ORIGINAL ARTICLE

Diagnostic Accuracy Study of CT Scan in Predicting the Need for Sternotomy in Management of Substernal Goiters

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Abstract

Aim and objective: To find a new predictor of sternotomy with thyroid gland measurements in CT scan.

Materials and methods: We performed a retrospective review of our endocrine surgery database between January 2012 and October 2017. We identified 123 patients treated for substernal goiter, 7 required an extra-cervical approach, and 116 a cervical one. The measurement of thyroid gland craniocaudal length, larger diameter of mediastinal component, and the diameter of thoracic inlet were performed in all patients with substernal goiter. ROC analysis was performed to determine craniocaudal length and mediastinal thyroid mass diameter cutoff value, which significantly predict the need of an extra-cervical approach for substernal goiter.

Results: The craniocaudal length of thyroid mass below thoracic inlet ≥34.5 mm and the diameter of mediastinal component ≥53.5 mm were significantly associated with the need of an extra-cervical approach ($p = 0.005$ and $p = 0.015$, respectively). We also analyzed the ratio between mediastinal component diameter and thoracic inlet diameter and the ROC analysis of this ratio identified ≥1.24 as the cutoff value with maximum accuracy. A ratio ≥1.24 was significantly associated with the need of sternotomy ($p = 0.03$) with a likelihood ratio of 9.09 (IC 4.32-19.51).

Conclusion: The ratio between mediastinal component diameter and thoracic inlet ≥1.24 was a significant determining factor for sternotomy.

Clinical significance: The ratio we suggest based in CT scan measurements allows the identification of patients who may need sternotomy, permitting referral patients to another hospital with thoracic surgeons and prior preparation of the surgical team. Furthermore, these measurements can be obtained by a trained head and neck surgeon.

Keywords: AUC, Diagnostic test accuracy study, Likelihood ratio, ROC curve, Substernal goiter, Thyroid.

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Introduction

Substernal goiter (SSG) has a worldwide incidence that varies significantly from 0.2 to 40.0%,[1] according to the defining criteria, because there is no universal definition of SSG.[2] Most commonly accepted definitions describe SSG as thyroid gland that descends below the level of the thoracic inlet (TI), or has >50% of its volume lying inferior to the TI.[3-5]

Clinical presentation of a SSG ranges from asymptomatic patients to a major dysfunction affecting swallowing, airway, and even compressing large vessels.[6,7]

The preferred treatment approach for patients with SSG is surgery, even for asymptomatic patients, owing to the high risk of malignancy or tracheal compression.[3,5] The surgical treatment of a SSG includes hemithyroidectomy or total removal of the thyroid gland.[8] Thyroidectomy can be accomplished via cervicotomy in most patients with SSG. The need of extracervical approach (ECA)–either partial/total sternotomy or lateral thoracotomy–usually does not exceed 10%.[1,9] Regardless of the surgical approach, thyroidectomy for SSG comprises a higher morbidity, with an increased risk for the patient if a sternotomy is performed.[10] Any surgeon performing thyroidectomy for SSG should be prepared for the need of sternotomy, as it requires more planning, a higher amount of resources, and potentially higher perioperative risks for the patient.[11] Preoperative identification of patients with SSG who might require a sternotomy is important, so we can advise the patient about the increased risk associated with this procedure. It also allows for the preparation of surgical team with support of a thoracic surgeon, specific equipment, and preparation of postoperative care.[1,2,11] CT scan is the most useful diagnostic modality for preoperative preparation and prediction of ECA.[2,12-14]

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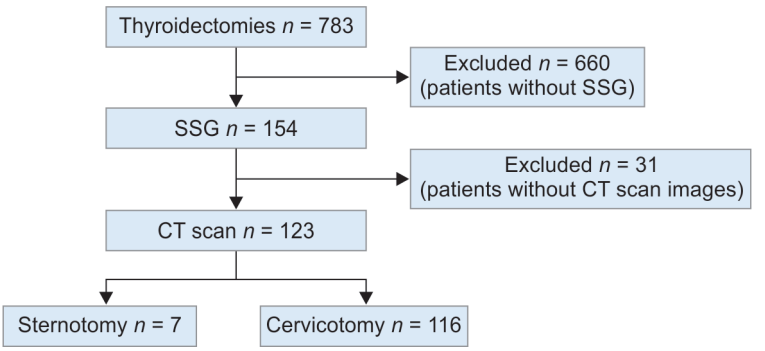
There are multiple classification systems that rely on CT findings to predict the need of sternotomy, however, there is no an acceptable universal marker that can be easily reproducible to predict the need of sternotomy.[1,2,9,12-14] The aim of the study is to find a new and reproducible predictor of sternotomy from thyroid gland measurements in CT scan.

Materials and Methods

We performed a retrospective review of our institutional endocrine surgery database. Between January, 2012 and December, 2017, 783 thyroidectomies were performed by general surgeons. We identified 123 patients with SGG and preoperative CT scan that were eligible consecutively for this study (Flowchart. 1). SSG was defined as radiological evidence of a thyroid gland extending below the

Flowchart 1: Flowchart of included patients



TI plane, as this definition refers to consistent anatomic landmarks that are easily recognized both radiologically and during surgery.

Surgeries were not performed by the same surgical team. During surgery, all cases were initially approached by cervicotomy. First thyroid vessels were ligated, then liberation of thyroid gland upper pole was performed. SSG thoracic component was retracted to cervical region by digital blunt dissection. Whenever blind dissection was considered unsafe with risk of mediastinal bleeding or recurrent laryngeal nerve (RLN) damage, surgical team opted for sternotomy. The same approach was selected when an enlarged mediastinal thyroid component could not be removed from the TI.

Our population had a median age of 63 years (18-85 years), and were mostly women (73%). 50.4% were symptomatic dysphagia, dyspnea, and hoarseness were the most common symptoms. All patients underwent preoperative neck and thorax CT scan to evaluate the extent of retrosternal portion. According to the CT scan, 40.7% had trachea deviation, 5.7% esophageal deviation, and 2.4% vascular deviation.

Patients who required sternotomy were classified as group 1 (5.7%) and patients who required cervical approach were classified as group 2 (94.3%). Age, sex, compressive symptoms rate, trachea, esophageal and vascular deviation, tracheal caliber reduction, malignancy, and postoperative complications were compared between groups.

After the definition of the study design, a general surgeon of our department performed several measurements of the SGG and TI from preoperative cervical CT scan of all patients with SSG submitted to thyroidectomy, but without the information of the surgical approach. Then these measurements were validated by a head and neck surgeon. These measurements were made in the SECTRA software, which is the software used in our institution to analyze CT scan images. Craniocaudal (CC) length (Fig. 1A) of thyroid gland mediastinal component was measured in coronal view, from the level of the suprasternal notch to the caudal limit of thyroid gland. Larger diameter (LD) of thyroid gland mediastinal component (Fig. 1B) and TI diameter (Fig. 1C) were measured in axial view. TI diameter was estimated by the length of a line between the first thoracic vertebra and sternoclavicular joint. In order to find a predictor of sternotomy, we calculated a ratio between LD of thyroid mediastinal component and TI diameter.

Statistical analysis was performed with SPSS version 25. Continuous variables are presented as means and standard deviations, or as median with minimum and maximum for variables with skewed distribution. Differences between groups were assessed using Mann-Whitney test for non-normally distributed data and Fisher test for categorical variables. A p value < 0.05 was considered to be statistically significant. ROC analysis and Youden index were performed to define the cutoff value for CC length and LD of thyroid gland mediastinal component, as well for the ratio between LD of thyroid mediastinal component and TI diameter, which significantly predict the need of sternotomy for substernal goiter.

Results

In our population, the rate of sternotomy was 5.7% ($n = 7$).

The demographic and clinic data of groups 1 and 2 are summarized in Table 1 and postoperative complications in Table 2. Group 1 patients were older than group 2, with significant difference between the two groups ($p = 0.008$). There was no association between the presence of compressive symptoms, tracheal, esophageal, or vascular deviation and tracheal caliber reduction with any type of surgical approach. There was also no association between the postoperative complications with any type of surgical approach. During postoperative time, there was no cases of bleeding with need of reintervention.

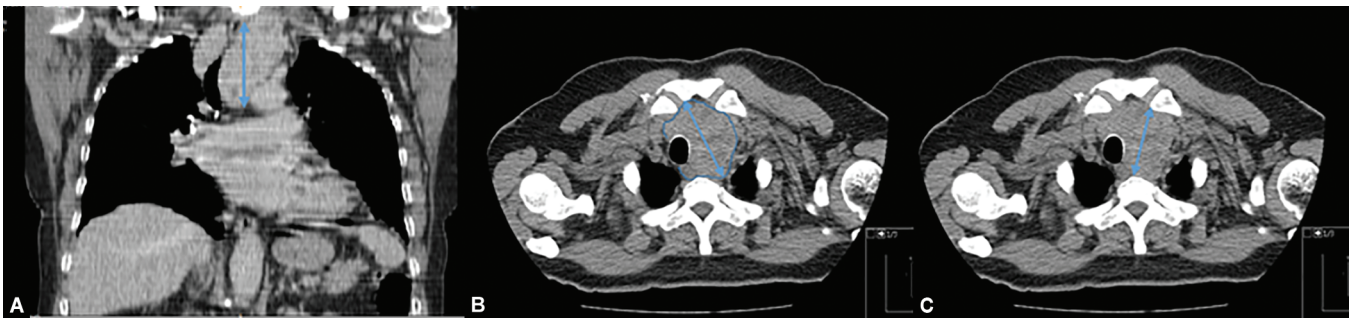
Results of measurements of CC length, LD of mediastinal component, TI diameter, and ratio between LD of thyroid mediastinal component and TI diameter are listed in Table 3.

The ROC analysis of CC length and LD of mediastinal component identified ≥34.5 mm and 53.5 mm as cutoff values with maximum accuracy, respectively (Figs. 2A and B). CC length ≥34.5 mm and LD of mediastinal component ≥ 53.5 mmm were significantly associated with the need of sternotomy ($p = 0.005$ and =0.015, respectively, Table 4). We also analyzed the ratio between the LD of mediastinal component and TI diameter (ratio LD/TI), and ROC analysis of this ratio identified ≥1.24 as the cutoff value with maximum accuracy (Fig. 2C). A ratio of ≥1.24 was significantly associated with the need of sternotomy ($p = 0.03$, Table 4). For predicting sternotomy, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the cutoff value for this ratio were 89%, 100%, 100%, 33%, respectively (Table 5).

Discussion

Substernal goiter is a particular entity in endocrine surgery, considering its volume and intrathoracic extension, with the need of surgical technique that rises surgical risk comparatively to cervical goiter. Hypoparathyroidism and RLN injury are the most frequent complications associated with SSG surgery because mediastinal position may displace RLNs and parathyroids from their usual location.

Most SSG can be removed without the need for sternotomy, although any surgeon performing this kind of procedure should be well prepared for that requirement.



Figs 1A to C: Measurement of CC length (A–coronal section), LD (B–axial section) of thyroid gland mediastinal component and TI diameter (C–axial section) on CT scan

Table 1: Demographic data and clinical features in patients with sternotomy (group 1) and cervical approach (group 2) for substernal goiter

	Group 1 (n = 7)	*Group 2 (n = 116)*	*p value*
Age (years)	73 (42-74)	63 (18-85)	0.008
Female (%)	86%	72%	0.673
Compressive symptoms (%)	29%	52%	0.421
Trachea deviation (%)	43%	41%	0.693
Tracheal caliber reduction (%)	29%	20%	0.345
Esophageal deviation (%)	14%	5%	0.308
Vascular deviation (%)	0	3%	1.000
Thyroid malignancy (%)	0	16%	0.592

Table 2: Postoperative complications in patients with sternotomy (group 1) and cervical approach (group 2) for substernal goiter

	Group 1 (n = 7)	*Group 2 (n = 116)*	*p value*
Dysphonia	29%	18%	0.316
Vocal cord paresis	0	5%	1.000
Hypocalcemia	14%	25%	1.000
Dysphagia	0	1%	1.000
Bleeding	0	0.8%	0

Table 3: CT scan measurements in patients with sternotomy (group 1) and cervical approach (group 2) for substernal goiter

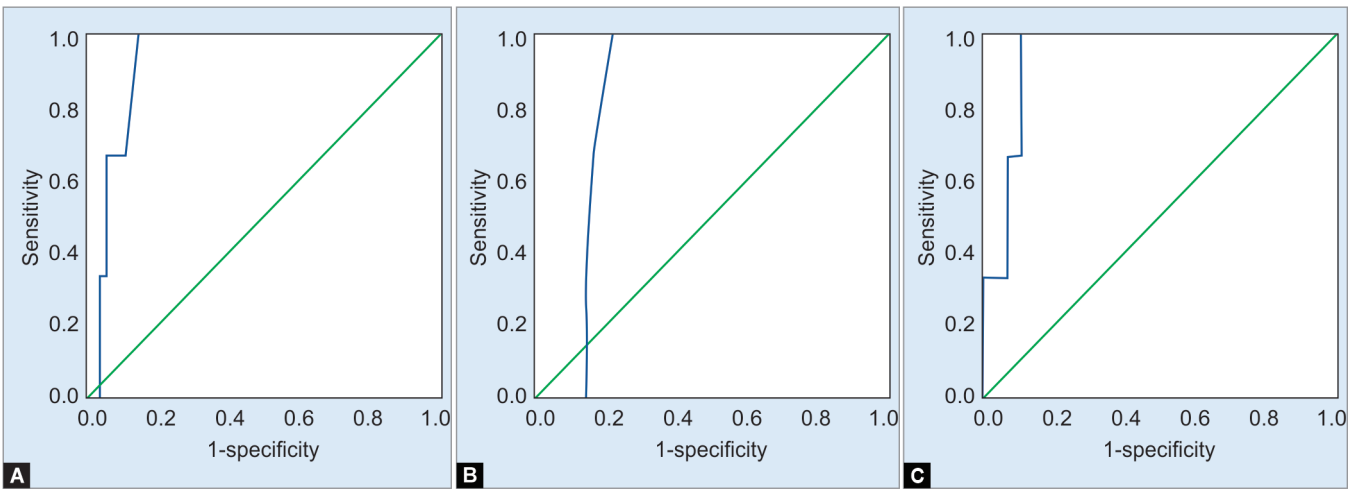
	Group 1 (n = 7)	*Group 2 (n = 116)*	*p value*
CC length of SSG (mm)	42 ± 7	21 ± 13	0.010
LD of SSG (mm)	55 ± 1	41 ± 14	0.000
TI (mm)	41 ± 4	48 ± 7	0.105
Ratio LD/TI	1.36 ± 0.15	0.87 ± 0.29	0.005

In this study, between the most common definitions, we defined SGG as radiological evidence of thyroid gland descending below the TI plane, as this definition is the most inclusive and refers to consistent anatomic landmarks that are easily recognized during surgery. In our population, the rate of sternotomy for SSG was 5.7% ($n = 7$), which is consistent with previous reports.[14] When sternotomy was anticipated, a thoracic surgical team was available for helping. Of the 16 patients in whom sternotomy was anticipated, this was only necessary in six cases. There was a case in which sternotomy was not anticipated.

Most of the classification systems found in literature for preoperative stratification of patients who would require ECA were based on the relationship of the substernal thyroid gland to major vessels and trachea and posterior mediastinal extension.[1,2,9,12-14] Thyroid cancer with or without recurrence, emergency surgery, need for reoperation, extension down to the aortic arch, iceberg shape, ectopic mediastinal goiter, and the presence of a large intrathoracic goiter, especially in the posterior mediastinum or producing superior vena cava syndrome, have all been reported as factors with significant association with ECA.[1,2,9,14-16]

Huins et al. reported a review including 34 studies with 2,426 patients and identified that ECA was required for 16% of the patients.[2] The investigators described a system comprising 3 grades according to the substernal extension of the thyroid gland. In this investigation, cervicotomy is appropriate for patients whose thyroid gland is above the level of the aortic arch (grade 1); however, sternotomy is safer for those with thyroid glands at grades 2 (between aortic arch and pericardium) or 3 (below the level of the right atrium).

Mercante et al. proposed another classification system divided into 3 grades based on thyroid CC length and anteroposterior dimension in CT images.[14] In their study, the rate of ECA was 6.7%.



Figs 2A to C: ROC curve of the ability to predict sternotomy of CC length (3A, AUC: 0,927, standard error: 0,039; Youden index = 0,782), LD of mediastinal component (3B, AUC: 0,836, standard error: 0,050; Youden index = 0,855) and ratio between LD and TI diameter (3C, AUC: 0,939, standard error: 0,038; Youden index = 0,891)

Table 4: Sternotomy according to the cutoff values

CC length of SSG (mm)	*Sternotomy (n = 7)*	*p value*
≥34.5	7	0.005
<34.5	0	
LD of mediastinal thyroid (mm)		
≥53.5	6	0.015
<53.5	1	
Ratio LD/TI		
≥1,24	7	0.003
<1.24	0	

In this analysis, ECA was significantly correlated with ≥ grade 2 SSG and/or retrotracheal extension and malignancy.

Sormaz et al.[17] showed that the CC length of the mediastinal extension was 77 ± 11 mm in patients who needed ECA. The cutoff value of CC length, which most accurately predicted ECA, was ≥66 mm, with an NPV of 97% in predicting ECA. They also evaluated the need for ECA in SSG according to the mediastinal thyroid volume. A mediastinal thyroid volume ≥162 cm^3 was a significant determining factor for ECA, with a NPV for the ECA of 100% for SSG with smaller volumes.

Our analysis showed that a CC length of mediastinal extension ≥34.5 mm and LD of mediastinal component ≥53.5 mm were significantly associated with the need for sternotomy, however, ROC analysis showed that they were not good predictors of sternotomy.

Our study is the first to evaluate the need for sternotomy in SSG according to the ratio between LD of mediastinal component and TI diameter. The aim of the current study was to predict the most crucial step on SGG surgery, which corresponds to the delivery of the thoracic extension by digital blunt dissection. In addition to the mediastinal portion diameter, a smaller TI diameter can also preclude mediastinal portion retraction. Normally, this step dictates the need for sternotomy or not. We found a ratio that was a good predictor of the need of sternotomy and showed that this ratio

Table 5: The sensitivity, specificity, PPV, NPV, the accuracy, LR and posttest probability of the cutoff value of the ratio LD/TI for predicting sternotomy

	Ratio LD/TI ≥ 1.24
Sensitivity (%)	100
Specificity (%)	89
PPV (%)	33
NPV (%)	100
Accuracy (%)	90
Likelihood ratio	9.09
Posttest probability (%)	33

≥1.4 is significantly associated with the need of sternotomy. In fact, all patients submitted to sternotomy had a ratio ≥1.4. With these findings, we suggest that this ratio could be applied to our clinical practice since these measurements can be performed by a trained head and neck surgeon.

Over the last years, other approaches have been introduced to limit comorbidity of classical thoracotomy and sternotomy, ranging from video thoracoscopy to mediastinoscopy and robotic procedures to increase safety in the dissection of mediastinal structures.

Limitations of the present study include the inherent biases in retrospective studies, with possibility of incomplete documentation or missing charts. It was performed in a non-controlled setting, with a small patient population and different size study groups, which might preclude a significant conclusion or extrapolation of the findings. Moreover, measurements of the CC length, LD mediastinal component, and TI diameter, in the image software, were performed by a head and neck surgeon. However, in the future, these measurements could be described in CT scan report by the radiologist. Also, patients in this study were managed by multiple surgeons.

Conclusion

Sternotomy is rarely indicated for resection of SSG, however, it must be anticipated, as it requires specific resources and preoperative discussion with the patient. CT scan is the most

accurate investigation to characterize SSG and helps to determine the surgical approach. The ratio we suggest based on CT scan measurements is a good predictor of sternotomy and patients with a ratio ≥1.4 could be referred to sternotomy.

Clinical Significance

The ratio we suggest based on CT scan measurements allows the identification of patients who may need sternotomy, permitting referral patients to another hospital with thoracic surgeons and prior preparation of the surgical team. Furthermore, these measurements can be obtained by a trained head and neck surgeon.

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