

Predictive Value of Preoperative Computed Tomography in Sternotomy for Substernal Goiter

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Abstract

Objective The aim of this study was to validate the predictors of peroperative computed tomography imaging parameters for sternotomy in patients with substernal goiter.

Methods We retrospectively reviewed complete clinical and computed tomography data of 37 patients who had substernal goiter and underwent surgery from January 2010 to February 2019. The patients were divided into two groups based on whether or not underwent sternotomy surgery. The maximum length and width, length behind sternum of tumors were measured on preoperative computed tomography images, the volume above and below sternum, and total volume of tumors was calculated. Logistic regression model and receiver operating characteristic curve analysis were performed to identify significant predictors associated with sternotomy.

Results Out of a total of 37 patients, 4 patients (10.8%) underwent sternotomy. The length, width and length behind sternum, as well as the volume below sternum and the total volume of tumors were significantly greater in patients with sternotomy compared to those without sternotomy (all $P < 0.05$). The length behind sternum (OR 1.152, 95% CI: 1.012-1.312, $P = 0.033$) of tumors was the simple and convenient predictor for sternotomy in substernal goiter. The optimal cut-off value of length behind sternum was 46.7 mm (area under the curve: 0.962, 95% CI: 0.896-1.028, $P \leq 0.01$), and the sensitivity and specificity was 100% and 87.9%, respectively.

Conclusion Computed tomography examination plays an important role in determining the surgery need for substernal goiter. The length behind sternum of tumor is a convenient and independent predictor of sternotomy for substernal goiter.

1 Introduction

Substernal goiter (SG) was first described by Haller in 1749 and first surgically removed by Klein in 1982¹. At present, the definition of SG is not uniform. The various different criteria have been suggested in different literatures, including more than 50% of the volume of goiter located behind sternum², or a thyroid gland extending 3 cm below the thoracic inlet, or extension of the gland below the fourth thoracic vertebra¹. SG can compress and shift the large vessels, trachea and nerves in the neck, resulting in dyspnea and dysphagia, and even Honer syndrome due to compression of cervical sympathetic nerve or obstruction of superior vena cava reflux^{3,4}. Surgery is an effective treatment for SG, regardless of sternotomy. Surgical strategy depends on the experience and comprehensive judgment of surgeon. Therefore, we collected and analyzed the preoperative computed tomography (CT) imaging parameters of SG patients to explore predictors for sternotomy.

2 Methods

2.1 Patients

The clinical and radiological data of all patients with substernal giant goiter were retrospectively obtained from our computerized database between January 2010 and February 2019, which was provided by the Breast Disease Center in the Southwest Hospital of the Army Medical University. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Southwest Hospital of Army Medical University. Patients all granted written informed consent for surgery and the use of clinical records in this study.

In the 8-year interval from 2010 to 2019, a total of 37 patients with SG diagnosed by CT, including 8 males and 29 females with an average age of 54 ± 10 years (range from 33 to 70 years), were enrolled. Giant substernal goiter was defined as follows based on CT scan: (1) a goiter extending below the plane of the thoracic inlet; (2) a goitre with $\geq 50\%$ of its mass located in the mediastinum; (3) a goiter with the maximum diameter exceeding 7 cm. For each patients, information on demographic data [age, sex, and body mass index (BMI)], medical history data, preoperative CT imaging data and pathological type of tumors were also collected. The patients with incomplete clinical data and CT data had been excluded.

Of these, 4 patients were converted to sternotomy because of the difficulty in traditional cervical approach. Based on surgical approaches, these patients were divided into two groups, the non-sternotomy approach group (33 patients) and sternotomy approach group (4 patients).

2.2 CT Data Processing

All patients had CT plain and enhanced axial and coronal 3D reconstruction cervical CT images. Two certified thyroid surgeons with 7 years and 12 years experience in cervical CT analyzed tumor features with regard to location, number, size, and shape. The maximum length and width, as well as the maximum length behind the sternum (defined as $\text{length}_{\text{sternum}}$) of tumors were measured on coronal or sagittal images. The area of each layer of tumors was measured on axial images. Then, according to the formula: $\text{volume} = \sum (\text{area} \times \text{thickness})$, the volume above sternum (defined as V_1), the volume below sternum (defined as V_2), and the total volume of tumor (defined as V_t) was calculated. In cases of discrepancies in the interpretations of the two radiologists, a consensus was reached.

2.3 Statistical Analysis

Statistical analysis was performed using the SPSS statistical software package (version 25.0, Chicago, IL, USA). Quantitative variables were presented as mean \pm standard deviation (SD), tested for normality and equality of variances using the Kolmogorov-Smirnov test, and compared using unpaired Student's t test or nonparametric test, whereas categorical variables were expressed as counts in percentages and compared using the chi-squared test or continuity correction test. We used logistic regression analysis to investigate the factors associated with sternotomy. Multi-collinearity was assessed by checking the Variance Inflation Factor. Variables significant at $P < 0.05$ by univariate analysis were subjected to forward stepwise multivariate logistic regression model to identify independent predictor for sternotomy. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic capability of CT parameters and to calculate the area under the ROC curve (AUC), optimal cut-off value,

sensitivities and specificities. All statistical tests of hypothesis were conducted at the 0.05 level of significance.

3 Results

3.1 Characteristics of Patients with SG

Of total 37 patients with SG, there were 33 cases (89.2%) in non-sternotomy group and 4 cases (10.8%) in sternotomy group. There were significant statistical differences in length, width, length_{sternum}, V_2 and V_t (all $P < 0.05$) between the two groups of patients with SG. There were no significant differences in age, sex, BMI and pathological types (all $P > 0.05$) between the two groups. The baseline characteristics of the two groups of patients were shown in Table 1.

Table 1
The baseline characteristics between two groups

Variables	Non-Sternotomy (n = 33)	Sternotomy (n = 4)	P
Age (years, $\bar{x} \pm s$)	54 \pm 9.6	53 \pm 11	0.821
Sex [M, n (%)]	6 (18.2)	2 (50.0)	0.144
BMI (kg/m ² , $\bar{x} \pm s$)	23.18 \pm 3.16	23.21 \pm 0.58	0.985
CT features			
Length (mm, $\bar{x} \pm s$)	98.36 \pm 18.08	125.20 \pm 26.70	0.011
Width (mm, $\bar{x} \pm s$)	56.53 \pm 12.12	76.06 \pm 20.29	\leq 0.01
length _{sternum} (mm, $\bar{x} \pm s$)	29.87 \pm 14.18	70.60 \pm 20.13	\leq 0.01
V ₁ (cm ³ , $\bar{x} \pm s$)	88.11 \pm 42.08	98.94 \pm 68.82	0.980
V ₂ (cm ³ , $\bar{x} \pm s$)	27.96 \pm 24.60	180.67 \pm 121.22	\leq 0.01
Vt (cm ³ , $\bar{x} \pm s$)	116.07 \pm 41.78	279.61 \pm 186.91	\leq 0.01
Pathological types [n (%)]			
Nodular goiter	15(45.4%)	1(25%)	0.039
Thyroid adenoma	12(36.4%)	1(25%)	
Hashimoto's thyroiditis	3(9.1%)		
Follicular carcinoma	2(6.1%)		
Atypical adenoma		1(25%)	
Hurthle cell tumor	1(3.0%)		
Papillary carcinoma		1(25%)	
V ₁ : the volume above sternum; V ₂ : the volume below sternum; Vt: total volume of tumor.			

3.2 CT Characteristics of tumors

The patients in sternotomy group had significant greater length (125.20 \pm 26.70 mm vs 98.36 \pm 18.08 mm), width (76.06 \pm 20.29 mm vs 56.53 \pm 12.12 mm), length behind the sternum (70.60 \pm 20.13 mm vs 29.87 \pm 14.18 mm), V₂ (180.67 \pm 121.22 cm³ vs 27.96 \pm 24.60 cm³) and Vt (279.61 \pm 186.91 cm³ vs 116.07 \pm 41.78 cm³) of tumor than those in non-sternotomy group (all P < 0.05). Although the volume

above sternum in sternotomy group ($98.94 \pm 68.82 \text{ cm}^3$) was larger than that in non-group sternotomy ($88.11 \pm 42.08 \text{ cm}^3$), there was no significant difference ($P > 0.05$) (Table 1).

3.3 Predictors Associated with Sternotomy for SG patients

In univariate analysis, length [OR 1.078 (95% CI: 1.005–1.156, $P = 0.033$)], width [OR 1.095 (95% CI: 1.011–1.187, $P = 0.027$)], length_{sternum} [OR 1.159 (95% CI: 1.014–1.324, $P = 0.031$)], and total volume [OR 1.000 (95% CI: 1.000–1.000, $P = 0.039$)] of tumor were significantly associated with sternotomy. The multivariate logistic regression analysis showed that length_{sternum} [OR 1.152 (95% CI: 1.012–1.312, $P = 0.033$)] was independent predictors of sternotomy for patients with SG (Table 2).

Table 2
logistic regression analysis of predictors influencing sternotomy for substernal goiter

Variables	Univariate		Multivariate	
	P	OR (95% CI)	P	OR (95% CI)
Length	0.036	1.078 (1.005–1.156)		
Width	0.027	1.095 (1.011–1.187)		
length _{sternum}	0.031	1.159 (1.014–1.324)	0.033	1.152 (1.012–1.312)
V ₁	0.645	1.000 (1.000–1.000)		
V ₂	0.051	1.000 (1.000–1.000)		
V _t	0.039	1.000 (1.000–1.000)		

V₁: the volume above sternum; V₂: the volume behind sternum; V_t: total volume of tumor; OR: odds ratio; CI: confidence intervals.

3.4 ROC curve analysis

ROC curve analysis suggested that the AUC in a decreasing order was $V_2 > \text{length}_{\text{sternum}} > \text{length} > \text{width} > V_t > V_1$, that is, V_2 (AUC: 0.976, 95% CI: 0.928–1.024, $P \leq 0.01$) and the length_{sternum} (AUC: 0.962, 95% CI: 0.896–1.028, $P \leq 0.01$) were the most valuable factor in judging whether sternotomy was warranted (Fig. 1). The cut-off value for V_2 of 68.96 cm^3 provided the optimal sensitivity and specificity of 100% and 93.6%, respectively. The cut off values of length_{sternum} was 46.7 mm with the sensitivity of 100% and specificity of 87.9%, respectively (Table 3).

Table 3
Receiver operating characteristic curve of CT parameters of substernal goiter

Variables	AUC (95% CI)	Cut off	Sensitivity	Specificity	P
Length	0.811 (0.512–1.105)	124.9	75.0	93.9	0.044
Width	0.796 (0.507–1.084)	71.7	75.0	90.9	0.056
length _{sternum}	0.962 (0.896–1.028)	46.7	100	87.9	≤ 0.01
V ₁	0.508 (0.093–0.923)	141.8	50.0	90.3	0.959
V ₂	0.976 (0.928–1.024)	69.0	100	93.6	≤ 0.01
V _t	0.782 (0.538–1.027)	315.9	50.0	100	0.070

AUC: Area under curve; V₁: the volume above sternum; V₂: the volume behind sternum; V_t: total volume of tumor; OR: odds ratio; CI: confidence intervals.

4 Discussion

Substernal goiter accounts for 1%-20% of patients undergoing thyroidectomy. Most of the patients are middle-aged women, and it is four times more common in women than in men ⁵. Due to the specific location of tumor, some patients have no obvious symptoms in the early stage. With the enlargement of the mass, the tumor is limited by the surrounding bone structure and tends to oppress the adjacent important organs and structures, thus presenting various clinical symptoms, such as dyspnea mainly due to the involvement of the trachea, dysphagia resulting from the involvement of the esophagus, and hoarseness caused by compression of the recurrent laryngeal nerve ⁶.

Surgical resection is an effective method for the treatment of SG ⁴⁻⁷. At present, there is no uniform criteria to evaluate sternotomy. Because of the limitations of cervical ultrasound for the proper assessment of SG, preoperative CT examination is recommended for evaluating the extension of the thyroid, the presence of tracheal compression, to understand the relationship with surrounding organs, nerve and blood vessels, and also to develop the surgical strategy ^{5,8}. For patients with tumor extending into deep sternum, or intimately adhered to surrounding tissues, and those who have huge tumor mass or require a secondary surgery, to ensure the safety of the surgery, it is necessary to make routine preparations for thoracotomy.

Some studies have shown some related indicators of preoperative CT imaging in the prediction of surgical methods for substernal goiter. CT features, such as 70% of the volume of the thyroid mass located behind the sternum ⁹, and the mass exceeding the aortic arch or tracheal carina ⁸ are the main indications for sternotomy. Malignant nodules, mass extending into the posterior mediastinum and the presence of ectopic solitary goiter were also the CT imaging indications of sternotomy ^{8,10-12}. In addition,

reoperation for recurrent SG, non-recurrent laryngeal nerve, and abnormal vascular variation are also factors to be considered in thoracotomy.

Our study showed that the length, width, length behind sternum, volume below sternum, and total volume of tumor in patients with sternotomy approach were significantly greater than those with non-sternotomy approach. The length behind sternum was an independent risk factor for sternotomy. ROC analysis found that the volume behind sternum and the length behind sternum were the most valuable factor in judging whether sternotomy was performed. Our findings provide a specific reference standard for clinical decision-making based on the comprehensive judgment of surgeon, so as to develop a more beneficial surgical strategy for patients.

We admit that several limitations still exist in our study. First of all, due to the relatively small number of patients in this study, our conclusion requires further verification in large studies. Secondly, there is a potential for unintentional bias because of the relatively small number of subjects. Thirdly, the limitations of retrospective and single center study design would lead to a potential information bias of our study.

5 Conclusion

CT examination plays an important role in developing surgery strategy for SG. The length behind sternum of tumor is a convenient and independent predictor of sternotomy for SG. However, due to the relatively small number of subjects in this study, further larger sample clinical studies are still needed for verification.

Abbreviations

AUC: Area under the curve; CI: Confidence interval; CT: Computed tomography; OR: Odds ratio; ROC: Receiver operating characteristic; SD: Standard deviation; SG: Substernal goiter

Declarations

Conflicts of Interest

The authors have no conflicts of interest to declare.

Data Availability Statement

The datasets used and analysed to support the findings of current study are available from the corresponding author upon reasonable request.

Author contributions

FZ conceived, organized and supervised the study. DWZ, THX, YZS, YL and XC collected data and conducted the research. DWZ, THX and YL performed the statistical analysis. YZS, YL and XC prepared

the pictures and tables. DWZ, THX and YL drafted the manuscript. FZ and YL revised the manuscript. All authors approved the final version to be published.

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Figures

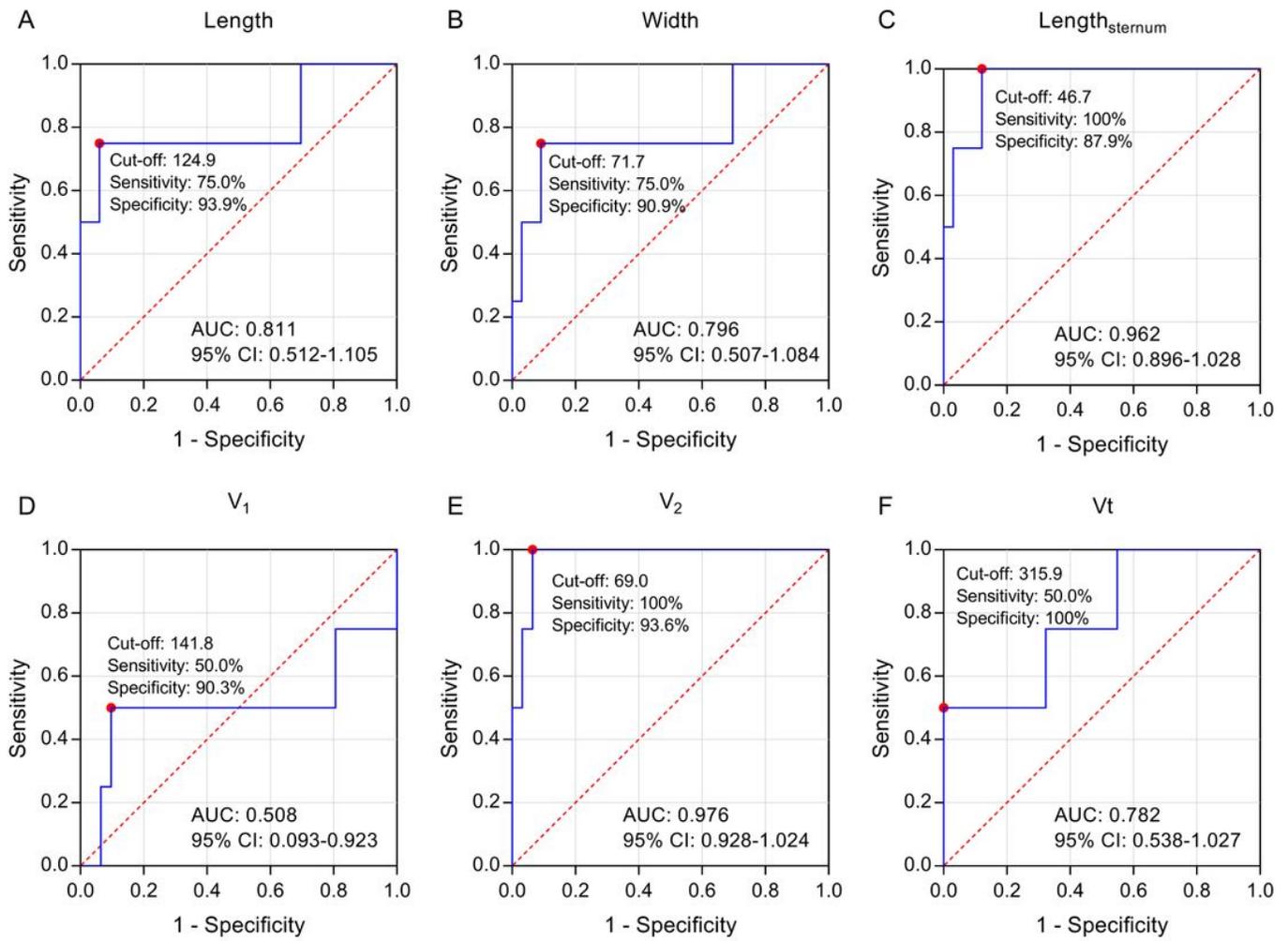


Figure 1

Receiver operating characteristic curve of CT parameters of tumor.