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Original Article

Evaluation of Upper Extremity Movement, Pain Intensity, and Respiratory Functions in Patients Who Received Thoracotomy Sparing the Serratus Anterior Muscle

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ABSTRACT

Objective: To evaluate upper extremity movement, pain intensity, and respiratory functions in preoperative and postoperative periods in patients undergoing thoracotomy sparing the serratus anterior muscle (TSSAM).

Methods: Forty-three patients (25 male and 18 female) were included in this prospective observational cohort type study. In the preoperative period and on postoperative days 1, 2, 3, and 5, ipsilateral shoulder range of motion was evaluated by a goniometer, pain intensity was evaluated by a visual analog scale (VAS), and respiratory functions were evaluated by spirometry.

Results: When compared with preoperative values, shoulder flexion and abduction angle, forced expiratory volume in 1 second (FEV_1), and functional vital capacity (FVC) decreased on postoperative day 1, while VAS significantly increased ($P < .05$). Shoulder flexion and abduction angle, FEV_1, and FVC significantly increased and VAS significantly decreased on postoperative days 2, 3, and 5 compared to postoperative day 1 ($P < .05$). However, they could not reach preoperative values on postoperative day 5 ($P < .05$). On postoperative day 1, while there was a correlation between pain and flexion ($r = -0.438$; $P = .003$) and abduction ($r = -0.503$; $P = .001$) angles, no correlation was found between pain and FEV_1 ($r = -0.189$; $P = .225$) and FVC ($r = 0.009$; $P = .953$). There was no correlation between pain and flexion, abduction, FEV_1, and FVC on postoperative days 2,3, and 5 ($P > .05$).

Conclusions: Patients undergoing the TSSAM had less upper extremity range of motion and respiratory functions and more pain intensity in the early postoperative period than in the preoperative period. It was observed that pain and flexion and abduction angles were negatively correlated on postoperative day 1. In the postoperative period, they should be taken into account in the design/development of rehabilitation programs.

Keywords: Respiratory function tests, thoracotomy, range of motion, pain

INTRODUCTION

Standard posterolateral thoracotomy (SPLT) is used for most general thoracic surgical procedures. This incision involves the incision of the latissimus dorsi and serratus anterior muscles and provides an excellent view of the entire chest cavity, which, however, causes increased blood loss, impaired pulmonary function, postoperative chest pain, and limitation of shoulder movement.[1,2] In order to minimize these disadvantages, muscle-sparing thoracotomy (MST) in which the latissimus dorsi and serratus anterior muscles are not cut, or thoracotomy sparing the serratus anterior muscle (TSSAM), in which only the latissimus dorsi muscle is cut, is preferred.[3] The serratus anterior muscle can be preferred as an alternative approach due to various advantages such as providing a wide view through posterolateral

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incision, combining muscle-sparing advantages, simple and fast application, facilitating thoracotomy closure, and the possibility of using in emergency surgical conditions.[4]

Thoracotomy may cause decreased shoulder range of motion and chronic pain. Upper extremity range of motion limitations in patients undergoing thoracotomy is thought to be due to complete denervation of the serratus anterior and latissimus dorsi muscles. Because the serratus anterior muscle and the trapezius muscle together provide the rotation of the scapula, which is necessary for shoulder abduction and flexion.[5] It has been stated that the latissimus dorsi is the most effective depressor of the humeral head, and it has been stated that it helps to hold the scapula against the thorax during upper extremity movements, by attaching the latissimus dorsi to the inferior angle of the scapula.[6] In addition, pain can be effective in these limitations.[7,8] Postoperative pain is caused by patient positioning during thoracotomy, intercostal nerve and vessel injuries during retraction, major muscle cuts, costa retraction, and chest tube placement.[8-11] Studies evaluating upper extremity range of motion and pain have generally been performed in patients with MST and SPLT.[12,13] It was reported that preserving the serratus anterior muscle increases shoulder mobility.[14] However, postoperative evaluations are needed in patients undergoing TSSAM. It is also important to determine the relationship between pain and range of motion.

It has been reported that a painful incision may cause a decrease in lung volume and respiratory functions by increasing muscle tone during inspiration. This may cause increased secretion, atelectasis, and respiratory tract infections.[15,16] Postoperative pulmonary complications are an important cause of morbidity after thoracotomy, leading to a prolonged hospital stay and increased health care costs.[17] It was stated that it is unclear whether sparing the serratus anterior muscle will enhance the recovery of postoperative respiratory function.[12] In this context, it is necessary to provide evidence to determine postoperative respiratory functions in patients undergoing TSSAM and to better predict its relationship with pain.

The aim of the study was to evaluate upper extremity movement, pain intensity, and respiratory functions in patients undergoing TSSAM on postoperative days 1, 2, 3, and 5. The hypothesis investigated was as follows: In the early postoperative period, upper extremity range of motion and respiratory functions decrease in patients undergoing TSSAM, the intensity of pain increases, and these parameters cannot reach preoperative values.

Main Points

- It was found that joint range of motion, pain, and respiratory functions were negatively affected in the early postoperative period compared to the preoperative period in patients undergoing the serratus anterior muscle (TSSAM).
- Pain on postoperative day 1 was negatively related to flexion and abduction angles.
- Joint range of motion, pain, and respiratory functions should be considered in rehabilitation programs to be applied in patients with TSSAM.

METHODS

Study Design

This prospective observational cohort type study was carried out in accordance with the rules of the Declaration of Helsinki. It was conducted at the Department of Thoracic Surgery of Gaziantep University The study was approved by the Ethics Committee of Gaziantep University (Date: October 13, 2014, Decision number: 2014/312). This study was conducted between 2014 and 2015.

Patients

Patients aged between 15 and 73 years, volunteering to participate in the study were assessed at the thoracic surgery clinic. Patients with pathology, such as tumor and tendinitis, which would cause limitation of shoulder movement on the incision side, those with an incision outside of TSSAM, those who received other incisions addition to TSSAM, or those with extended incisions such as chest wall resection were not included in the study. All patients were informed about the study and signed consent forms were obtained.

Procedures

After the patients were monitored for vascular access, arterial blood pressure, heart rhythm, and urine output, they were placed under general anesthesia. The cardiovascular and respiratory systems became available for monitoring and manipulation. The patients were placed on the operating table in the lateral decubitus position with the operated side up. A pillow was placed under the chest to increase the gap between the ribs and armpit support to prevent injury to the brachial plexus. While the upper leg was in full extension, the lower leg was kept slightly flexed. The arms were placed in flexion on the arm boards. The knee was supported for peroneal nerve damage. In addition, sternum and hip stabilizers were used. The incision site was covered with sterile drapes to prevent bacterial migration. The patients were intubated with a double-lumen endotracheal tube.[18]

The incision, which started approximately 4 cm below the nipple and at the level of the anterior axillary line, continued 1 cm below the lower end of the scapula. The incision proceeding posteriorly from the medial of the scapula was terminated after 3-4 cm over the lower end of the scapula. After the subcutaneous tissue was passed, the latissimus dorsi, serratus anterior sheath and, if necessary, the lower part of the trapezius was cut a little to reach the intercostal space. A thorax retractor was placed in the appropriate intercostal space, and the ribs were stretched enough (8-10 cm) to perform the procedure. At the end of the procedure, the thoracotomy incision was closed in the same way in each patient.[14,18]

Evaluations

The patients' age, gender, body mass index, diagnosis, and operation types were evaluated in the preoperative period. Upper extremity joint range of motion, pain intensity, and respiratory functions were evaluated both in the preoperative period and on postoperative days 1, 2, 3, and 5. In addition, all patients routinely performed the exercises (toe climbing on the wall in addition to breathing exercises) given in the department of thoracic surgery. All assessments were performed by the same physiotherapist.

Shoulder Range of Motion

The flexion and abduction angles of the ipsilateral shoulder were measured with a goniometer. The normal range of motion of the shoulder is 0-180° for flexion and abduction.[19]

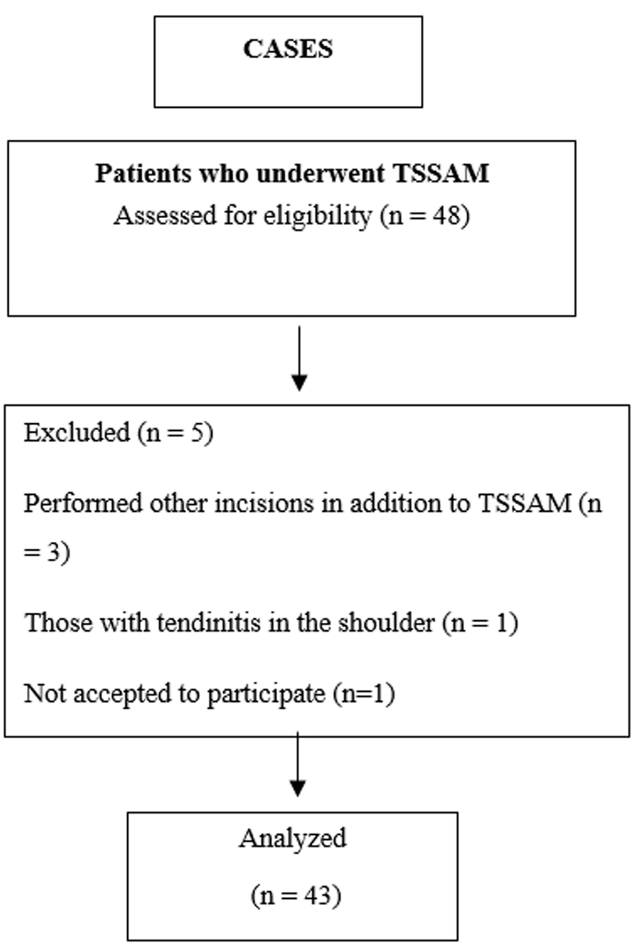
Pain Intensity

Pain intensity of the patients was evaluated with a visual analog scale (VAS). The VAS is a 10-cm horizontal line, where 0 represents no pain and 10 represents excruciating pain. All patients were asked to indicate the pain intensity they perceived on the horizontal line.[20]

Respiratory Functions

The respiratory functions of the patients were evaluated with a portable spirometer (MIR Spirobank Hand-Held Spirometer, Rome, Italy) in an upright sitting position. During the measurements, the American Thoracic Society and European Respiratory Society criteria were followed.[21] To prevent air leakage, patients wore a nose clip. First, a forced inspiration and then a forced expiration were performed. The best of 3 measurements was recorded. The volume of air exhaled in the first second of forced expiration (FEV_1) and forced vital capacity (FVC) values was recorded.[21]

Figure 1. The flowchart diagram for the patients.



Sample Size and Statistical Analyses

The effect size was calculated as 0.45 in the power analysis performed considering previous studies[12,22] on the parameters to be investigated in patients who underwent TSSAM. According to the power analysis made before the study, it was observed that at least 41 individuals should be included when the power is 80%, the error level is 0.05, and when the hypothesis is determined as bidirectional. This analysis was carried out with a statistical power analysis program (G*Power, Version 3.1.9.2, Franz Faul, Universität Kiel, German).

One-way repeated-measures analysis of variance was used to compare the measurements obtained at different times. As introductory statistics, mean ± standard deviation values for numerical variables and number and percentage values for categorical variables are given. IBM Statistical Package for the Social Sciences Statistics for Windows, Version 21.0 (Armonk, NY, USA) was used in analyses. Any *P* < .05 was considered statistically significant.

Table 1. Demographic and Clinic Characteristics of the Patients.

	Patients (n=43)
Age (years, X ± SD)	**52.07 ± 14.46**
BMI (kg/m², X ± SD)	**28.81 ± 6.49**
Diagnosis (n, %)	
Lung cancer	22 (51.2)
Hydatid cyst	8 (18.6)
Mesothelioma	4 (9.3)
Bullous disease of the lung	1 (2.3)
Aspergilloma	1 (2.3)
Bronchiectasis	1 (2.3)
Malignant solitary fibrosis tumor	1 (2.3)
Mediastinal mass	1 (2.3)
Osteosarcoma	1 (2.3)
Prostate cancer	1 (2.3)
Renal cell carcinoma	1 (2.3)
Solitary pulmonary nodule	1 (2.3)
Procedure (n, %)	
Wedge resection	14 (32.6)
Lobectomy	10 (23.3)
Cystotomy + Capitonnage	6 (14)
Decortication	1 (2.3)
Pleural mass excision	4 (9.3)
Pneumonectomy	4 (9.3)
Exploration	3 (7)
Mediastinal mass excision	1 (2.3)

X, mean, SD, standard deviation; BMI, body mass index.

Table 2. Range of Motion on Operative Side, Visual Analog Scale, Pulmonary Function Tests, Values for Preoperative and Postoperative Days 1, 2, 3, and 5

Values	Preop (X ± SD)	Postop First (X ± SD)	Postop Second (X ± SD)	Postop Third (X ± SD)	Postop Fifth (X ± SD)	p1	ITI-p
Shoulder ROM Flexion (0-180°)	175.18 ± 4.86	127.74 ± 13.84	140.69 ± 10.97	154.79 ± 10.99	164.83 ± 10.46	**0.001***	**p2:0.001,* p3:0.001* p4:0.001,* p5:0.001* p6:0.001,* p7:0.001* p8:0.001,* p9:0.001* p_{10}:0.001,* p_{11}:0.001***
Abduction (0-180°)	177.32 ± 3.93	137.27 ± 15.41	150.32 ± 11.37	164.55 ± 10.45	171.88 ± 7.61	**0.001***	**p2:0.001*, p3:0.001* p4:0.001*, p5:0.001* p6:0.001*, p7:0.001* p8:0.001*, p9:0.001* p_{10}:0.001*, p_{11}:0.001***
VAS (cm)	1.58 ± 1.19	8.53 ± 1.12	6.13 ± 1.31	4.88 ± 1.29	2.53 ± 0.90	**0.001***	**p2:0.001,* p3:0.001* p4:0.001,* p5:0.001* p6:0.001,* p7:0.001* p8:0.001,* p9:0.001* p_{10}:0.001,* p_{11}:0.001***
Pulmonary function FEV_1 (L)	2.47 ± 0.71	0.82 ± 0.24	1.05 ± 0.29	1.36 ± 0.25	1.61 ± 0.31	***0.001***	**p2:0.001,* p3:0.001* p4:0.001,* p5:0.001* p6:0.001,* p7:0.001* p8:0.001,* p9:0.001* p_{10}:0.001,* p_{11}:0.001***
FVC (L)	3.39 ± 0.89	1.23 ± 0.24	1.59 ± 0.31	2.00 ± 0.36	2.33 ± 0.41	**0.001***	**p2:0.001,* p3:0.001* p4:0.001,* p5:0.001* p6:0.001,* p7:0.001* p8:0.001,* p9:0.001* p_{10}:0.001,* p_{11}:0.001***

*$P < .05$.
ITI-p; inter-time interaction, sub-group comparisons; p1, difference between times; p2, comparison of the preop and postop day 1; p3, comparison of the preop and postop day 2; p4, comparison of the preop and postop day 3; p5, comparison of the preop and postop day 5; p6, comparison of the postop day 1 and postop day 2; p7, comparison of the postop day 1 and postop day 3; p8, comparison of the postop day 1 and postop day 5; p9, comparison of the postop day 2 and postop day 3; p10, comparison of the postop day 2 and postop day 5; p11, comparison of the postop day 3 and postop day 5; X, mean; SD, standard deviation; preop, Preoperative; Postop, postoperative; ROM, range of motion; VAS, visual analog scale; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity.

RESULTS

Forty-eight patients were evaluated for the study. In total, 43 patients met the inclusion criteria (Figure 1). Demographic and clinical characteristics of the patients (25 male (58.1%), 18 female (41.9%)) are shown in Table 1. Twenty-three patients (53.5%) who underwent TSSAM had right thoracotomy and 20 (46.5%) had left thoracotomy (Table 1).

Shoulder flexion and abduction angle and FEV_1 and FVC values decreased significantly on postoperative day 1 in patients compared to preoperative values who underwent TSSAM ($P < .05$). There was a significant increase every day on postoperative days 2-5 compared to postoperative day 1 ($P < .05$). However, these values could not reach preoperative values even on postoperative day 5 ($P < .05$) (Table 2).

Pain intensity increased significantly on postoperative day 1 compared to the preoperative values ($P < .05$). There was a significant decrease in pain intensity on postoperative days 2-5 compared to postoperative day 1 ($P < .05$). However, even on postoperative day 5, the pain intensity could not reach the preoperative value ($P < .05$) (Table 2). The variation between days in shoulder flexion and abduction angle, pain, and FEV_1 and FVC values is shown in Figures 2-6.

In patients who underwent TSSAM, there was a moderate negative correlation on postoperative day 1 between pain and flexion ($r = -0.438$; $P = .003$) and abduction ($r = -0.503$; $P = .001$) angles. On the other hand, no significant correlation was found between pain and FEV_1 ($r = -0.189$; $P = .225$) and FVC ($r = 0.009$; $P = .953$) scores. At postoperative days 2-5, no correlation was found between pain and flexion angle ($r = -0.145$, $P = .354$; $r = -0.136$, $P = .386$; $r = -0.011$, $P = .946$), abduction angle ($r = -0.108$, $P = .491$; $r = -0.044$, $P = .778$; $r = 0.030$, $P = .849$, FEV_1 value ($r = -0.095$, $P = .544$; $r = -0.111$, $P = .477$; $r = 0.031$, $P = .845$), and the FVC value ($r = -0.041$, $P = .795$; $r = 0.053$, $P = .734$; $r = 0.062$, $P = .692$).

Figure 2. Demonstration of changes in flexion angle between preoperative values and values from postoperative days 1, 2, 3, and 5.

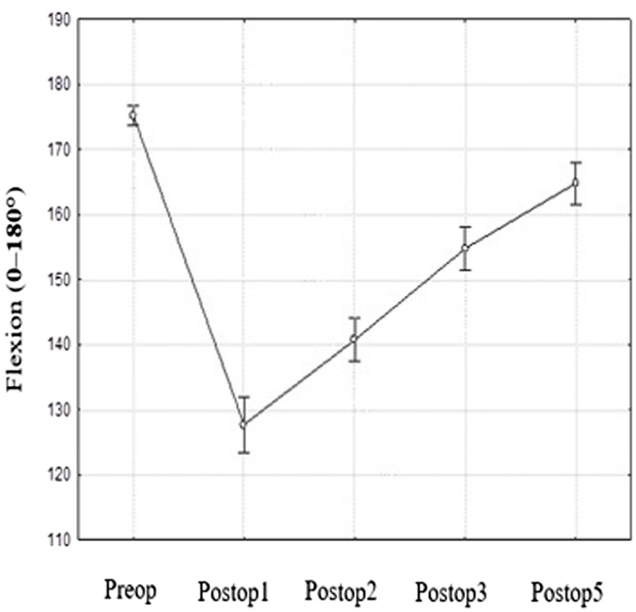


Figure 3. Demonstration of changes in abduction angle between preoperative values and values from postoperative days 1, 2, 3, and 5.

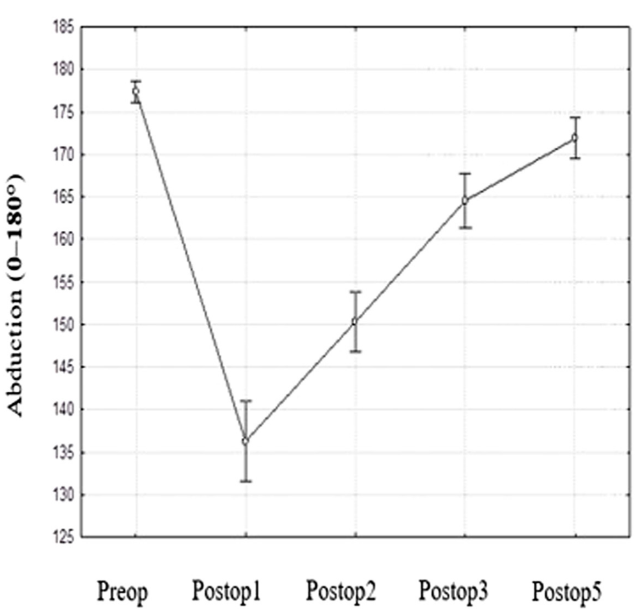


Figure 4. Demonstration of changes in VAS between preoperative values and values from postoperative days 1, 2, 3, and 5. VAS, visual analog scale.

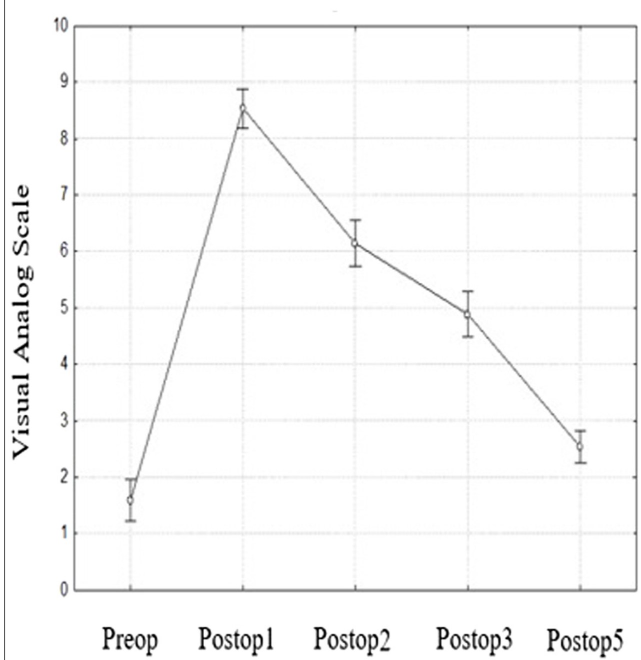
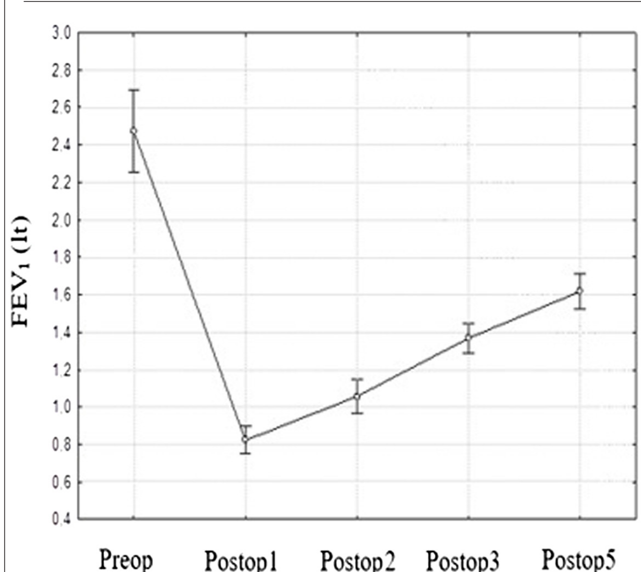


Figure 5. Demonstration of changes in FEV_1 between preoperative values and values from postoperative days 1, 2, 3, and 5. FEV_1, forced expiratory volume in 1 second.

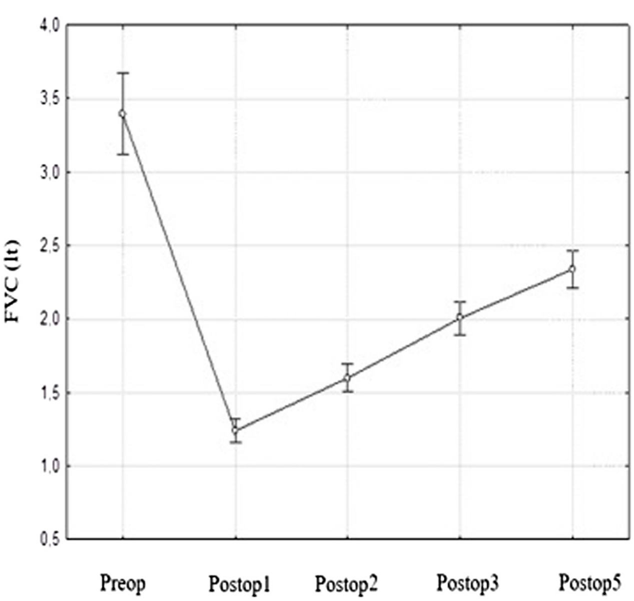


DISCUSSION

The following were observed in the present study: (i) On postoperative day 1, shoulder joint range of motion and respiratory function decreased, while pain intensity increased. (ii) On postoperative days 2-5, the shoulder joint range of motion and respiratory functions increased, while the pain intensity decreased compared to postoperative day 1. (iii) Even on postoperative day 5, none of the parameters reached the preoperative value. (iv) There was a moderate and negative correlation between the intensity of pain and range of motion on postoperative day 1.

Thoracotomy affects shoulder mobility, but muscle-sparing approaches have been reported to facilitate shoulder mobility.[14] Studies have generally focused on differences between shoulder

Figure 6. Demonstration of changes FVC between preoperative values and values from postoperative days 1, 2, 3, and 5. FVC, functional vital capacity.



joint range of motion in various thoracotomy approaches.[13,23] In the study of Öztürk et al.[23] in the comparison of the patients who underwent MST or TSSAM, it was reported that shoulder flexion and abduction were less restricted in those who underwent MST on postoperative days 1, 2, and 7. In the study of Çobanoğlu et al.[13] flexion and abduction angles were quite different than preoperative values on postoperative day 7 in the TSSAM group. In addition, the following results were obtained when thoracotomy types were compared in the same study: It was found that the shoulder abduction angle was similar in the TSSAM and MST group on postoperative day 7, and the abduction angle in both groups was significantly higher compared to SPLT. It was stated that the flexion angle was higher in the MST group compared to TSSAM on postoperative day 7, and was lowest in the SPLT group. In the study of Akçalı et al.[12] flexion and abduction angles approached the preoperative values in postoperative week 2 in patients who underwent MST. Therefore, they stated that the shoulder joint range of motion recovered in 2 weeks in the MST group. In addition, in this study in which thoracotomy types were compared, it was stated that the shoulder joint range of motion was less affected in patients who underwent MST than those who underwent SPLT. Athanassiadi et al[24] examined 2 groups who underwent MST or SPLT and found that flexion and abduction angles could not reach preoperative values in week 1, but returned to preoperative values later in the first month. In our study, it was found that flexion and abduction angles decreased in the early postoperative period. The decrease in joint range of motion may be caused by the incision of an important and large muscle group, such as the latissimus dorsi, even if the serratus anterior muscle is preserved; it may occur due to the tension on the intercostal nerves by spacing the intercostal space by means of retractors used during entry into the thorax; or, it may develop due to rib injuries that may occur at this angle (injury due to compression in the periosteum, or rib cracks/fractures).[12,13] Flexion and abduction angles increased significantly on postoperative days 2, 3, and 5, in this order. Although these results are similar with the ones reported in the literature,[12,13] flexion and abduction angles of the patients showed a faster recovery in a short period of 5 days compared to other studies. This may be due to the effects of developing surgical techniques, correct positioning, and exercises performed for the shoulder joint beginning with postoperative day 1. In cases in whom TSSAM is applied, it is important that the rehabilitation program is applied comprehensively by physiotherapists to increase the range of motion of the upper extremity in the early postoperative period.

Pain after thoracotomy is an important risk factor for morbidity. Therefore, surgeons should be aware of the effects of the techniques they have developed on pain.[25] Çobanoğlu et al[13] reported that pain intensity decreased from an average of 8-1.2 on postoperative day 7 in groups who underwent TSSAM and MST. Akçalı et al[12] reported that the postoperative day 8 pain level was 2.03 in the group who underwent MST. There are studies reporting that TSSAM and MST are less painful than SPLT and that patients who underwent TSSAM and MST have less VAS value and they need lower narcotic analgesics in the early postoperative period.[24,26] In their meta-analysis, Uzzaman et al[27] reported that pain scores were the same in patients who underwent SPLT and MST on postoperative day 1, but they were lower in patients who underwent MST on postoperative day 7 compared to those who underwent SPLT. Similar to the studies in the literature, in this study, it was determined that pain decreased to 2.53, a significant decrease, on postoperative day 5. Excessive pain in the early period may be due to the cut of the skin and pleura and retraction of the costae. The outcome that pain approaches preoperative values in the following days may be related to the fact that the retraction of the costae and the presence of chest drains are less problematic and that epidural analgesia is more effective. Physiotherapy agents can be used in the early postoperative period in order to reduce the intensity of pain in patients who underwent TSSAM.[28]

Thoracotomy causes volume loss due to impaired lung compliance and lung resection. Therefore, postoperative respiratory dysfunction is inevitable. Differences between thoracotomy types may be related to the incision of the latissimus dorsi and serratus anterior muscles, which are weak respiratory muscles. Uzzaman et al[27] stated in their meta-analysis that there may be a significant difference in pulmonary function tests in SPLT and MST groups. However, due to the limited number of studies performed in postoperative week 1, they could not evaluate respiratory functions. Ponn et al[29] stated that MST may result in better long-term pulmonary function, but the differences with other thoracotomy types are small and do not provide a significant clinical difference in the patient. Cobanoglu et al[13] found that pulmonary functions were significantly better in the MST group than in the TSSAM and SPLT groups on postoperative days 3 and 7. Hazelrigg et al[23] found that pulmonary functions reached the preoperative value approximately 1 month later. According to Miyoshi et al.[30] FEV_1 and FVC values approached 60% and 70% of the preoperative values, respectively, at an average of postoperative 9 and 26 days. In our study, it was found that although respiratory function parameters decreased in the early postoperative period and increased within days, they did not reach the preoperative values. Although these results are compatible with the studies in the literature, the reason for not reaching the preoperative values may be the incision of the latissimus dorsi muscle. In addition, the most important parameter affecting respiratory functions is the surgical procedures that require parenchymal loss (wedge resection, lobectomy, and pneumonectomy) in a significant portion of patients. Due to low respiratory functions in the postoperative period, a pulmonary rehabilitation program should be applied more intensively beginning with the early period.

A correlation was found between pain and range of motion only on postoperative day 1. The lack of correlation between pain and range of motion on other days may be due to the early mobilization and exercises for the shoulder joint routinely given to the patients by the surgeons and accompanying physiotherapists. If there is no relationship between pain and respiratory functions, it may be that the pain improves in a shorter time and the respiratory functions need a longer time to recover.

The first limitation of the study is that it involves a short-term evaluation. Future studies should also consider long-term evaluations. Because in the long-term evaluation, positive results can be seen regarding the postoperative values reaching the preoperative values. Second, there was no control group in the study. Further studies should include a control group. Third, there are variations in surgical procedures performed in patients undergoing thoracotomy.

CONCLUSION

In conclusion, in this study, it was observed that the shoulder joint range of motion and respiratory functions decreased and the intensity of pain increased in the early postoperative period in patients who underwent TSSAM. On postoperative day 1, pain and upper extremity range of motion were found to be negatively correlated. The findings of the study suggested that these parameters should be taken into account in the evaluation of patients who underwent TSSAM and in the physiotherapy methods to be used in the treatment.

Ethics Committee Approval: The study was approved by the Gaziantep University Ethics Committee (Date: October 13, 2014, Decision number: 2014/312).

Informed Consent: Informed consent was obtained from all patients participating in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Y.K., A.C., S.G., M.Ş.; Design – Y.K., A.C., A.U., S.G., M.Ş.; Supervision – Y.K., A.C., A.U., S.K., S.G., M.Ş.; Resources – Y.K., A.U., S.G., M.Ş.; Materials – Y.K., A.C., S.G., M.Ş.; Data Collection and/or Processing – Y.K., S.G., M.Ş.; Analysis and/or Interpretation – Y.K., A.C., A.U., S.K.; Literature Search – Y.K., A.C., A.U., Writing Manuscript – Y.K., A.C., A.U.; S.K., S.G., M.Ş.; Critical Review – Y.K., S.K., S.G., M.Ş.

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REFERENCES

1. Park S, Gu JH, Jang HK, Oh MS, Lee EJ, Jung IC. Electroacupuncture for post-thoracotomy pain: protocol for a systematic review and meta-analysis. *Med (Baltim)*. 2020;99(9):e19312. [CrossRef]
2. Alzahrani T. Pain relief following thoracic surgical procedures: a literature review of the uncommon techniques. *Saudi J Anaesth*. 2017;11(3):327-331. [CrossRef]
3. Bernstein DT, Zhuge W, Blackmon SH, Marco RAW. A novel muscle-sparing high thoracotomy for upper thoracic spine resection and reconstruction. *Eur Spine J*. 2018;27(7):1567-1574. [CrossRef]
4. Elshiekh MA, Lo TT, Shipolini AR, McCormack DJ. Does muscle-sparing thoracotomy as opposed to posterolateral thoracotomy result in better recovery? *Interact Cardiovasc Thorac Surg*. 2013;16(1):60-67. [CrossRef]
5. Neumann DA, Camargo PR. Kinesiologic considerations for targeting activation of scapulothoracic muscles - part 1: Serratus anterior. *Braz J Phys Ther*. 2019;23(6):459-466. [CrossRef]
6. Campbell ST, Ecklund KJ, Chu EH, McGarry MH, Gupta R, Lee TQ. The role of pectoralis major and latissimus dorsi muscles in a biomechanical model of massive rotator cuff tear. *J Shoulder Elbow Surg*. 2014;23(8):1136-1142. [CrossRef]
7. Gerner P. Postthoracotomy pain management problems. *Anesthesiol Clin*. 2008;26(2):355-367, vii. [CrossRef]
8. Kutlu CA, Akin H, Olcmen A, Biliciler U, Kayserilioglu A, Olcmen M. Shoulder-girdle strength after standard and lateral muscle-sparing thoracotomy. *Thorac Cardiovasc Surg*. 2001;49(2):112-114. [CrossRef]
9. Khelemsky Y, Noto CJ. Preventing post-thoracotomy pain syndrome. *Mt Sinai J Med*. 2012;79(1):133-139. [CrossRef]
10. Wenk M, Schug SA. Perioperative pain management after thoracotomy. *Curr Opin Anaesthesiol*. 2011;24(1):8-12. [CrossRef]
11. Landreneau RJ, Pigula F, Luketich JD, et al. Acute and chronic morbidity differences between muscle-sparing and standard lateral thoracotomies. *J Thorac Cardiovasc Surg*. 1996;112(5):1346-50. [CrossRef]
12. Akçali Y, Demir H, Tezcan B. The effect of standard posterolateral versus muscle-sparing thoracotomy on multiple parameters. *Ann Thorac Surg*. 2003;76(4):1050-1054. [CrossRef]
13. Cobanoğlu U, Hız O, Melek M, Edirne Y. Is muscle-sparing thoracotomy advantageous. *Turk J Thorac Cardiovasc Surg*. 2011;19(1):43-48.
14. Heitmiller RF. The serratus sling: a simplified serratus-sparing technique. *Ann Thorac Surg*. 1989;48(6):867-868. [CrossRef]
15. Husch HH, Watte G, Zanon M, et al. Effects of transcutaneous electrical nerve stimulation on pain, pulmonary function, and respiratory muscle strength After posterolateral thoracotomy: a randomized controlled trial. *Lung*. 2020;198(2):345-353. [CrossRef]
16. Boisseau N, Rabary O, Padovani B, et al. Improvement of 'dynamic analgesia' does not decrease atelectasis after thoracotomy. *Br J Anaesth*. 2001;87(4):564-569. [CrossRef]
17. Marshall K, McLaughlin K. Pain management in thoracic surgery. *Thorac Surg Clin*. 2020;30(3):339-346. [CrossRef]
18. Elswick SM, Blackmon SH, Sharaf B. Muscle-sparing thoracotomy. *Oper Tech Thorac Cardiovasc Surg*. 2017;22(2):110-121. [CrossRef]
19. Krishnan R, Björsell N, Gutierrez-Farewik EM, Smith C. A survey of human shoulder functional kinematic representations. *Med Biol Eng Comput*. 2019;57(2):339-367. [CrossRef]
20. DeLoach LJ, Higgins MS, Caplan AB, Stiff JL. The visual analog scale in the immediate postoperative period: intrasubject variability and correlation with a numeric scale. *Anesth Analg*. 1998;86(1):102-106. [CrossRef]

21. Quanjer PH, Tammeling GJ, Cotes JE, Pedersen OF, Peslin R, Yernault JC. Lung volumes and forced ventilatory flows. Report Working Party Standardization of lung Function Tests, European Community for Steel and Coal. Official Statement of the European Respiratory Society. *Eur Respir J Suppl*. 1993;16:5-40.
22. Hazelrigg SR, Landreneau RJ, Boley TM, et al. The effect of muscle-sparing versus standard posterolateral thoracotomy on pulmonary function, muscle strength, and postoperative pain. *J Thorac Cardiovasc Surg*. 1991;101(3):394-400; discussion 400 [discussion]. [CrossRef]
23. Öztürk M. *Standart posterolateral Torakotomiyle serratus anterior Kasını Koruyucu Torakotominin Çok Değişkenli Karsılaştırılması* Erciyes Üniversitesi Tıp Fakültesi, Tıpta Uzmanlık Tezi. 2007.
24. Athanassiadi K, Kakaris S, Theakos N, Skottis I. Muscle-sparing versus posterolateral thoracotomy: a prospective study. *Eur J Cardiothorac Surg*. 2007;31(3):496-499. [CrossRef]
25. El-Hag-Aly MA, Hagag MG, Allam HK. If post-thoracotomy pain is the target, integrated thoracotomy is the choice. *Gen Thorac Cardiovasc Surg*. 2019;67(11):955-961. [CrossRef]
26. Scawn ND, Pennefather SH, Soorae A, Wang JY, Russell GN. Ipsilateral shoulder pain after thoracotomy with epidural analgesia: the influence of phrenic nerve infiltration with lidocaine. *Anesth Analg*. 2001;93(2):260-264. [CrossRef]
27. Uzzaman MM, Robb JD, Mhandu PC, et al. A meta-analysis comparing muscle-sparing and posterolateral thoracotomy. *Ann Thorac Surg*. 2014;97(3):1093-1102. [CrossRef]
28. Solak O, Turna A, Pekcolaklar A, et al. Transcutaneous electric nerve stimulation for the treatment of postthoracotomy pain: a randomized prospective study. *Thorac Cardiovasc Surg*. 2007;55(3):182-185. [CrossRef]
29. Ponn RB, Ferneini A, D'Agostino RS, Toole AL, Stern H. Comparison of late pulmonary function after posterolateral and muscle-sparing thoracotomy. *Ann Thorac Surg*. 1992;53(4):675-679. [CrossRef]
30. Miyoshi S, Yoshimasu T, Hirai T, et al. Exercise capacity of thoracotomy patients in the early postoperative period. *Chest*. 2000; 118(2):384-390. [CrossRef]