type B aortic dissections were included in the study. Four (24%) of the aortic aneurysms were ruptured (Figure 1). Of the unruptured aneurysms, 4 were saccular (31%) and 9 (69%) were fusiform aneurysms. Only one of the saccular and fusiform aneurysms had associated ulcerated plaques. 83% (n=14) of the dissection patients had acute dissection and 3 of them (21%) had traumatic dissection.

Except for patients with traumatic dissection, all patients had at least one accompanying chronic disease (Table 2). The most common disease accompanying the patients was hypertension. 76% of aneurysm patients and 82% of dissection patients had hypertension. Smoking was higher in aneurysm patients (n=7) than in dissection patients (n=3). One of the patients with traumatic aortic dissection had multiple rib and vertebral fractures and splenic rupture. This patient underwent splenectomy before graft placement.

No early complications or early endoleaks were observed in 16 of 34 patients who received endovascular treatment during an average

Figure 1. In thoracic aortography (a) ruptured aneurysm, (b) the image of the same patient after the procedure

follow-up period of 10 months. Complications after EVSG procedure are shown in Table 3.

The most common complication was late leakage (n=7, 21%). Leak was most common in patients with unruptured aneurysms (n=5, 71%). The minimal type 1 leak seen in three of these patients resolved during follow-up. In one of the other two patients, type 2 leakage originating from the intercostal arteries resolved over time. In the other, a new aneurysm developed two years after treatment and required an additional stent. However, type 1 leak occurred due to stent migration, which resolved after placement of a third stent. Subsequently, type 2 leakage from the intercostal arteries was noted during late phase control angiography, but no additional intervention was performed because there was no sign of further leakage at follow-up.

In the only acute dissection patient in whom we detected a leak, balloon angioplasty was performed to address the leak and the leak was successfully resolved. However, the same patient later developed a type 2 leak from the closed subclavian artery and closed on its own during follow-up.

Leak was detected in only 1 of the patients with aneurysm rupture. In this patient, control CTA showed active extravasation extending to the abdomen and thorax at both ends of the graft. Four stent grafts were performed to manage leaks. Distal extravasation continued. It was thought that this leak was due to the incompatibility between the calcified atherosclerotic aortic wall and the stent. Additionally, simultaneous mid-stent leakage was observed. While the middle stent leak was effectively closed by placing two additional stent grafts at the leak sites, distal leak continued despite balloon dilatation. Percutaneous embolization was then closed for this area (Figure 2).

The least common complications were stent graft failure (3%) and bleeding (3%).

Acute renal failure was seen in three patients (9%). In one of these patients, a stent was placed for a type A dissection extending into the left renal artery. The other patient developed acute cerebral infarction and nosocomial infection and was lost during follow-up. The third patient was followed up with compensated renal failure.

Acute cerebral infarction (n=5, 15%) was most frequently seen in ruptured aortic aneurysms (n=3, 60%). One of these patients had acute renal failure and nosocomial infection mentioned above and was lost to follow-up.

Recurrence was detected on follow-up imaging in three patients (9%) (two with dissection and one with aneurysm). Among these two patients, one had type A dissection and the other had type A dissection, dissection in the superior mesenteric artery and bleeding in the jejunal artery branches. Surgery was performed for type A dissection. The recurrent aneurysm was treated with stent graft, and the other dissection was treated with microcoil embolization.

Figure 2. (a) Rupture of proximal and distal parts of the graft, (b) after procedure leakage (white arrow) and hematoma in thorax (black arrow) and abdomen (thick white arrow), (c) leakage (white arrow) and hematoma (black arrow), (d) leak continues after second EVSG

EVSG: Endovascular stent graft

Table 2. Risk factors of the diseases, coexisting diseases

	HT	DM	CAD	COPD	CRD	Cigarette smoking
Aneurysm	14	5	2	3	4	7
Dissection	13	2	5	1	1	3

HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, COPD: Chronic obstructive pulmonary disease, CRD: Chronic renal disease

Table 3. Complications in the patients who were performed stent graft procedure

	Descendan aort aneurysm (n=17)		Descendan aort dissection (n=17)	
	Non-ruptured (n=13)	Ruptured (n=4)	Acute (n=14)	Chronic (n=3)
Primer failure	-	1	-	-
Hemorrhage	-	-	1	-
Acut renal failure	-	1	1	1
Acut cerebral infarct	1	3	1	-
Nasocomial infection	1	2	1	-
Leakage	5	1	1	-
Additional stent necessity	1	1	2	2

Table 4. Stent-grafts used during the procedure and mortality rates			
	Gore TAG	Medtronic Valiant/Captiva	Jotec E-VITA
Patient (n)	6	20	8
Mortality rates	17% (n=1)	10% (n=2)	0

In a patient treated for an aneurysm, a follow-up CTA scan performed one month after discharge revealed air and an abscess within the thrombosed aneurysmal wall. The patient had symptoms of fatigue, loss of appetite, cough and sputum production. The patient's infection was treated with appropriate antibiotic therapy (Figure 3).

A total of four patients, two with dissection, one with traumatic dissection, and one with a ruptured aneurysm, did not attend follow-up examinations and were therefore categorized as lost to follow-up.

The average hospital stay was 6 days in acute and chronic dissection cases, 4.2 days in aneurysm patients, and 14.6 days in traumatic dissections.

In the stent usage analysis, Medtronic VALIANT/CAPTIVA stents (29 devices) (n=20, 59%) were used the most. The mortality rate for these stents was 16.6% (1/6). There were no deaths among patients treated with E-VITA stents (Table 4).

Four patients were lost to follow-up after discharge, and no significant late complications were detected in the remaining patients.

The 30-day mortality rate of the patients was 8.82% (3/34) and the in-hospital mortality rate was calculated as 11.7% (4/34).

While the mortality rate in patients with ruptured aneurysms was 75% (3/4), this rate was 7% (1/14) in those with acute dissection. No mortality was observed in patients who underwent traumatic transection or chronic dissection.

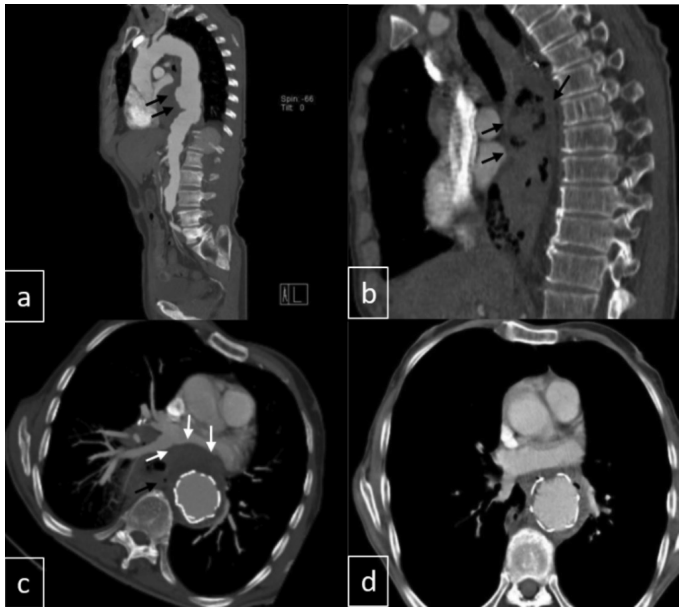


Figure 3. (a) Thrombosed aneurysm in the descending aorta (b), post-procedural air densities and abscess (c), air images (black arrow) in the right vicinity of stent graft and abscess (white arrow) (d), evident regression and decline in air images after treatment

Discussion

EVSG treatment in the thoracic aorta was first introduced in 1991 by Volodos et al.,[18] with the first clinical series reported by Dake et al.[19] in 1994 using Dacron-coated EVSG in 13 patients with descending aortic aneurysm, the first usage was reported by Bilgen et al.[20] in 2002 for thoracic aortic aneurysm (TAA) cases.

For aortic dissections, EVSG aims to close the intimal tear, promote thrombosis in the false lumen, improve flow in the true lumen, and restore perfusion to the aortic branches. In TAA, the aim is to reduce the aneurysmal tension by excluding the affected segment.

Pre-procedural evaluation with CT angiography is critical, as accessing the vascular system can be challenging in patients with underlying atherosclerosis.

As technology evolves, improvements in stent designs and more accurate indications have helped provide increasingly favorable data on mid- and long-term mortality outcomes following EVSG. Despite technological advances, data remain variable due to differences in stent choice and procedural indication. Elective surgical repair of aneurysms is known to effectively and permanently prevent rupture; however, mortality rates range from 5-22%.[21] This rate increasly patients and those with comorbidities, including coronary artery disease, chronic renal failure, and chronic obstructive pulmonary disease. Mortality reaches approximately 50% in the presence of rupture,[22] underscoring the need for e intervention in patients with advanced age or comorbidities.

Despite advancements in surgical techniques and postoperative care, urgent surgical intervention in acute Stanford type B dissection cases remains associated with high morbidity and mortality. In large published series, mortality rates in cases of acute traumatic rupture are 15-28%,[23] and for ruptured thoracic aneurysm orsection, 50-60%.[24] Although endovascular procedures cannot revascuintercostal arteries, some literature has reported spinal cord ischemia as a complication. In our study, paraplegia did not occur in any patient, but cerebral infarction developed in three cases (8.82% or 3/34) in the early phase. Due to early diagnosis and treatment, two of these cases had no residual effects, while one patient, who had a ruptured aneurysm, died in the second month due to concurrent acute renal failure and nosocomial infection. Recognizing early and late complications and implementing vigilant follow-up after EVSG are essential for timely diagnosis and appropriate intervention.

Because EVSG does not involve aortic clamping, patients generally maintain stable hemodynamics throughout the procedure.[25] Compared to surgery, EVSG often results in shorter hospital and intensive care unit stays, reducing complications such as nosocomial infections. In our study, the mean hospital stay was notably short, although traumatic transection patients required longer hospitalization due to associated traumatic injuries.

Complications can arise from both the procedure and the stent or graft itself, including aortic dissection, arterial perforation, distal embolization, pseudoaneurysm, infection, stent graft displacement,

collapse, endoleakage, and occlusion. Early-phase endoleakage rates are reported to range from 30-40%.[26] In our study, leakage occurred at a rate of 20.5% (7/34). All but one of the leaks were type 1 leaks. The type 2 leak seen in this patient during the follow-up examination resolved over time. While leakage continues to be a problem in EVSG, ongoing advances in stent technology, early detection and improved indications are attempting to alleviate this problem.

Among 10 patients treated for dissection, minimal false lumen filling was observed in the late phases of follow-up. Since this delayed filling reduces the direct transmission of systemic pressure to the false lumen and may inhibit aneurysm progression, these patients were observed without further intervention.[24]

Additional and complementary surgical interventions are sometimes required following EVSG.[18] In this series, two patients with type A dissection underwent EVSG after surgical graft interposition in the aortic arch and ascending aorta. The rate of post-procedural surgical intervention was 5.8% (2/34): one due to newly developing dissection in the aortic arch and ascending aorta, and the other due to left carotid-subclavian bypass surgery for closing the left subclavian artery.

Study Limitations

The first limitation of our study is its design and small sample size. The effectiveness, complexities, and limitations of EVSG should be validated by conducting larger-scale studies in the future. The second limitation is the short follow-up period of the patients. In this regard, tracking times can be extended to at least 5 years.

Conclusion

In conclusion, stent-graft placement is a safe, less invasive, and effective treatment for thoracic aortic aneurysms and fistulas and the complications of type B dissection. The major limitation of surgery is the presence of concomitant conditions, whereas the major limitation of stent-graft therapy is anatomic suitability. In selected patients, short-term morbidity and mortality from endovascular therapy compare favorably with those from surgery. Stent-graft therapy is currently the best option for a significant number of patients with descending thoracic aortic disease who are poor candidates for surgical repair.

Ethics

Ethics Committee Approval: Ethical approval for the study was granted by the Ethics Committee of Başkent University (code: KA 12-04, date: 16.02.2012).

Informed Consent: Because this was a retrospective study, informed consent was not required by the ethics committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: F.B., C.A., Concept: Ş.Y., F.B., C.A., Design: Ş.Y., C.A., Data Collection or Processing: Ş.Y., A.M.A., Analysis or Interpretation: Ş.Y., A.M.A., Literature Search: Ş.Y., A.M.A., Writing: Ş.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Dake MD, Kato N, Mitchell RS, et al. Endovascular stent-graft placement for the treatment of acute aortic dissection. N Engl J Med. 1999;340:1546-52.
2. Saremi F, Hassani C, Lin LM, et al. Image Predictors of Treatment Outcome after Thoracic Aortic Dissection Repair. Radiographics. 2018;38:1949-72.
3. Sailer J, Peloschek P, Rand T, Grabenwöger M, Thurnher S, Lammer J. Endovascular treatment of aortic type B dissection and penetrating ulcer using commercially available stent-grafts. AJR Am J Roentgenol. 2001;177:1365-9.
4. Taylor PR, Gaines PA, McGuinness CL, et al. Thoracic aortic stent Grafts-early experience from two centres using commerically availabledevices. Eur J Vasc Endovasc Surg. 2001;22:70-6.
5. Won JY, Lee DY, Shim WH, et al. Elective endovascular treatment of descending thoracic aortic aneurysms and chronic dissections with stent-grafts. J Vasc Interv Radiol. 2001;12:575-82.
6. Ameli-Renani S, Pavlidis V, Morgan RA. Secondary Endoleak Management Following TEVAR and EVAR. Cardiovasc Intervent Radiol. 2020;43:1839-54.
7. Cambria RP, Brewster DC, Lauterbach SR, et al. Evolving experience with thoracic aortic stent graft repair. J Vasc Surg. 2002;35:1129-36.
8. Fattori R, Napoli G, Lovato L, et al. Descending thoracic aortic diseases: stent-graft repair. Radiology. 2003;229:176-83.
9. Rousseau H, Soula P, Perreault P, et al. Delayed treatment of traumatic rupture of the thoracic aorta with endoluminal covered stent. Circulation.1999;99:498-504.
10. Leurs LJ, Bell R, Degrieck Y, et al. Endovascular treatment of thoracic aortic diseases: combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. J Vasc Surg. 2004;40:670-80.
11. Makaroun MS, Dillavou ED, Kee ST, et al. Endovascular treatment of thoracic aortic aneurysms: results of the phase II multicenter trial of the GORE TAG thoracic endoprosthesis. J Vasc Surg. 2005;41:1-9.
12. White RA, Donayre CE, Walot I, et al. Endovascular exclusion of descending thoracic aortic aneurysms and chronic dissections: initial clinical results with the AneurRX device. J Vasc Surg. 2001;33:927-34.
13. Taofan T, Dakota I, Kang SG, et al. A Revolutionary Device for Endovascular Aortic Repair of Abdominal Aortic Aneurysm: A Pilot Study. F1000Res. 2024;13:892.
14. Kupferthaler A, Hauck SR, Schwarz M, et al. Endovascular Repair of Penetrating Thoracic Aortic Ulcers Using Tubular Stent Grafts Versus Stent Grafts With a Proximal Scallop. J Endovasc Ther. 2024;31:821-30.
15. Hashizume K, Mori M, Yagami T, et al. Safety and efficacy of physician-modified thoracic endovascular aortic repair using a low-profile device for aortic arch lesions. Asian Cardiovasc Thorac Ann. 2023;31:340-7.
16. Chang H, Jin D, Wang Y, Liu B, Wang W, Li Y. Chimney Technique and Single-Branched Stent Graft for the Left Subclavian Artery Preservation During Zone 2 Thoracic Endovascular Aortic Repair for Type B Acute Aortic Syndromes. J Endovasc Ther. 2023;30:849-58.
17. de Beaufort HWL, Vos JA, Heijmen RH. Initial Single-Center Experience With the Knickerbocker Technique During Thoracic Endovascular Aortic Repair to Block Retrograde False Lumen Flow in Patients With Type B Aortic Dissection. J Endovasc Ther. 2024;31:597-605.
18. Volodos NL, Karpovich IP, Troyan VI, et al. Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. Vasa Suppl. 1991;33:93-5.
19. Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. N Engl J Med. 1994;331:1729-34.

20. Bilgen F, Narin A, Hobikoğlu G, Şerbetçioğlu A, Aykaç Z, Van Elst F. Treatment of the thoracic aortic aneurysms with endovascular stent graft: case report. Turkish J Thorac Cardiovasc Surg. 2002;10:53-5.

21. von Oppell UO, Dunne TT, De Groot MK, Zilla P. Traumatic aortic rupture: twenty-year metaanalysis of mortality and risk of paraplegia. Ann Thorac Surg. 1994;58:585-93.

22. Glimåker H, Holmberg L, Elvin A, et al. Natural history of patients with abdominal aortic aneurysm. Eur J Vasc Surg. 1991;5:125-30.

23. Heijmen RH, Deblier IG, Moll FL, et al. Endovascular stent-grafting for descending thoracic aneurysms. Eur J Cardiothorac Surg. 2002;21:5-9.

24. Miller DC, Mitchell RS, Oyer PE, Stinson EB, Jamieson SW, Shumway NE. Independent determinants of operative mortality for patients with aortic dissection. Circulation. 1984;70:153-64.

25. Lamme B, de Jonge IC, Reekers JA, de Mol BA, Balm R. Endovascular treatment of thoracic aortic pathology: feasibility and mid-term results. Eur J Vasc Endovasc Surg. 2003;25:532-9.

26. Chutter TA, Faruqi RM, Sawhney R, et al. Endoleak after endovascular repair of abdominal aortic aneurysms. J Vasc Surg. 2001;34:98-105.

2024 Referee Index

Ali Altan Ertan Boz
Ali Devebacak
Ali Nouraeinejad
Ali Osman Saatçi
Almila Sarıgül Sezenöz
Arzu Taşkıran Çömez
Atılım Armağan Demirtaş
Ayşe Bozkurt Oflaz
Banu Yaman
Bediz Özen
Bengü Ekinci Köktekir
Berna Yüce
Burak Ulaş
Canan Bor
Elif Erdem
Emine Çiloğlu
Emine Esra Karaca
Esat Çınar
Esin Baser
Esin Sarı
Fatih Aslan
Ferdane Ataş
Gözde Şahin Vural
Hande Taylan Şekeroğlu
Harun Cakmak
İlayda Korkmaz
İlkben Günüşen
Mahmut Kaya
Matrin Litev
Mehmet Cem Sabaner
Mehmet Özgür Zengin
Meryem Altın Ekin
Mine Esen Barış
Muhammed Altınışık
Murat Kaşıkçı
Mutlu Acar
Naim Ceylan
Necip Kara
Nihat Sayın
Nurullah Çağıl
Onur Furundaoturan
Oya Dönmez
Ömer Kartı
Pelin Kıyat
Pelin Özyol
Pınar Özer
Reşat Duman
Sait Eğrilmez
Selçuk Sızmaz
Semra Akkaya Turhan
Serhad Nalçacı
Serhat İmamoğlu
Serhat Mangan
Sibel Kocabeyoğlu
Sinan Bekmez
Sirel Gür Güngör
Taylan Öztürk
Tolga Kocatürk
Tuncay Küsbeci
Züleyha Yalnız Akkaya

2024 Author Index

2024 Subject Index