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Pectus excavatum treatment with the Nuss procedure: comparative results in pediatric and adult patients – experiences of a single physician

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ABSTRACT

Introduction and aim. Pectus excavatum (PE) is a chest wall deformity characterized by a collapse of the rib cage. The Nuss procedure, originally intended for pediatric patients, is now also used in adults. The main aim of this study is to investigate whether the Nuss procedure can also lead to successful results in adult patients, although it is a widely used treatment method in pediatric patients.

Material and methods. Data from 90 patients (October 2008-May 2020) included age, gender, preoperative findings, Haller index, operative details, and postoperative outcomes. The groups were divided into pediatric (<18 years) and adult (≥18 years) patients. Mann-Whitney U and chi-square tests were used to assess group differences.

Results. The adult group had a significantly higher bar length and preoperative complaints rate ($p<0.05$). No significant differences were found for other parameters ($p>0.05$).

Conclusion. The Nuss procedure is safe and effective in both pediatric and adult PE patients. Age and preoperative symptoms influence surgical planning and outcomes, emphasizing their importance for treatment strategies.

Keywords. adult, Nuss procedure, pectus excavatum, pediatric

Introduction

Pectus excavatum (PE) is a congenital deformity characterized by an inward collapse of the sternum due to abnormal growth of the cartilaginous parts of the ribs on the anterior chest wall. There are symmetrical and asymmetrical forms. This condition is four times more common in men than in women. Pectus excavatum can occur at any age, but is usually recognized in the first year after birth and is more common during or

after puberty. This deformity is more common in Caucasians. Although the etiology of PE is not exactly known, it is assumed that genetic factors play a role. A familial predisposition is present in 15–45% of patients with PE. There is also an association with some genetic syndromes such as Marfan syndrome, Ehlers-Danlos syndrome, Noonan syndrome and Turner syndrome; however, the exact interaction of these syndromes in the development of PE has not yet been clarified.[1]

The adverse health effects of PE can be physical and psychological. Physically, the depression of the sternum can put pressure on the lungs and heart, impairing respiratory and cardiac function and causing symptoms such as chest pain, shortness of breath and cardiac arrhythmias. Psychologically, it can lead to problems such as lack of self-confidence, social isolation, depression and anxiety due to the shape of the ribcage.[2]

Pectus excavatum can be diagnosed based on the shape of the anterior chest wall. The severity and symptoms of PE can vary with age. Imaging techniques and tests such as magnetic resonance imaging (MRI), thoracic computed tomography (CT), echocardiography and pulmonary function tests (PFT) can be used to measure the severity of PE and its impact on cardiopulmonary function. The Haller Index is a measure used to assess the severity of PE and to determine the need for surgery. The Haller index is calculated based on the ratio between the widest transverse diameter of the chest and the anteroposterior diameter in the plane of maximum PE. While this ratio is 2.56±0.35 in normal individuals, it can be 3.25 or more in patients with PE. Surgical treatment is recommended for patients with a Haller index above 3.25.[3]

Surgical and non-surgical methods are used to treat PE. However, there is no scientific evidence that non-surgical methods lead to anatomical correction. One of these treatment methods is the vacuum bell, a device used to pull the sternum forward by applying negative pressure to the chest wall. However, it is not suitable for all patients and its success depends on the age of the patient, the flexibility of the chest wall and the type and severity of the PE. Surgical treatment methods include the modified Ravitch and Nuss procedures. In the modified Ravitch procedure, an incision is made in the anterior chest wall, the cartilaginous parts of the ribs are removed and the sternum is corrected. The Nuss procedure is a minimally invasive procedure and was described in 1998.[4]

The ideal age for the Nuss surgery is usually between 12 and 17 years. At this age, the procedure can be more effective because the rib cage is more flexible and the healing process is faster. With increasing age, the flexibility of the rib cage can decrease and the difficulty of the procedure can increase. The likelihood of recurrence after surgery can also increase with age. It is therefore recommended that Nuss surgery be performed before puberty if possible. Thanks to the Nuss procedure, successful results can now also be achieved in patients in their 30s and 40s.[5,6]

The Nuss procedure is a surgical intervention performed under general anesthesia. To correct the depression in the chest, a metal bar is inserted through 2-centimeter incisions. This bar is rotated 180 degrees with a special tool to push the rib cage outwards and correct the depression. An aluminum model is also used to

determine the height, and the bar is shaped according to this model and inserted into the chest. The operation is performed with a video thoracoscope (VATS) and the procedure is completed by suturing the incisions.[6]

Aim

The main aim of this study is to investigate whether the Nuss procedure can also lead to successful results in adult patients, although it is a widely used treatment method in pediatric patients.

Material and methods

This study comprises a retrospective review of the Nuss procedure performed on patients with PE. Data were collected at a single center between October 2008 and May 2020 (Fig. 1A, 1B, 1C). A total of 90 patients who had not previously undergone surgical PE treatment and had been diagnosed with PE took part in the study. Patients were divided into two groups: under 18 years of age (pediatric group, n=53) and 18 years and older (adult group, n=37). Data examined in the study included age, gender, preoperative findings, Haller index, duration of surgery, length and number of bars used, number of stabilizers, length of hospital stay, perioperative and postoperative complications, and mortality. Haller index above 3.3 were included in the study. These data were taken from hospital records and patient files. This study was conducted in accordance with the Declaration of Helsinki. The study was approved by Istanbul Training and Research Hospital; protocol number (2020/450). Informed consent was obtained from all patients participating in the study.

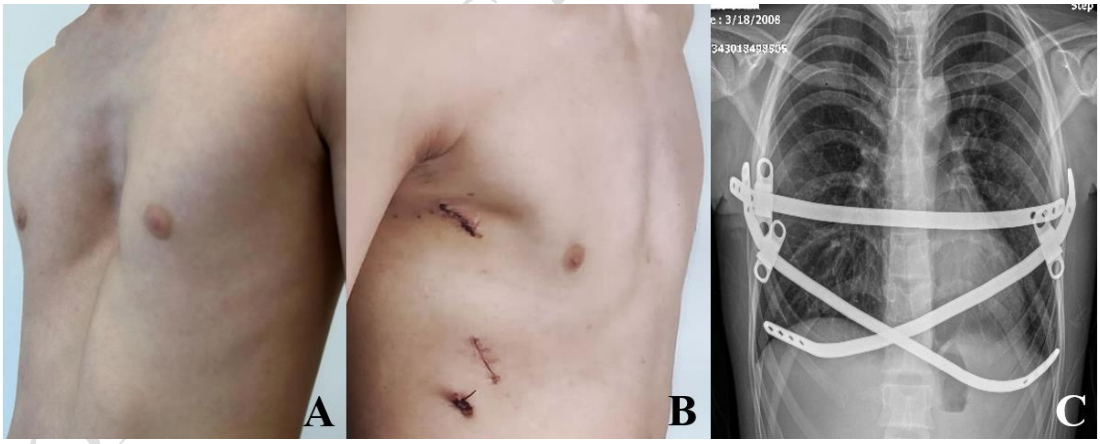

Fig. 1. A: PE, preoperative, B: postoperative image, C: postoperative x-ray

Statistical analysis

Descriptive statistics were used to analyze the data. Mean, standard deviation, median, minimum and maximum values were calculated for numerical data. The distribution of categorical data was examined and statistical significance was assessed using the Kolmogorov-Smirnov test. The Mann-Whitney U test was

used for quantitative independent data and the chi-square test for categorical independent data. All analyzes were performed using SPSS 27.0 software (IBM, Armonk, NY, USA). The significance level was accepted as $p<0.05$.

Results

The mean age of all patients in the study was 16.6 years (20±7.8, min. 12, max. 42), with 24.4% female (n=22) and 75.6% male (n=68), and the mean Haller index was 4.2 (4.3±0.7, min. 3.4 max. 6.1).

The patients' concomitant diseases included scoliosis, kyphoscoliosis, Marfan syndrome, Ehlers-Danlos syndrome, asthma, congenital heart defects, valvular heart disease and cardiac arrhythmias. Preoperative patient complaints included cosmetic and psychological problems, chest pain, palpitations, dyspnea on exertion and fatigue. Early postoperative complications in patients included pneumothorax, hemothorax, pleural effusion, skin infection, allergic reaction to the bar, early bar displacement, and need for reoperation. Late postoperative complications included chronic persistent pain, relapse after bar removal, and change in bar position (Table 1).

Table 1. Clinical and demographic characteristics of all patients

		Min–max	Median	Mean±SD/n (%)
Age		21–42	16.5	20±7.8
Gender	Woman			22 (24.4)
	Male			68 (75.6)
Haller index		3.4–6.1	4.2	4.3±0.7
Concomitant symptoms of diseases	(–)			22 (24.4)
	(+)			68 (75.6)
	Scoliosis			30 (33.3)
	Kyphoscoliosis			11 (12.2)
	Marfan syndorme			4 (4.4)
	Ehler-Danlos syndrome			1 (1.1)
	Asthma			13 (14.4)
	Congenital heart anomaly			1 (1.1)
	Heart valve disorder			7 (7.8)
	Cardiac arrhythmia			1 (1.1)
Duration of operation/minute		20–85	35	39.9±13.1
Bar length/mm		240–360	290	293.6±30
Number of bars		1–3	1	1.18±0.46

Number of stabilizers		1–3	1	1.17±0.46
Preoperative complaints	(–)			6 (6.7)
	(+)			84 (93.3)
Cosmetic and psychological				28 (31.1)
Pain in the chest				33 (36.7)
Palpitations				41 (45.6)
Shortness of the breath with increasing exertion, Rapid fatigue				38 (42.2)
Postoperative early complications (<3 months)	(–)			80 (88.9)
	(+)			10 (11.1)
Pneumothorax				2 (2.2)
Hemothorax				2 (2.2)
Pleural effusion				2 (2.2)
Skin infection				1 (1.1)
Bar-related allergic reaction				2 (2.2)
Early slippage of the bar and re-operation				
Postoperative complaints (>3 months)	(–)			75 (83.3)
	(+)			15 (16.7)
Chronic persistent pain				9 (10)
Relapse after bar extraction				4 (4.4)
Change in bar position (late phase)				2 (2.2)
Duration of hospitalization		3–7	4	4.3±1
Time of bar extraction (year)		1.5–5	3	3.2±0.7
Pediatric group				53 (58.9)
Adult group				37 (41.1)

The study included 53 pediatric patients (age range: 12–17, mean age: 15, female: 13, male: 40) and 37 adult patients (age range: 18–42, mean age: 26, female: 9, male: 28). The mean Haller index was 4.2 (4.4±0.6) in the pediatric group and 4.1 (4.3±0.7) in the adult group. The prevalence of concomitant diseases was 69.8% in the pediatric group and 83.8% in the adult group.

The most common concomitant disease in the pediatric group was scoliosis (34%), the second most common disease was bronchial asthma (15%). In the adult group, the most common concomitant disease (32.4%) was scoliosis, while the second most common diseases (13.5%) were kyphoscoliosis, asthma and valvular heart disease, in equal proportions.

The frequency of preoperative complaints was reported as 88.7 % in the pediatric group and 100 % in the adult group. The most common complaint in the pediatric group (45.3%) was palpitations, while the second most common complaint (37.7%) was shortness of breath and fatigue, which increased with exertion. In the adult group, the most common preoperative complaints (48.6%) were shortness of breath and fatigue, which increased with exertion, while the second most common (45.9%) were chest pain and palpitations in equal proportions.

The average bar length (mm) used in the surgery was 280 mm (279.1±24) in the pediatric group and 320 mm (314.3±25.2) in the adult group. The mean number of bars applied was calculated as 1 (1.1±0.38) in the pediatric group and 1 (1±0.105) in the adult group. The average number of stabilizers used was 1 (1.09±0.35) in the pediatric group and 1 (1.00±0.055) in the adult group. The average operation time was 35 minutes (39.0±12) in the pediatric group and 37 minutes (41.2±14.6) in the adult group. The average length of hospital stay (days) was 4 (4.2±0.9) in the pediatric group and 4 (4.4±1.1) in the adult group (Table 2).

Table 2. Comparison of complications between pediatric and adult groups

		Pediatric group		**Adult group**		**p**
		n	%	n	%	
Postoperative early complication	(–)	48	90.6	32	86.5	0.545 X^2
	(+)	5	9.4	5	13.5	
	Pneumothorax	1	1.9	1	2.7	
	Hemothorax	1	1.9	1	2.7	
	Pleural effusion	0	0	2	5.4	
	Skin infection	0	0	1	2.7	
	Bar associated allergic reaction	2	3.8	0	0	
	Early bar displacement and re-surgery	1	1.9	0	0	
Postoperative late complication	(–)	44	83	31	83.8	0.924 X^2
	(+)	9	17	6	16.2	
	Chronic persistent pain	8	15.1	1	2.7	
	Relapse after bar removal	0	0	4	10.8	
	Change in bar position (late phase, 3<month)	1	1.9	1	2.7	
X^2-Ki-square-test						

The early postoperative complication rate was determined in the pediatric group (9.4%, n1: 5) and in the adult group (13.5%, n2: 5). The most common early postoperative complications in the pediatric group

included pneumothorax (1.9%, n1: 1), hemothorax (1.9%, n1: 1), early bar slippage and reoperation (1.9%, n1: 1). In the adult group, the most common early postoperative complication was pleural effusion (5.4%, n2: 2), followed by pneumothorax (2.7%, n2: 1), hemothorax (2.7%, n2: 1) and skin infections (2.7%, n2: 1), which were found in equal proportions. No mortality was observed in either group. The postoperative late complication rate was found to be 17% in the pediatric group (n1: 9) and 16.2 % in the adult group (n2: 6). While the most common late postoperative complication in the pediatric group was chronic persistent pain (15.1%, n1: 8), recurrence after bar removal (10.8%, n2: 4) was the second most common in the adult group. The duration of bar removal (years) was analyzed with an average of 3 years (3.2±0.7) in the pediatric group and an average of 3 years (3.0±0.354) in the adult group (Table 2).

In patients who developed significant pneumothorax in both groups, lung expansion was achieved by tube thoracotomy (2/day). As culture examination revealed no growth for the skin infection, non-specific antibiotic therapy (1000 mg cephalexin 2×1, 5 days) was administered. Epidural analgesics, opioids and non-steroidal analgesics were used for early postoperative pain control. Other complications resolved spontaneously. In the late phase, some patients were consulted by the algology clinic and placed on an analgesic treatment protocol for patients with chronic pain. Patients who were found to have bar displacement during postoperative follow-up were readmitted for revision.

Given these results, statistical analysis did not detect a significant difference between the adult and pediatric groups in terms of gender distribution, Haller index, comorbidity rate, operative time, number of bars, number of stabilizers, postoperative early and late complication rates, hospital stay, and bar removal time ($p>0.05$). However, it was found that the bar length and the preoperative discomfort rate were significantly higher in the adult group than in the pediatric group ($p<0.05$) (Table 3, Figures 2 and 3).

Table 3. Comparative result between pediatric and adult group

		Pediatric group		**Adult group**		**p**	
		Mean±SD/n (%)	Median	Mean±SD/n (%)	Median		
Gender	Woman	13 (24.5)		9 (24.3)		0.982	X^2
	Male	40 (75.5)		28 (75.7)			
Haller index		4.4±0.6	4.2	4.3±0.7	4.1	0.450	m
Concomitant disease	(–)	16 (30.2)		6 (16.2)		0.129	X^2
	(+)	37 (69.8)		31 (83.8)			
Operation duration/minute		39±12	35.0	41.2±14.6	37	0.626	m
Bar length (mm)		279.1±24	280.0	314.3±25.2	320	<0.001	m

Number of bars		1.11±0.38	1.00	1.27±0.56	1	0.105	m
Namber of stabilizers		1.09±0.35	1.00	1.27±0.56	1	0.055	m
Preoperative complaints	(–)	6 (11.3)		0 (0)		0.034	X^2
	(+)	47 (88.7)		37 (100)			
Postoperative early complication	(–)	48 (90.6)		32 (86.5)		0.545	X^2
	(+)	5 (9.4)		5 (13.5)			
Postoperative late complication	(–)	44		31 (83.8)		0.924	X^2
	(+)	9 (17)		6 (16.2)			
Length of hospital stay		4.2±0.9	4.0	4.4±1.1	4	0.377	m
Period of bar removal (years)		3.2±0.7	3.0	3.1±0.7	3	0.354	m
Mann-Whitney-U-test / X^2-Ki-square-test							

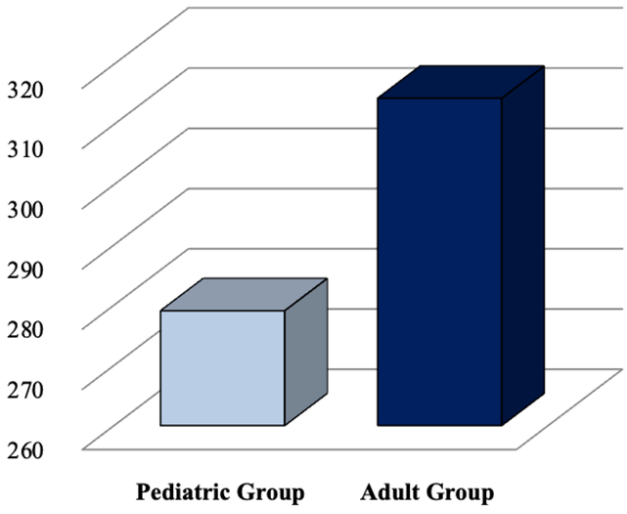

Fig. 2. Comparison between the groups of pediatric and adult in terms of bar length

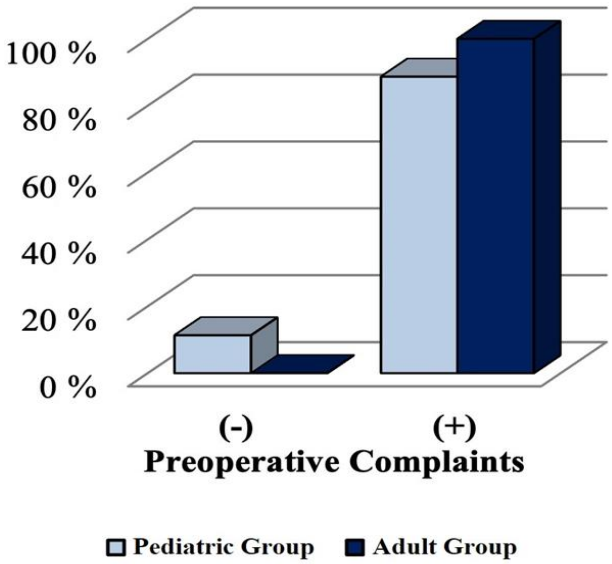

Fig. 3. Comparison between the groups of pediatric and adult in terms of preoperative complaints

Discussion

The Nuss procedure generally takes between 35 minutes and 2 hours, depending on the number of bars to be used. No intensive care is usually required after the operation. Patients usually stay in hospital for 3–5 days. Discomfort such as pain and shortness of breath may occur during the first week, but this can be reduced with painkillers, physiotherapy and exercises. After the operation, patients lie on their back and avoid lying on their side for about a month.[6]

In our study, there was no significant difference between the pediatric and adult groups in terms of surgery time, suggesting similar success rates. The fact that there was no significant difference between the two groups in terms of hospitalization suggests that the postoperative recovery process does not depend on age. Positive surgical outcomes were achieved in the adult group, which are consistent with the results reported in the literature, but differences in postoperative morbidity were found between the two groups.

The Nuss procedure offers advantages such as a short operation time, minimal blood loss, minimal scarring and rapid recovery. Displacement of the bar may have potential disadvantages such as pneumothorax, infection and recurrence of the pectus and, in rare cases, complications may arise such as nickel allergy to the steel rod. For patients who develop a nickel allergy, the bar may need to be removed or replaced with a titanium bar. A skin test for nickel allergy can be carried out before the operation. Sports should be avoided for a period of time after surgery, but activities such as swimming or fitness can be resumed after 3 months. Sports that require contact can be practiced after 6 months. Removal of the metal bar usually performed after 2 to 4 years. This procedure is shorter and less painful, and patients are usually discharged after one day.[4,6]

In the original procedure described by Nuss, a single bar was used in most cases. In cases where additional stabilization was required due to more severe deformities, two bars were used. This technique was later

slightly modified in some cases by using shorter and more bars to reduce the possibility of bar displacement.[7]

The Nuss procedure has had a positive effect on cardiopulmonary function in adult patients, with studies showing a significant improvement in maximal oxygen uptake during exercise.[5]

One of the most common known failures of the Nuss procedure is the displacement of the bar. The reason for bar displacement may be due to inadequate stabilization of the bar or the patient's movements, e.g., heavy contact sports, etc., in the postoperative period. Complications such as chronic pain lasting longer than 3 months have been reported to be more common in adult patients than in pediatric patients.[8,9]

In the selection of our patients, no distinction was made between symmetric and asymmetric PE, and asymmetric PE was present in both groups, but its number was low. Early and late displacement or shift of the bar was observed in 1.9% and 0.0% of pediatric patients and in 1.9% and 2.7% of adult patients, respectively.

The surgical technique and the number of stabilizers used were similar in both groups. In the pediatric group, bar slippage was associated with the patient not following certain rules after surgery. For example, activities such as sports or sleeping on the side can cause increased bar slippage. In contrast, late displacement or slippage of the bar in the adult group was attributed to the stiffer chest wall. Inadequate fixation of the bar was possible in both groups.

Patients compliance with certain restrictions and consideration of anatomical differences in the postoperative period are important to prevent or reduce rod slippage.

In our study, multiple bars were used in both groups. In the pediatric group, more bars (2 or 3) were preferred due to the Grand Canyon Deep Type PE. In addition, the number of stabilizers used was similar in both groups. The reason for using 3 bars in the adult group was that more bars were required due to the hardness of the rib cage. Therefore, we assume that the displacement rates of the bars could decrease due to the altered force distribution.

Kim et al. reported that the risk of postoperative complications was higher in adult patients due to the more frequent asymmetric deformity. The most common complication of asymmetric deformity is bar displacement. They reported that the risk of complications and outcomes in adults with symmetric deformities were comparable to those of children and adolescents, and they emphasized the importance of appropriate patient selection for the Nuss procedure.[10]

Jaroszewski and colleagues reported that bar displacement was observed after the Nuss procedure in 1%, 4% and 2% of patients in different age groups, aged 7–14, 15–20 and 21 years, respectively.[11]

In a study by Casamassina and colleagues, similar displacement rates of 2% and 7% in patients aged 18–29 years and 30–72 years, respectively, were reported. In patients with an average age of 31 years, a bar displacement rate of 4% was observed. [12]

The excessive stiffness of the sternum in adults is also likely the reason why they require more than one bar compared to pediatric patients; this could explain their higher observed average operative times and postoperative infection rates.[13,14]

Durry al. added a subxiphoid incision to the Nuss procedure to allow better visualization of the anterior mediastinum and reduce the risk of cardiac or pericardial perforation. However, they pointed out that this additional incision increases the operating time and that this can lead to complications.[15-17]

In our study, apart from the Nuss procedure, no additional surgical intervention was required in only one patient, apart from a 5 mm incision to place a sternal sling at the deepest point of the deformity due to scoliosis and asymmetric deep pectus. We can say that the Nuss procedure can prove its effectiveness in the surgical treatment of PE.

In the study conducted by Di Salvo et al, the most common complication in the early postoperative period in pediatric patients was pleural effusion that did not require chest drainage (8.3%), while the most common late complication was seroma that did not require drainage (55%).[18]

In our study, the most common complication in the early postoperative period among patients in the pediatric group was an allergic reaction related to the bar (3.8%), while the most common complication in the late postoperative period (15.1%) was chronic persistent pain. This difference is probably due to several factors, such as the patient population and differences in treatment during postoperative follow-up. Additionally, bar-related allergic reactions in pediatric patients may indicate a special situation that should be considered in the postoperative follow-up of this group.

Study limitations

The main limitations of this study include the fact that it was conducted in a single center, its retrospective design and associated bias, and the limited size of the study group. In future studies, larger participant groups and a prospective design can be used to ensure that the results obtained are more robust.

Conclusion

This study confirms that the Nuss procedure is a safe surgical treatment technique for PE in both young and adult patients. Although the risk of long-term pain after surgery is more common in the pediatric population, adult patients are not more prone to other complications compared to pediatric patients.

Declarations

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Author contributions

Conceptualization, T.D.; Methodology, T.D.; Software, T.D.; Validation, T.D.; Formal Analysis, T.D.; Investigation, T.D.; Resources, T.D.; Data Curation, T.D.; Writing – Original Draft Preparation, T.D.; Writing – Review & Editing, T.D.; Visualization, T.D.; Supervision, T.D.; Project Administration, T.D.; Funding Acquisition, T.D.

Conflicts of interest

No potential conflict of interest was reported.

Data availability

The data used in the study and the details of the method can be requested from the corresponding author.

Ethics approval

This study was conducted in accordance with the Declaration of Helsinki. The study was approved by Istanbul Training and Research Hospital; protocol number (2020/450). Informed consent was obtained from all patients participating in the study.

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