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Original Research

Computed Tomography Findings Affecting the Decision of Sternotomy in Substernal Goiter

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ABSTRACT

Objectives: Although thyroidectomy is completed with a cervical incision in most patients with substernal goiter (SG), sternotomies may be required occasionally. The purpose of this study is to examine computed tomography (CT) findings that may predict the need for sternotomy in SG surgery.

Methods: Neck-thoracic CT images of patients who underwent total thyroidectomy with the diagnosis of SG between 2013 and 2022 were retrospectively examined. The patients (n=41) were divided into two groups: sternotomies (n=6) and cervical (n=35). Preoperative pathological data, CT findings, and postoperative complications of the patients were recorded.

Results: The total thyroid volume of the sternotomy group (280.75±127.01 mm^3) was significantly greater than that of the cervical group (155.38±74.18 mm^3) (p=0.015). The retrosternal thyroid volume (mm^3), thyroid craniocaudal, and anterior-posterior dimensions (mm) were significantly greater in the sternotomy group (p=0.001, p<0.001, and p=0.004, respectively). While the majority of mediastinal extension degrees in the cervical group were grade 1 (80%), grade 2 (83%) predominated in the sternotomy group (p=0.001).

Conclusion: The radiological findings of total thyroid volume, retrosternal thyroid tissue volume, retrosternal thyroid length, thyroid anterior-posterior dimension, and mediastinal extension degree on CT are valuable in predicting the decision to perform a sternotomy in SG surgery.

Keywords: Computed tomography, sternotomy, substernal goiter, total tiroidectomy

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The extension of the enlarged thyroid gland below the thoracic inlet or the presence of more than 50% of its volume below the thoracic inlet is considered a substernal goiter (SG).[1,2] Gravity, a large mediastinal space, and negative intrathoracic pressure all contribute to the goiter's extension into the mediastinum. The reported prevalence is highly diverse (0.1–21%), and the incidence is observed in 1/5000 people.[2]

As the majority of the thyroid gland exhibits a retrosternal extension, the thyroid gland is not palpable in the neck in 20–30% of patients with SG, and approximately 40% are discovered incidentally.[3] Computed tomography (CT) of

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the neck and chest, which is widely used for preoperative imaging of SG, can evaluate the morphology, size, and relationship of the thyroid lobes with their placement, mediastinal extension, mediastinal vessels, and organs.

Thyroidectomy can be performed through a cervical incision in the majority of SG patients, while a sternotomy or thoracotomy is required in 2–19% of patients.[4] A surgical history, posterior mediastinal placement, and extension under the carina are all risk factors for sternotomy in SG.[1,5] There have been very few studies published on the decision to perform a sternotomy based on preoperative CT findings. The purpose of this study is to identify the CT findings that predict the indication for sternotomy in SG cases.

Methods

Patients who underwent total thyroidectomy with the diagnosis of SG in the general surgery clinic between 2013 and 2022 were examined retrospectively. Ethics committee approval was obtained for the study on June 21, 2022. Patients who underwent thyroid surgery for the 1st time and obtained preoperative neck-thorax CT images were included in the study. Patients who did not have CT images, had a history of autoimmune thyroid disease or thyroid surgery, and underwent neck dissection due to malignancy were excluded from the study. A total of 41 patients were included in the study as a result of exclusion criteria. In the calculation made for the power analysis carried out with the G Power 3.1.9.7 (Franz Faul, Germany) program, it was assumed that the effect size would be d=1.205. In the calculation made with the determined effect size and a 5% margin of error, the strength of the study was found to be 84.9%.

The patients were divided into two groups: sternotomy and cervical. A partial sternotomy was performed on all patients in the sternotomy group. The preoperative pathology data of the patients was recorded according to the Bethesda classification. The preoperative neck and thoracic CT images of the patients were retrospectively examined by two specialist radiologists with 8 years of experience in head and neck radiology. The following parameters were measured: lateralization, total thyroid volume (mm^3), retrosternal thyroid volume (mm^3), retrosternal thyroid length (mm), cervical length (mm), thyroid anterior-posterior (A–P) dimension (mm), thyroid mediolateral (M-L) dimension (mm), thyroidosternal length (mm), tracheal deviation length (mm), extension to posterior mediastinum, and mediastinal extension degree (Figs. 1 and 2). These parameters were determined according to the following criteria:

- Cervical length: the distance between the hyoid bone and the suprasternal notch
- Thyroidosternal length: the distance between the thyroid cartilage and the suprasternal notch
- Tracheal deviation length: the distance between the deviated trachea and the midline (vertebral axis).

The degree of mediastinal extension was determined based on the classification reported by Huins et al.[6]: Grade 1: thyroid tissue extending to the aortic arch; grade 2: between the aortic arch and pericardium; grade 3: thyroid tissue extending below the right atrium.

To measure thyroid volumes, postcontrast neck CT recon-

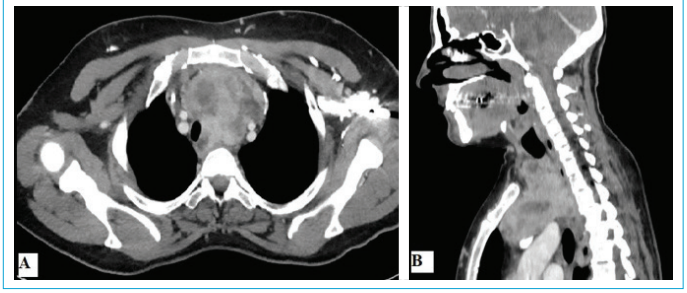

Figure 1. Computed tomography images of a substernal goiter case. (**a**): Axial section, (**b**): Sagittal section.

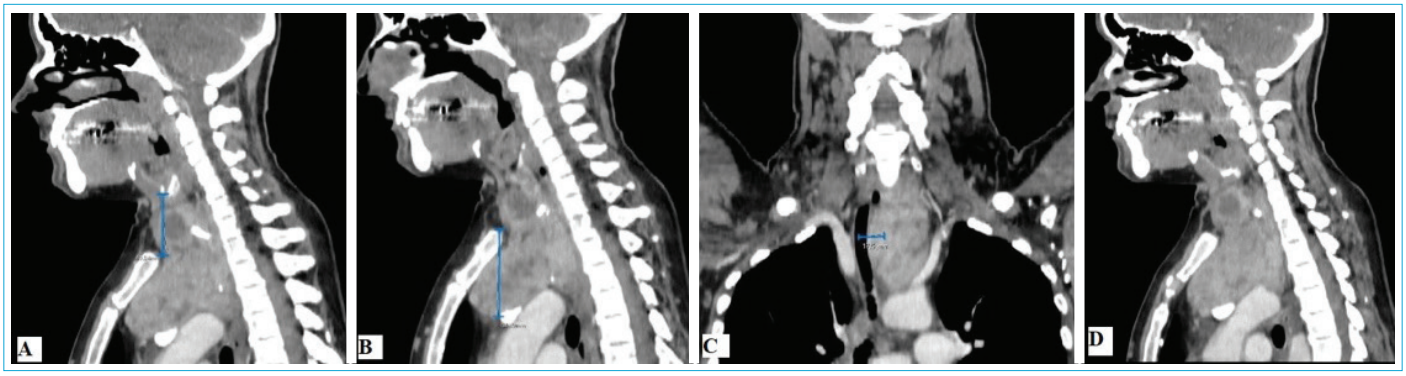

Figure 2. Images of radiological measurements (Computed tomography scan, sagittal (a, b, and d) and coronal sections (c)) (**a):** Thyroidosternal length measurement (**b):** Retrosternal thyroid length measurement (**c):** Tracheal deviation length measurement (**d):** A case of substernal goiter with mediastinal extension degree 2.

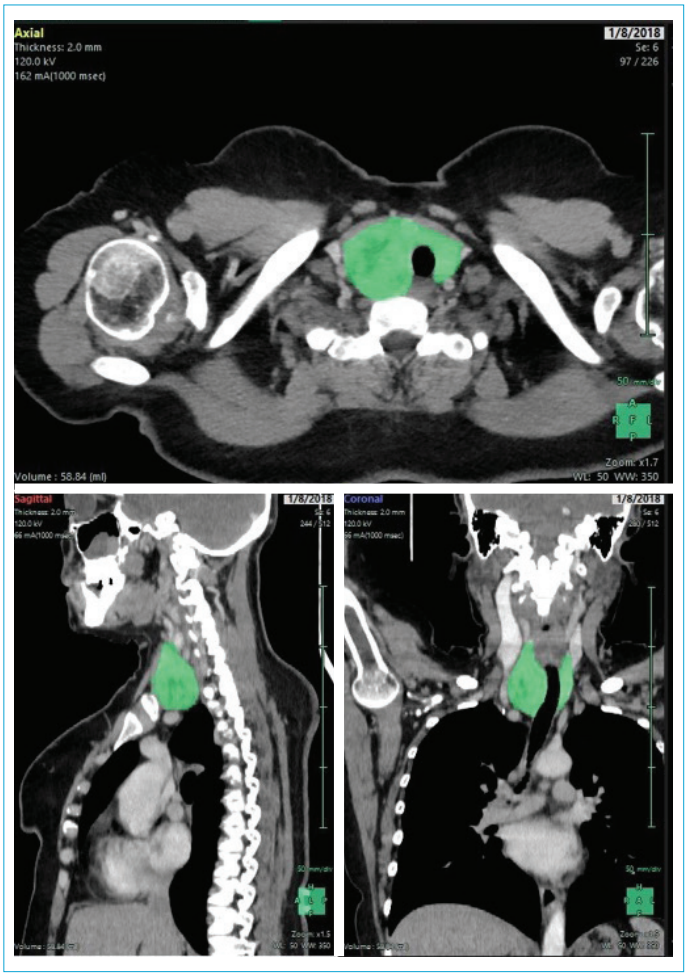

Figure 3. Postcontrast neck and thorax Computed tomography images of a 46-year-old female with substernal goiter and the volumetric measurement of thyroid tissue in the axial, sagittal, and coronal images.

structed with a 2 mm section thickness at 1 mm intervals was used. FUJIFILM SYNAPSE 3D and SYNAPSE PACS Software (Fujifilm Medical Systems, Tokyo, Japan) were used for volumetric assessments as follows: After manual selection of thyroid tissue in the axial sections, this package provides an automated calculation of total thyroid tissue volume. When the initial segmentation is complete, organ margins are verified and adjusted by the operator when necessary. Total thyroid tissue volume was expressed in mm^3 (Fig. 3).

Statistical Analysis

SPSS was used for statistical analysis of data (Statistical Packages for the Social Sciences, software, edition 21, SPSS Inc., Chicago, USA). The normality of the variables was examined with histogram graphs and the Kolmogorov-Smirnov test. Mean, standard deviation, median, and min-max values were used when descriptive analyses were presented. Categorical variables were compared with the Chi-square test. The Mann-Whitney U Test was used when evaluating nonparametric variables that did not show a normal distribution. Decently between the two groups. The factors affecting the sternotomy decision were examined by logistic regression analysis. Significant cut-off values that could predict sternotomy were examined by receiver operating characteristic (ROC) analysis. The cases where the p-value was below 0.05 were evaluated as statistically significant.

Results

The mean age of all cases was 54.0±13.9 years, of which 21 were male and 20 were female. There were 6 patients in the sternotomy group and 35 patients in the cervical group. There was no difference between the two groups in terms of age and gender (Table 1). The Bethesda score distribution of the two groups was similar (p=0.513). In the sternotomy group, unilateral recurrent nerve injury was observed in one patient, while in the cervical group, recurrent nerve injury occurred in one patient, transient hypocalcemia in four patients, and hematoma in one patient.

Total thyroid volume, retrosternal thyroid volume, retrosternal thyroid length, and thyroid A-P dimension were significantly higher in the sternotomy group (p=0.015, 0.001, 0.001, and 0.004, respectively) (Table 1 and Fig. 4). While the mediastinal extension degree of the cervical group was grade 1 in 80% (n=28), grade 2 was predominantly present in the sternotomy group (83%, n=5) (p<0.001).

When logistic regression analysis was performed, it was statistically observed that the parameters of total thyroid volume, retrosternal thyroid volume, retrosternal thyroid length, and thyroid A-P dimension were predictive factors for sternotomy (Table 2). It was found that a one-unit increase in total thyroid volume, retrosternal thyroid volume, and retrospective thyroid length increased the risk of sternotomy by 1.014, 1.058, 1.180, and 1.192 times, respectively (Table 2).

In the ROC analysis, significant cut-off values that may predict being in the sternotomy group for total thyroid volume, retrosternal thyroid volume, retrosternal thyroid length, and thyroid A-P dimension were calculated as 195 mm^3, 85 mm^3, 50 mm, and 59.5 mm, respectively (Table 3 and Fig. 5).

Discussion

SG usually occurs secondary to the extension of the thyroid gland to the intrathoracic region, with various effects such as negative intrathoracic pressure, gravity, a wide mediastinal space, a short neck of the patient, and esophageal motility. More rarely (2%), primary cases of SG arising from ectopic thyroid tissue in the mediastinum and hav-

Table 1. Comparison of demographic, radiological and clinical data between Sternotomy and Cervical Groups

	Sternotomy Group n (%)/ mean±SD	Cervical Group n (%)/ mean±SD	Total n (%)/ mean±SD	p
Age	53.6±11.4	54.0±14.4	54.0±13.9	0.926[1]
Gender (M/F)	4/2	17/18	21/20	0.613[2]
Bethesda score				
0	-	1 (3.0)	1 (2.5)	0.513[2]
1	-	2 (6.0)	2 (5.1)	
2	4 (66.6)	27 (81.8)	31 (79.4)	
3	1 (16.6)	2 (6.0)	3 (7.6)	
4	1 (16.6)	1 (3.0)	2 (5.1)	
Total thyroid volume (mm^3)	280.7±127.0	155.3±74.1	173.7±93.3	**0.015**[1]
Lateralization				
Right	1 (16.6)	3 (8.5)	4 (9.7)	0.795[2]
Left	2 (33.3)	15 (42.8)	17 (41.4)	
Bilateral	3 (50.0)	17 (48.5)	20 (48.7)	
Retrosternal thyroid volume (mm^3)	147.1±83.3	30.4±27.0	47.5±56.8	**0.001**[1]
Retrosternal thyroid length (mm)	58.5±17.2	20.1±13.0	25.7±19.2	**<0.001**[1]
A-P dimension (mm)	66.67±12.37	51±8.79	53.29±10.78	**0.0041**
M-L dimension (mm)	87.33±11.06	83.14±14.53	83.76±14.03	0.459[1]
Cervical length (mm)	56.3±16.7	65.9±17.6	64.5±17.6	0.238[1]
Thyroidosternal length (mm)	32.5±16.9	42.5±15.3	41.0±15.8	0.105[1]
Tracheal deviation length (mm)	14.0±9.2	13.2±7.5	13.4±7.6	0.941[1]
Extension to posterior mediastinum	1 (16.67)	5 (14.29)	6 (14.63)	0.879[2]
Mediastinal extension degree				
0	-	1 (2.8)	1 (2.4)	**<0.001**[2]
1	-	28 (80.0)	28 (68.3)	
2	5 (83.3)	6 (17,14)	11 (26.8)	
3	1 (16.6)	-	1 (2.4)	
Postoperative complication	1 (16.6)	7 (21.2)	8 (20.5)	0.800[2]

[1]Mann Whitney U Test; [2]Chi-square test; M: Male; F: Female; A-P: Anterior-posterior; M-L: Medial-lateral.

Table 2. Independent risk factors for sternotomy in SG patients

	B	S.E.	p	Exp (B)	95% C.I. for EXP (B)	
					Lower	Upper
Total thyroid volume (mm^3)	–0.014	0.006	**0.014**	1.014	1.003	1.025
Retrosternal thyroid volume (mm^3)	–0.056	0.022	**0.011**	1.058	1.013	1.105
Retrosternal thyroid length (mm)	–0.165	0.065	**0.011**	1.180	1.039	1.340
A-P dimension (mm)	0.176	0.074	**0.017**	1.192	1.032	1.377

Binary logistic regression; A-P: Anterior-posterior.

Table 3. ROC analysis and sensitivity, specificity, PPD, NPD values of predictive factors for sternotomy

	AUC (95% CI)	p	Cut-off	Sensitivity	Specificity	PPD	NPD
Total thyroid volume (mm^3)	0.814 (0.638–0.991)	**0.015**	≥195	(83.33)	(74.29)	(35.71)	(96.30)
Retrosternal thyroid volume (mm^3)	0.938 (0.837–1.000)	**0.001**	≥85	(83.33)	(94.29)	(71.43)	(97.06)
Retrosternal thyroid length (mm)	0.952 (0.861–1.000)	**0.000**	≥50	(83.33)	(100.00)	(100.00)	(97.22)
A-P dimension (mm)	0.852 (0.683–1.000	**0.006**	>59.5	(83.33)	(77.14)	(38.46)	(96.43)

A-P: Anterior-posterior; ROC: Receiver operating characteristic.

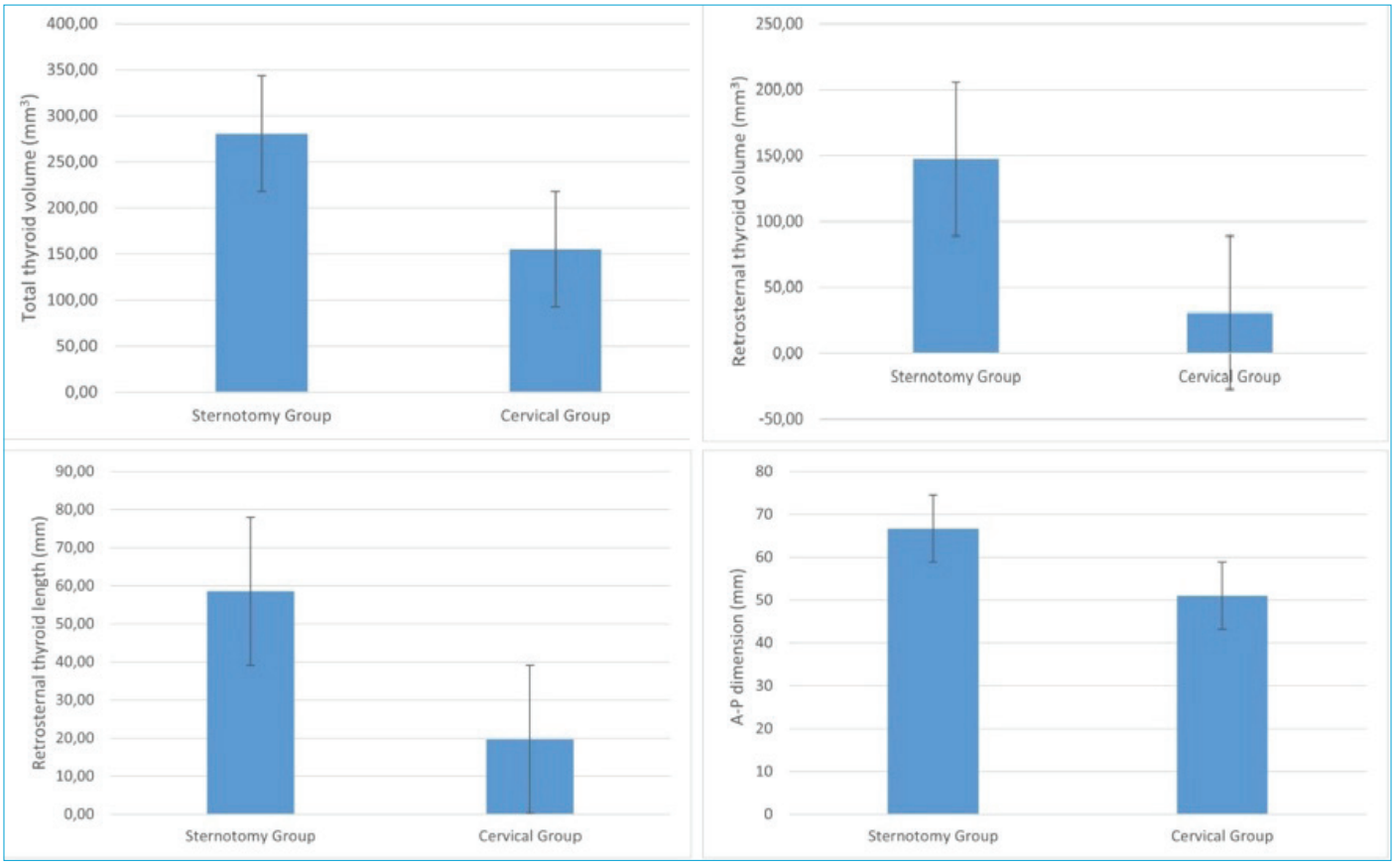

Figure 4. Comparison of the total thyroid volume, retrosternal thyroid volume, and retrosternal thyroid length in the sternotomy and cervical groups with graphics.

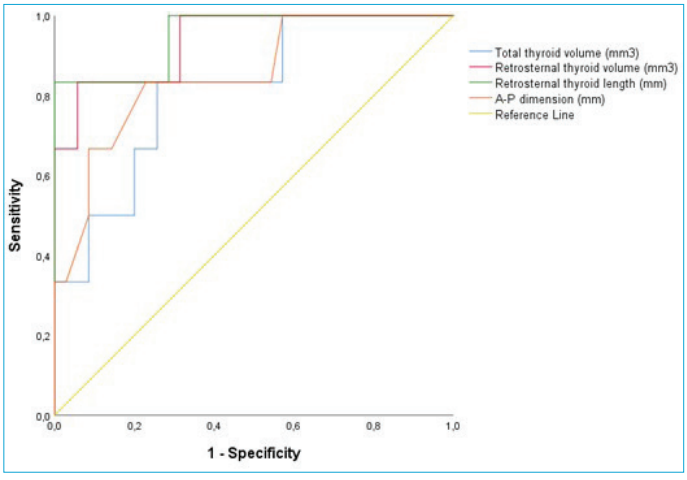

Figure 5. Receiver operating characteristic analysis of significant predictive factors.

ing no connection with the cervical thyroid gland may be observed.[7] In patients with SG, the most common compressive-related dyspnea (30–60%), swallowing difficulties, cough, hoarseness, or superior vena cava syndrome (Horner's syndrome) may occur during admission.[1,7,8] Patients with SG are asymptomatic by 20–40%, and an incidental diagnosis can be made by the appearance of tracheal deviation on a lung X-ray.[9]

Substernal total thyroidectomy is the surgical treatment for SG. Radioactive iodine ablation or thyroid hormone replacement therapies are unsuccessful in patients with SG.[1] Radyoactive iodine can potentially lead to acute goiter enlargement and further compression symptoms. In addition, it is difficult to perform a fine-needle biopsy in patients with SG, and this increases the risk of overlooked malignancies. For these reasons, surgery is the first treatment option that should be preferred, even if patients with SG are asymptomatic.[1,8,10]

A cervical incision (Kocher's incision) is sufficient for thyroidectomy in most of the SGs; however, sternotomy or thoracotomy may be required less frequently (2–11.7%).[11] A safe thyroidectomy will be possible with proper surgical planning and a dissection-based surgical plan. A partial sternotomy, also called a sternal split, is suitable for resection of SGs extending to the level of the aortic arch.[12] The most crucial tool for determining which patients might need sternotomies before surgery is radiological imaging. Posteroanterior chest X-rays give information about

trachea deviation or narrowing in patients with SG. Ultrasonography is the main imaging method for determining the volume, structure, size, shape, and content of thyroid tissue and possible metastatic lymph nodes, but it is limited in cases of SG because it cannot evaluate the bottom of the thoracic intervention well. Scintigraphy is an imaging method especially suitable for imaging hyperfunctional thyroid tissues. However, its sensitivity may decrease in SG due to the overlapping of intrathoracic vascular structures and the sternum.[13]

The most thorough examination for determining the extent of a SG and its effects on nearby anatomical structures is now CT scanning.[14] However, it should be remembered that positional factors will affect the images during CT shooting. If the patient's arms are positioned to be on the sides during CT, more healthy information about the substernal extension distance of the goiter is obtained. Riffat et al. [15] reported that the need for a sternotomy can be predicted with preoperative CT findings. Extension below the carina, below the posterior mediastinum, and a "conical" goiter, in which the thoracic inlet creates a ring of constriction, were the important prognostic markers requiring sternotomy.[15] According to Rugiu and Piemonte it has been reported that total thyroid volume is an effective factor in predicting sternotomy.[1] In our study, similar to the literature, total thyroid volume, retrospective thyroid volume, and length were found to be predictive factors for sternotomy.

Some authors have found that the sternotomy rate is higher in patients with SG who go below the lower border of the arcus aorta or have an extension to the posterior mediastinum, according to CT findings.[16,17] According to Huins et al.,[6] in an analysis involving 34 studies and 2426 patients, he proposed a classification to predict the incision shape in SG. The authors found that sternotomy or thoracotomy was required in 16% of 2426 patients. According to the substernal extension of the thyroid gland, they created a 3° classification: Grade 1: Above the aortic arch (above T4); Grade 2: Aortic arch to the pericardium; Grade 3: Below the right atrium. They have argued that cervical incision is sufficient for thyroidectomy in Grade 1 patients, but manubriotomy or sternotomy is safer in Grade 2 or 3 patients.[6] In this study by Huins et al.,[6] the extension of SG to the anterior or posterior mediastinum or the bilateral or unilateral extension of the extension were not taken into account. In our study, in parallel with the literature, the mediastinal extension degree of the sternotomy group was found to be significantly higher.

Mercante et al.[18] divided the craniocaudal length into 3° in CT images of SG, and the arcus aorta was selected as the critical anatomical point. Goiters extending from the thoracic entrance to the convex part of the arcus aorta are classified as (1) degrees; those extending to the concave part of the arcus aorta are (2) degrees; and those extending below the concave part of the arcus aorta are (3) degrees and are classified as SG. In addition, according to the relationship of the substernalgoid to the veins and trachea, those located in front or behind the veins were defined as type A or B, and those extending towards the back of the trachea were defined as type C. Researchers have found that the sternotomy rate is higher in goiters extending below the level of the arcus aorta.[18] Mercante et al.[18] also found that the sternotomy rate is 12 times higher in cases of thyroid malignancy compared to benign pathology. In our study, the Bethesda score was not found to be a determining factor for the decision to have a sternotomy.

In our study population, 14.6% of patients (n=6) developed one or more postoperative complications, which is comparable to the results reported in the literature.[19,20] It is known that sternotomies are an independent risk factor for morbidity.[20] In the present study, the absence of a significant difference between the sternotomy and cervical groups in terms of postoperative complications may be due to the small sample size.

The fact that it is retrospective and includes a small patient group was one of the limitations of our study.

Conclusion

As a result, a cervical incision is sufficient for thyroidectomy in most patients with SG. Multidisciplinary evaluation before surgery with preoperative neck or thoracic CT is important for a safe thyroidectomy. In CT, total thyroid volume, retrosternal thyroid volume, retrosternal thyroid length, thyroid anterior-posterior dimension, and mediastinal extension degree are effective predictive factors for making sternotomy decisions in SG surgery.

Disclosures

Ethics Committee Approval: The study was approved by the Ethics Committee of Bakirkoy Dr. Sadi Konuk Training and Research Hospital Local Ethics Committee (No: 2022-21-06, dated 07.11.2022).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – O.A.; Design – O.A., E.I., S.A.; Supervision – E.I., A.C.D.; Materials – S.A., D.G., O.A., H.A.; Data collection and/or processing – O.A., H.A., S.A.; Analysis and/or interpretation – O.A., D.G., A.C.D.; Literature review – D.G., O.A., H.A.; Writing – O.A., O.A.; Critical review – E.I., A.C.D.

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