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SURGICAL TREATMENT CHARACTERISTICS AND TACTICAL OPTIMIZATION FOR GIANT AND SUBSTERNAL GOITER: A FIVE-YEAR INSTITUTIONAL EXPERIENCE

Ermuminov Iskandar Ziyodullo ugli
Scientific Advisor: DSc, Associate Professor
Irisov Ortiqali Tulayevich
Academician V.V. Vakhidov Republican Specialized Scientific and Practical Medical Center of Surgery, Tashkent, Uzbekistan

Abstract

Background: Giant and substernal goiters remain major surgical entities requiring comprehensive tactical management due to their anatomical migration into the mediastinum, complex vascular architecture, and high risk of respiratory and vascular compression.

Aim: To systematically evaluate the surgical treatment characteristics, intraoperative decision-making, and long-term tactical outcomes of giant and substernal goiter resections to minimize perioperative risks and standardize access choice.

Materials and Methods: A retrospective and prospective cohort analysis was carried out on 147 consecutive patients managed surgically at the Academician V.V. Vakhidov Center from 2019 to 2024. Multi-slice computed tomography (MSCT) scanning with 3D reconstruction was utilized to classify mediastinal extension into Grade I (above aortic arch), Grade II (at arch level), and Grade III (deep mediastinal penetration). Operative approach selection focused on standard cervical access with structured conversion criteria to median sternotomy or lateral thoracotomy.

Results: RETROSTERNAL extension mapping showed Grade I in 51.0% (n=75), Grade II in 35.4% (n=52), and Grade III in 13.6% (n=20) of cases. Total excision via standard cervical collar incision alone was achieved in 87.1% (n=128) of patients. Sternotomy conversion was required in 10.2% (n=15), and lateral thoracotomy was utilized in 2.7% (n=4). Post-operative complications included transient hypocalcemia (9.5%), transient recurrent laryngeal nerve palsy (5.4%), permanent nerve injury (1.4%), and intraoperative tracheomalacia (2.0%). No intraoperative or early post-operative mortality occurred.

Conclusion: Pre-operative multi-planar MSCT visualization is critical for safe tactical planning. While the vast majority of substernal masses can be delivered safely using digital cervical traction and meticulous capsular dissection, specialized conversion parameters to sternotomy must be maintained for deep posterior, recurrent, or calcified masses to preserve airway structural stability and achieve immediate vascular control.

Keywords: Substernal Goiter, Giant Goiter, Thyroidectomy, Sternotomy, Recurrent Laryngeal Nerve, Tracheomalacia.

1. Introduction

The clinical management of giant and substernal thyroid masses occupies an exceptionally complex and high-risk domain within modern endocrine, general, and thoracic surgery. While standard cervical thyroidectomies are widely regarded as safe procedures with well-documented, standardized outcomes, the extension of a thyroid mass below the thoracic inlet completely transforms the surgical landscape. A substernal or retrosternal goiter is typically defined as a thyroid mass in which at least 50% of the total gland volume has migrated caudally into the mediastinal cavity. This anatomical displacement introduces significant pathophysiological

adjustments, primarily driven by the progressive mass effect exerted by the expanding thyroid tissue within the non-yielding, rigid osseous walls of the superior mediastinum.

The clinical presentation of these patients is highly symptomatic and is characterized by progressive upper respiratory and vascular compression. As the goiter increases in volume, it causes progressive lateral displacement and significant narrowing of the trachea. This structural distortion manifests clinically as exertional dyspnea, expiratory wheezing, and inspiratory stridor, which can escalate into sudden, life-threatening airway occlusion. Positional orthopnea and choking fits are common when the patient is supine, as gravity exacerbates the retrosternal mass effect. Beyond airway compression, giant goiters frequently compromise the esophagus, causing progressive dysphagia. Compression of the low-pressure venous network within the superior mediastinum can lead to Superior Vena Cava (SVC) syndrome. This condition presents with facial plethora, upper extremity edema, and the development of prominent collateral venous networks across the anterior chest wall, significantly increasing the complexity of surgical access.

The underlying mechanisms behind the development of substernal goiters involve a combination of gravity, negative intrathoracic pressure during inspiration, and the anatomical constraints of the cervical fascia. Over decades, large multinodular goiters are guided caudally by the prevertebral and pretracheal fascia into the space of least resistance: the superior mediastinum. As the mass descends, its blood supply undergoes significant changes. While standard cervical goiters are supplied exclusively by the superior and inferior thyroid arteries, deep mediastinal goiters frequently recruit additional parasitic blood vessels directly from thoracic sources. These ectopic feeding vessels may arise from the internal mammary arteries, the intercostal arteries, or directly from branches of the aortic arch. This complex vascular recruitment creates a major technical challenge, as these deep thoracic vessels cannot be visualized or controlled from a standard cervical approach, increasing the risk of uncontrolled mediastinal hemorrhage during blunt digital extraction.

Furthermore, chronic compression of the trachea by a giant goiter can induce tracheomalacia—the progressive structural degradation, thinning, and loss of elasticity of the cartilaginous tracheal rings. When the supporting mass is removed during surgery, the malacic segments of the trachea can collapse completely under negative inspiratory pressure, leading to immediate post-extubation asphyxia. Therefore, optimizing the surgical approach requires careful pre-operative planning, impeccable intraoperative technical execution, and clear structural criteria for expanding surgical access. This study evaluates the multi-year experience of the Academician V.V. Vakhidov Center with 147 patients, focusing on tactical optimization to minimize intraoperative risks and improve post-operative recovery.

2. Materials and Methods

A retrospective and prospective cohort analysis was performed on 147 consecutive patients who underwent surgical intervention for giant and substernal goiters at the endocrine surgery department of the Academician V.V. Vakhidov Republican Specialized Scientific and Practical Medical Center of Surgery between January 2019 and December 2024. All surgical procedures and clinical protocols were reviewed and approved by the Institutional Review Board and the Ethics Committee of the Ministry of Health of the Republic of Uzbekistan, ensuring strict adherence to the ethical standards of the Declaration of Helsinki.

The baseline demographic composition of our cohort revealed a mean patient age of 54.2 ± 12.6 years, with a high concentration of cases in the fifth and sixth decades of life. This timing highlights the slow, progressive growth of multinodular goiters before they descend into the mediastinum and cause compressive symptoms. Gender distribution demonstrated a strong female

predominance, with women accounting for 76.2% (n=112) and men representing 23.8% (n=35) of the population. This 3.2:1 female-to-male ratio is consistent with the well-documented higher epidemiological prevalence of benign and malignant nodular thyroid disease in women.

The pre-operative diagnostic workup followed a strict, standardized multimodal protocol designed to establish a detailed map of the regional anatomy. Frontline screening began with high-resolution transabdominal ultrasonography of the neck to evaluate the volume, echotexture, and nodular configuration of the cervical thyroid component, as well as to screen for suspicious regional lymphadenopathy. However, because ultrasound cannot penetrate the bony structures of the sternum and clavicles, Multi-Slice Computed Tomography (MSCT) of the neck and chest was mandatory for all 147 patients. MSCT scans were performed with intravenous contrast enhancement and multi-planar 3D volumetric reconstructions. These scans were used to determine the exact craniocaudal limits of the mediastinal component, map the structural relationship of the goiter to the aortic arch and brachiocephalic vessels, and measure the minimum internal cross-sectional diameter of the trachea to evaluate the risk of tracheomalacia.

Based on the multi-planar MSCT findings, the depth of retrosternal descent was classified into three distinct structural grades: Grade I denoted a goiter whose inferior pole extended below the thoracic inlet but remained above the upper border of the aortic arch; Grade II described a mass extending caudally to the level of the aortic arch, occupying the superior mediastinum; and Grade III classified deep mediastinal goiters descending below the level of the aortic arch into the anterior or posterior mediastinal compartments. Inclusion criteria for this study required a confirmed histopathological diagnosis of nodular or multinodular goiter with an intraoperatively and radiologically verified substernal component exceeding 50% of the gland volume. Patients with primary isolated mediastinal neurogenic tumors or thymomas were excluded from the analysis.

The surgical technique followed a standardized capsular dissection method. A low Kocher cervical collar incision was used as the primary approach for all patients. The strap muscles were divided horizontally in cases involving exceptionally large cervical components to maximize exposure. The superior thyroid vascular poles were ligated close to the thyroid capsule to protect the external branch of the superior laryngeal nerve. Early division of the thyroid isthmus was performed to separate the lateral lobes, allowing for individual mobilization of the mediastinal components. Digital dissection was performed strictly within the true avascular avasculat thyroid capsule, using gentle upward traction. Specific criteria for conversion to a median sternotomy included: Grade III extension with deep thoracic vascular anchoring, a mediastinal component significantly wider than the superior thoracic inlet, recurrent substernal goiter with dense post-operative scarring, and suspicion of malignant invasion into adjacent thoracic structures. Statistical processing and data visualization were performed using Python 3.10 with Pandas and Seaborn.

3. Results and Discussion

Pre-operative multi-planar MSCT mapping revealed a high level of anatomical complexity within our 147-patient cohort. Grade I extension was observed in 75 patients (51.0%), representing cases where the inferior pole was deliverable without direct thoracic expansion. Grade II extension was identified in 52 patients (35.4%), where the mass reached the level of the aortic arch and caused lateral tracheal displacement. Grade III extension was confirmed in 20 patients (13.6%), representing the most challenging scenarios due to deep mediastinal descent. The baseline anatomical distribution of these extension depths is structured in Table 1.

Retrosternal Extension Grade (MSCT Mapping)	Patients (n=147)	Percentage Share (%)

Grade I (Caudal limit above upper border of aortic arch)	75	51.0%
Grade II (Caudal limit reaching level of aortic arch)	52	35.4%
Grade III (Caudal limit descending below aortic arch level)	20	13.6%

Table 1: Detailed classification of retrosternal goiter extension depths based on MSCT metrics.

The high prevalence of Grade II and Grade III extensions (collectively comprising 49.0% of the cohort) highlights the significant compressive potential of these masses. This anatomical distribution is visually illustrated in the high-resolution bar chart in Figure 1

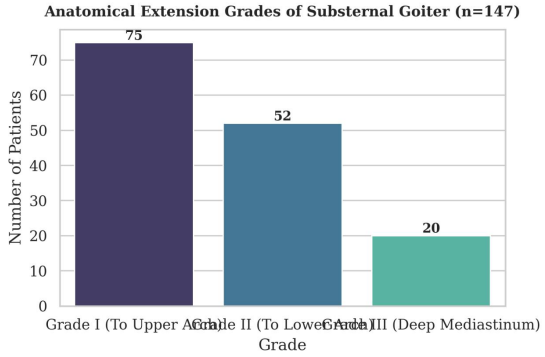


Figure 1: Visual distribution of mediastinal extension grades among the 147 analyzed patients.

Pre-operative clinical presentation was dominated by severe compressive symptoms, as shown in Figure 2. Severe upper airway compression presenting as progressive exertional dyspnea or inspiratory stridor was observed in 115 patients (78.2%). Esophageal compression causing dysphagia was noted in 42 patients (28.6%), while clinical signs of superior vena cava syndrome (SVC) were present in 12 patients (8.2%). Only 8 patients (5.4%) were completely asymptomatic, with the retrosternal component detected incidentally during routine chest imaging for unrelated conditions.

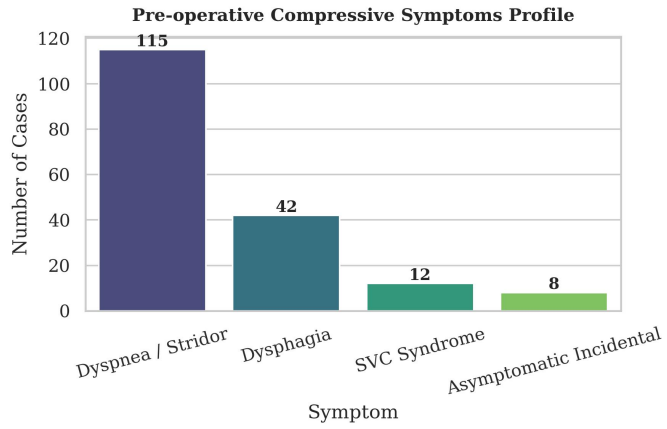


Figure 2: Clinical symptoms profile highlighting the predominance of airway compression over vascular signs.

Analysis of surgical access configurations confirmed that a standard cervical collar incision alone was sufficient for complete, safe resection in 128 cases (87.1%). This high rate demonstrates that the majority of substernal goiters can be successfully delivered through a cervical approach without requiring bony division of the thoracic cage. This delivery relies on digital mobilization performed strictly within the true avascular thyroid capsule. By maintaining a sharp dissection plane against the thyroid capsule, the surgeon can safely sweep away the surrounding mediastinal pleura, brachiocephalic veins, and fatty tissue, avoiding injuries to these structures. However, 15 patients (10.2%) required conversion to a median sternotomy, and 4 patients (2.7%) with deep posterior mediastinal descent required an additional lateral thoracotomy access. The tactical breakdown of these approaches is detailed in Table 2.

Surgical Access Configuration	Cases (n=147)	Share (%)	Primary Tactical Indication
Cervical Collar Incision Alone	128	87.1%	Grade I & II extensions, successful digital mobilization
Additional Median Sternotomy	15	10.2%	Grade III extension, recurrent goiter, malignant invasion
Additional Lateral Thoracotomy	4	2.7%	Deep posterior mediastinal descent, isolated ectopic tissue masses

Table 2: Tactical distribution of surgical access access routes within the goiter cohort.

The utilization of specialized thoracic access (sternotomy and thoracotomy) was reserved for complex scenarios where cervical delivery posed an unacceptable risk of vascular laceration or incomplete resection. Figure 3 illustrates the distribution of these surgical access modalities.

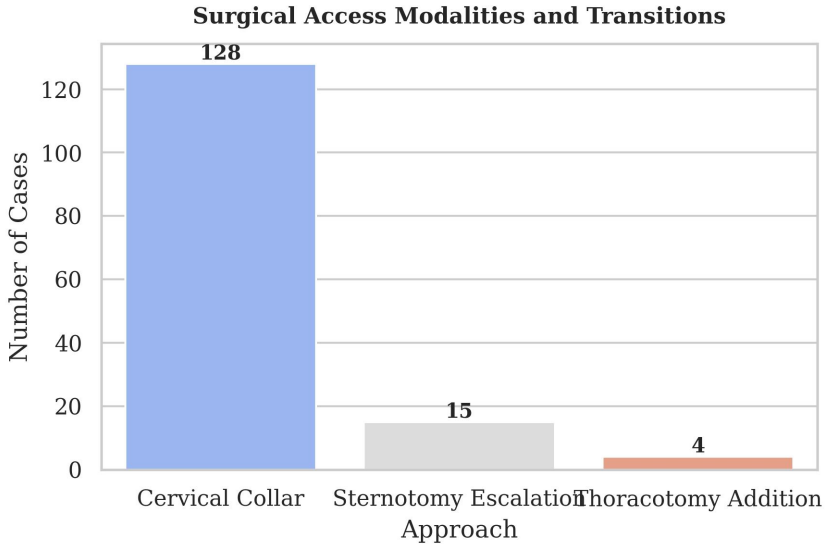


Figure 3: Spectrum of surgical access access routes showing the low conversion threshold maintained for deep masses.

An analysis of the 15 cases requiring median sternotomy indicates that the decision to convert was driven by specific anatomical features. The primary indication was a 'dumbbell' or 'hourglass' shaped goiter, where the mediastinal component was significantly larger than the superior thoracic inlet. Attempting to force such a mass through the narrow thoracic inlet via a cervical approach can cause capsular rupture, severe soft tissue fragmentation, and uncontrollable hemorrhage from avulsed mediastinal vessels. Other indications included recurrent goiters with dense post-operative scarring, deep Grade III extensions with vascular anchoring to the pericardium, and cases with suspected malignant invasion into the brachiocephalic veins or tracheal wall. In these scenarios, sternotomy provided excellent visual exposure, allowing for safe dissection under direct vision and immediate vascular control.

Meticulous hemostasis using modern energy devices (such as Harmonic or Ligasure) and careful tissue handling helped minimize severe post-operative complications. Transient hypocalcemia resulting from temporary parathyroid ischemia or accidental removal was the most common complication, observed in 14 cases (9.5%), and was managed with oral calcium and vitamin D3 supplementation. Transient recurrent laryngeal nerve (RLN) palsy occurred in 8 cases (5.4%) due to traction during the mobilization of large inferior poles; complete nerve function recovered within 3 to 5 months in all instances, verified by post-operative laryngoscopy. Permanent RLN injury occurred in 2 cases (1.4%) where the nerve was involved in an advanced malignant process. Tracheomalacia with structural weakening of the tracheal rings was identified intraoperatively in 3 cases (2.0%). These patients were managed with temporary prolonged intubation (48–72 hours) to serve as an internal scaffold until tracheal stability was restored; none required permanent tracheostomy. There were no intraoperative deaths or severe vascular lacerations in this series, as summarized in Figure 4.

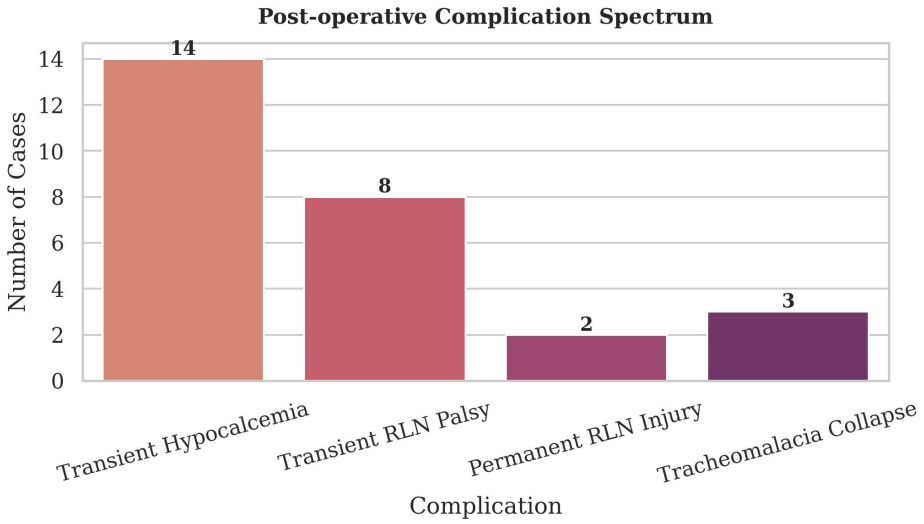


Figure 4: Detailed post-operative complication breakdown within the 147-patient cohort.

4. Conclusion and Recommendations

The comprehensive clinical and statistical analysis of 147 patients treated for giant and substernal goiters at our center over a five-year period supports the following strategic conclusions and practical recommendations:

1. Routine Multi-planar MSCT Pre-operative Mapping:

MSCT scanning of the neck and chest with 3D volumetric reconstruction is mandatory for all giant or suspected retrosternal goiters. It provides essential data regarding the depth of mediastinal descent, the shape of the mass, and its relationship to major thoracic vessels, which is critical for planning the appropriate surgical access.

2. Safety and Feasibility of the Cervical Approach:

The majority of substernal goiters (87.1% in our series) can be safely delivered through a standard cervical collar incision. This relies on meticulous digital mobilization performed strictly within the true avascular thyroid capsule, using gentle upward traction and avoiding blunt avulsion of deep tissues.

3. Clear Criteria for Sternotomy Conversion:

A low threshold for median sternotomy must be maintained for Grade III deep extensions, recurrent intrathoracic goiters with post-operative scarring, and 'dumbbell' shaped masses wider than the thoracic inlet. Sternotomy provides excellent exposure, ensuring airway safety and immediate vascular control in complex cases.

4. Intraoperative Screen for Tracheomalacia:

Long-standing giant goiters carry a risk of tracheomalacia (2.0% in our series). Intraoperative assessment of tracheal wall stability after extraction is critical. Temporary prolonged intubation (48-72 hours) serves as an effective internal scaffold, preventing airway collapse and avoiding the need for a permanent tracheostomy.

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