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# Surgical approach to the substernal goiter

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Surgery for substernal goiters can be technically demanding. Extensive mediastinal extension brings the thyroid gland into close quarters with vital intrathoracic structures. Proper preoperative planning is required to determine the potential need for an extracervical approach. Assessing the risk of requiring an extracervical approach is typically based on findings from cross-sectional imaging of the neck and chest. This article addresses the important anatomical considerations when resecting a large substernal goiter and also reviews various extracervical approaches.



## Introduction

Substernal goiter (SSG) can be a challenging disease, and the thyroid surgeon should encounter it with appropriately afforded respect. Although the disease process is benign, the mediastinal extension brings it in close contact with vital structures. Proper planning is required to avoid disaster.

Due to endemic iodine deficiency, up to 20% of the world's population is affected by goiterous disease of the thyroid. Adequate iodination has rapidly reduced the incidence of multi-nodular goiter in developed countries. Typically, surgery is reserved for extreme scenarios, favoring a more conservative approach [1]. With a raised threshold for surgical intervention, advanced cases of SSG may constitute a more significant proportion of thyroid surgery.

Thyroid disease extending outside the confines of the neck could arguably be the first concept identifying complexity in surgical disease bestowed upon the new medical student [2]. When the gland extends into the chest, it can extend onto critical structures including the great vessels, pleura,

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recurrent laryngeal and phrenic nerves, and displace aerodigestive structures in the chest, in an area with difficult access through a transcervical incision. Thus, the traditional approach to SSG has been one of justifiable trepidation, with treatment understandably and appropriately confined to specialist facilities. Evolution of medical technologies, both in the operating room and in the pre-operative patient assessment, have aided in calming some of the historical fear and angst associated with SSG.

Despite the dictum for consideration of median sternotomy in the surgical approach to SSG being well taught and extensively published, over 90% of these lesions are now able to be safely and adequately excised through a cervical incision [3]. Although most SSGs are accessible via a transcervical approach, the significant morbidity of a median sternotomy mandates careful preoperative planning and consultation with a thoracic surgeon when appropriate. Unplanned division of the sternum is to be avoided. With this in mind, we discuss the evaluation and treatment of SSG, with a view to recognizing factors in cross-sectional imaging that help identify those patients at risk of requiring a transsternal operative approach.

## Definition/Classifications

Substernal sternal goiter, presumptively non-malignant by definition, is defined as an enlarged thyroid gland with a component extending into the mediastinum. Retrosternal and intrathoracic are terms used interchangeably in published literature. Since first being described by Haller in 1749 [4], the SSG has endured an identity crisis courtesy of the wide-ranging variety of definitions to which it has been attributed. This lack of consensus has made academic discussion problematic, as each clinician presents collated series that cannot be equitably compared [5]. Thus, literature on SSG report varies widely, with a wide range of disease incidence and rate of postoperative complications. The proportion of SSG cases that require an extracervical operative approach are similarly imprecisely defined.

In a critical analysis of previous definitions of SSG, Rios et al. advocates for the application of the clinical definition, whereby on physical examination, a portion of the thyroid gland remains retrosternal; it is simple, easily applicable, and is as sensitive as all other definitions for determining luminal compression, airway difficulty during anesthesia, and the risk of postoperative complications [6]. With particular attention to risk of sternotomy, they found Katlic et al.'s definition [7], in which > 50% of the goiter is in a retrosternal position, to be most applicable. While simple classification systems have proved to be the most clinically efficacious, numerous factors intrinsic to the SSG must be processed in totality when assessing the patient at risk of requiring an extracervical approach to surgical resection.

## Indications and options for treatment

Clinical compression of the trachea and esophagus is often the cause of complaints in the symptomatic patient. Compression can result in globus sensation, dysphagia, and dyspnea, often exacerbated when supine. In severe cases, large vessel venous compression may manifest as superior vena cava syndrome [8]. Risk of occult malignancy and a natural history of progressive enlargement mandate active treatment.

Surgery is the standard treatment modality for the symptomatic SSGs. Non-surgical therapy with radioactive iodine ablation should be reserved only for rare cases of poor candidacy for general anesthesia. Unfortunately, radioactive iodine therapy can also result in an acute inflammatory process that exacerbates clinical compression, potentially threatening the patient's airway. Other minimally invasive local treatment modalities have been described, such as radiofrequency ablation and laser microfilament ablation. However, these methods have yet to be validated in large studies.

The rise of neck imaging has also increased the number of incidentally found, asymptomatic SSGs [9,10]. It is unclear whether these lesions require treatment, given that the natural history of an untreated SSG is not well characterized. Complementary to similar programs in malignant thyroid disease [11], active surveillance of SSG in a minimally symptomatic patient may be considered, and allow the lesion to declare its behavior over time.

## Preoperative assessment

Surgical intervention for SSG is best undertaken in a specialist facility by experienced, high-volume surgeons at the behest of a well-supported, multi-disciplinary unit. The involvement of the thoracic surgical service at the facility is vital. Specialist planning, group consensus decisions, and regular practice review enable best-informed patient decisions, optimal outcomes, and minimizes complications.

The nature of any proposed surgical intervention for SSG is predicated on the synthesis of all available information contributing to the disease state and its extent. Other than history pointing to an increased likelihood of malignancy, detailed description of symptoms should be elicited, as these may heighten clinical suspicion of disease magnitude and severity. The speed of the onset of the notable symptoms of dyspnoea, dysphagia, stridor, and dysphonia can indicate the rapidity of the growing mass, while the impact that these have on the patient quality of life may help identify those that require more urgent intervention. It is not unheard of for patients with large compressive SSG to be incorrectly diagnosed with obstructive sleep apnea [12]. It must be noted that while benign disease affecting the recurrent laryngeal nerve (RLN) is rare, compressive forces in large volume disease may impact neural function or compromise perineural vasculature. The resultant dysphonia manifest from such an insidious process may not be overtly obvious to the patient nor the clinician.

Therefore, particular care must be employed in the thorough examination of laryngeal function prior to undertaking surgery for SSG. Roman et al. identified key reasons for the special attention required in the pre-operative laryngeal examination [13]. Vocal cord paralysis (VCP) may not be clinically evident in the absence of dysphonic changes. The presence of VCP influences patient consent and counselling about risks of potential surgery. Knowledge of pre-operative laryngeal function should influence intraoperative decision pertaining to nerve monitoring. Extent of surgery and can also serve as a baseline for comparison of post-operative laryngeal function, ensuring quality in the auditing of surgical complications. Finally, with many thyroid surgical peer-societies having guidelines for laryngeal examination, pre-operative documentation of vocal cord function can aid in any potential medicolegal process related to accusation of iatrogenic injury. The American Head and Neck Society and The American Thyroid Association have produced guidelines and consensus statements emphasizing the notion that pre-operative laryngeal examination be performed on all patients undergoing thyroid surgery who are at high-risk for nerve injury [14,15]. Even though such peer reviewed and produced standards are delivered in the context of malignant disease [15], it would be hard to argue against these being similarly applicable to the high-risk entity of SSG, despite the fact it is nominally benign.

In SSG, the performance of fine needle aspiration (FNA) of suspicious nodules for diagnostic cytology is limited by safety of access and is further dependent on whether a diagnosis of malignancy would dramatically alter the nature of the primary surgical intervention. With this in mind, all benign thyroid disease should be managed in concert with an endocrinologist experienced in strategic surgical intervention. Diagnosis of auto-immune thyroid disease and acute gland dysfunction is best navigated by an endocrinologist. Their recommendations for the management of these processes in the perioperative setting is critical to optimizing patient safety and outcomes. Pulmonary physicians and thoracic surgeons should also form part of the multidisciplinary discussion in SSG providing assessment of severity of disease sequelae, performance of diagnostic endoscopic procedures, and in the devising of surgical strategy.

## Radiological assessment

Traditionally, due to assessment of thyroid nodules being most clinically efficacious with ultrasound, cross-sectional imaging has not been an integral part of the pre-operative thyroid surgical evaluation. ATA guidelines recommend ultrasound as the only imaging modality for most thyroid pathologies, but cross sectional imaging is indicated when there is substernal extension [16].Computed tomography (CT) and/or magnetic resonance imaging (MRI) are essential in the surgical decision-making for SSG, giving a clear definition of multi-dimensional size and morphology and defining the relevant and at-risk anatomical structures in the impending surgical field [17]. Furthermore, the

substernal portion needs to be assessed for possible malignancy, which is not accessible by ultrasound. In our practice, we favor CT imaging with IV contrast because we believe it is easier for the operating surgeon to interpret. CT allows better definition of the trachea and lymph nodes.

Important areas to focus on when reviewing cross sectional imaging are listed in Table 1. It is important to distinguish between tracheal deviation versus compression. Deviation has less clinical significance and is most common with unilateral enlargement. Compression is more common when there is bilateral enlargement of the thyroid lobes. Airway distress may not occur until the airway is narrowed to 4 mm or less.

Recognition of the posterior mediastinal SSG is of utmost importance, as the RLN may be anteriorly displaced due to posterior extension of the thyroid, placing it a significantly higher risk of inadvertent injury [18]. Identification of tracheal tortuosity and luminal restriction may also help airway-management planning [19]. The experienced surgeon can process multiplanar imaging to visualize an operation prior to its performance, thus identifying areas of potential difficulty and planning the solutions required to address them. Despite MRI giving superior soft tissue definition, CT scan remains the most readily accessible and economically viable form of cross-sectional imaging and provides more than adequate critical information for the operative planning of SSG.

## Assessing the potential need for an extracervical approach

Fundamentally, the nature of the operative approach to the SSG is shaped by whether appropriate access to the mediastinum can be obtained through the traditional thyroid neck incision. Given that a vast majority of SSGs can be safely removed transcervically, it is important to engage astute preoperative evaluation to adequately identify patients at risk of requiring a trans-sternal approach for safe resection [20]. The performance of thorough history and clinical examination with evaluation of the larynx and the acquisition of cross-sectional imaging (CT or MRI) are clearly the crucial components of this evaluation. While tissue sampling via FNA may assist preoperative diagnosis, it may be practically challenging, potentially non-diagnostic, and may be an exercise in futility if not altering the path of surgical management given increased risks.

Given that SSG is nominally benign disease, division of the sternum is only required under rare circumstances. Simply planning to have a thoracic surgeon on standby is not ideal. Instead, the need for an extracervical approach should be assessed an important part of preoperative evaluation and should be discussed with the patient as part of a complete informed consent. High-risk patients should be referred to a thoracic surgeon. Size, impacted anatomy, and retractability into the neck are the fundamental considerations in planning. With respect to assessing risk for requiring a trans-sternal approach, Simo et al. have established the most thorough identification of disease factors allowing for stratification based on CT scan results [21]. Risk factors that can be identified on cross-sectional imaging that increase the likelihood for an extracervical approach are listed in Table 2 (Figs. 1 and 2) [20].

## Anesthetic considerations

This combined work-up is fundamental to optimizing patient planning for surgery. Endoscopic and radiological assessment of the airway facilitates appreciation of vocal cord function and anticipates any difficulties pertaining to intubation during surgery. It must be noted that the vast majority

**Table 1**
Radiologic considerations on cross-sectional imaging for SSG.

| Suspicious nodules within thyroid gland |
|---|
| Unilateral or bilateral mediastinal extension |
| Anterior versus posterior mediastinal extension |
| Inferior extent of mediastinal extension |
| Relation to aortic arch, superior vena cava, aerodigestive structures |
| Presence and degree of tracheal deviation |
| Presence and degree of tracheal compression |

**Table 2**
Risk factors requiring an extracervical approach to substernal goiter.

| High-risk | Moderate-risk | Low-risk |
|---|---|---|
| SSG below arch of aorta | SSG reaching aortic arch | Retroclavicular extension |
| Recurrent goiters to or below AA | Oval or tubular morphology reaching to aortic arch | |
| Giant extension (i.e. weight >260 g) | Minimal posterior mediastinal/retrotracheal extension | |
| Involvement of multiple mediastinal compartments | | |
| Iceberg or conical morphology | | |
| Extension to posterior pleura | | |
| Goiter with separate components | | |

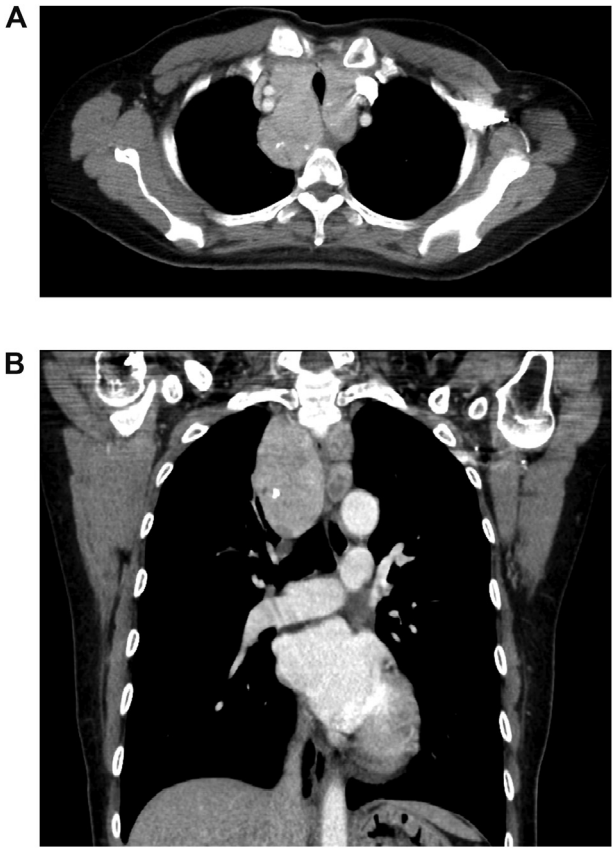


**Fig. 1. A.** Axial section of large substernal goiter, CT of chest with IV contrast. Greater mediastinal extension on the right rather than left, approaching level of carina. Mild airway narrowing is noted. **B.** Coronal section of large substernal goiter; CT of chest with IV contrast.

of SSG patients do not exhibit signs of supraglottic compromise and are able to be intubated without difficulty. Intubation is most appropriately performed under general anesthesia by a senior anesthesiologist in an atraumatic manner. Given that airway compression in the SSG patient is affected distally in the trachea, awake fiberoptic intubation is generally not necessary; in fact, trauma to the larynx during conscious intubation may lead to multi-level compromise (and the potential for

**Fig. 2.** Coronal section of large substernal goiter extending to level of aortic arch. CT of chest with IV contrast.

airway-related emergency). Even in the significantly narrowed and deviated tracheal lumen, an adequately-sized endotracheal tube (1–2 sizes smaller than the standard for that particular patient) can be readily negotiated past affected areas [4]. A collaborative approach to airway management should be employed, and the surgeon and anesthesiologist should articulate the agreed airway plan clearly to the other clinical staff in the operating room, prior to commencement. Communication with the anesthetic team should also confirm the pattern of anesthesia, the use of paralytic agents and their impact on neural monitoring, the use of opioids, and the plan for postoperative care (emergence, extubation, and the need for monitored or higher-dependency bedding, such as in the intensive care unit) [11].

## Risks of SSG surgery

The utility of manubriotomy, or sternal split, has long been a dilemma in surgery for the SSG. While providing unparalleled exposure to the infra-cervical disease, it is a procedure imparting significant morbidity on the patient, with both positive and negative connotations for risk of postoperative complications.

### *Risk to RLN*

In surgery for the SSG, numerous factors contribute to the risk of permanent damage to the RLN being inherently increased. Rates of permanent RLN injury following SSG surgery range from 2%–4%, despite inconsistencies with reporting. With the course of the left RLN originating at the arch of the aorta, a SSG has the potential to impact the nerve over its entire course. Dissection of any nerve over long segments risks injury that results from physical trauma and potential devascularization. A space occupying lesion of the finite space of the mediastinum has greater potential for distorting normal anatomy, and when coupled with increased gland size implies a technically demanding procedure where the RLN may not be easily identifiable nor in its textbook anatomic location. In a recent Italian study, Testini et al. incorporating some 15,000 subjects, showed a statistically significant increase in the rate of both transient and permanent RLN palsy when an SSG is approached extracervically via manubriotomy compared to the traditional transcervical approach [21]. Obviously, population selection contributes to this difference, but it clearly highlights the difficulties of resecting severe disease, even with maximal exposure.

Intraoperative nerve monitoring (IONM) is a risk minimization tool utilized to verify RLN integrity during thyroid surgery. The incidence of RLN injury and subsequent postoperative vocal cord

dysfunction is reported at varying rates in the published literature. Consensus indicates that permanent vocal cord paralysis occurs in approximately 1%–2% of all thyroid cases performed in high volume, specialist surgical departments. With a lack of uniformity around assessment, timing and manner of laryngeal evaluation, studies reporting lower rates of vocal cord paralysis with IONM, have not reached statistical significance [22]. Dralle et al. calculated that adequately powered prospective study would require recruitment of more than 9 million subjects with benign goiters to achieve statistical significance [23]. However, in surgery for certain clinical entities implying elevated risk, IONM has been shown to decrease rate of RLN injury; situations of malignancy, revision procedures, and large goiters with substernal involvement being among them [24]. While the benefits of IONM are debated by statisticians, it is not plausible to deny its utility in the SSG.

In the event that IONM is being utilized, the anesthesiologist should be made aware of requirements pertaining to administration of paralytic agents [25]. Specific instruction regarding other equipment availability and potential for use should also be given to operating room staff. RLN IONM is rapidly gaining ascent as standard of care in thyroid surgery, and despite studies with a high-level of evidence failing to demonstrate a statistically significant difference in permanent RLN injury with its use (compared to direct RLN visualization), literature supports use in revision surgery, invasive malignancy, and large SSGs. With anatomical manifestations dictating the left RLN being at greater risk with advancing mediastinal dissection, the controversial option of continuous monitoring of the left vagus nerve may be considered in extensive mediastinal disease, particularly if it lateralizes to the left and there is a favorable risk–benefit profile [26]. Bilateral RLN palsy is the greatest causative factor for tracheostomy in the SSG patient, with rates of tracheostomy approximately 2%–3% in this population.

### *Risk of hypoparathyroidism*

Given SSGs have significant volume and morphological diversity, adequately preserving the parathyroid glands can present a significant challenge. Consequently, surgery conveys an increased risk of hypoparathyroidism. The parathyroid tissue may be adherent to the fibrotic thyroid capsule, may be enveloped by the growing nodular thyroid parenchyma, or may be considerably displaced. The extent of the SSG may further place ectopic parathyroidal tissue at risk of damage.

Even if the parathyroid glands are able to be identified and structurally preserved, an even more significant challenge arises in the SSG patient, with respect to maintaining their uninterrupted blood supply. With vasculature first described by Halstead in 1907, each parathyroid gland receives arterial supply from an end-artery [27]. Reeve championed the technique best avoiding disruption of the parathyroidal vascular supply, by dividing branches of the inferior thyroid artery on the thyroid gland capsule, thus beyond the parathyroid. This ideal technique may not be feasible if development of SSG has relocated the parathyroid glands. Specifically in SSG, while the inferior PTG are more likely to be displaced and be truly intrathoracic in location, the position of the superior PTG is often unaffected. Given the superior PTG are more likely to be identifiable, considerable attention must be committed to their localizing and preservation. Surgical approach does not appear to be a factor in the development of hypoparathyroidism. Testini et al. in a large multicenter study suggest the risk of permanent hypoparathyroidism following surgery for SSG being in the order of 2.1% for transcervical and 2.9% for trans-sternal [28].

The utility of intra-operative PTH monitoring should be carefully considered for SSG surgery, and in cases where no identifiable parathyroidal tissue is visualized during the procedure, the surface of specimen should be closely examined prior to passing off for pathology.

### *Risk of hemorrhage*

SSG is an independent factor increasing risk of postoperative hemorrhage in the thyroid surgery patient. This potentially fatal complication has been shown to become apparent in the hours immediately following the operation and is often associated with coughing on emergence from anesthesia

and extubation. The SSG will often develop additional venous and arterial channels to meet the vascular demands of the enlarged gland. Engorgement of named vessels is a common finding of congruent etiology. Isolation and ligation of the inferior thyroid venous channels is critical to minimizing postoperative bleeding, for they rapidly retract into the mediastinum when divided and are often culprit vessels in hemorrhage. Drains are often used in large volume SSG cases and may remain in place for days to minimize the risk of catastrophic sequelae.

*Risk of tracheomalacia*

While being a concern justified by the compressive pathological process of the SSG, tracheomalacia is rarely described as a clinically significant concern in the literature; even endemic goiter populations report very low incidence. Significantly powered studies in developed countries have shown little evidence, with rates reported as being <1.5% [29]. Patients with suspected tracheomalacia need other causes of airway obstruction excluded immediately. Generally, re-intubation is uneventful even in confirmed tracheomalacia. This intervention facilitates time for improvement of collapse or for further airway management planning.

*Mortality risk*

The incorporation of a sternotomy into the surgical approach to the SSG implies a significant increase in mortality risk. Obvious self-selecting population bias aside, post-operative complications such as infection have an increased severity profile from the opening of the chest and exposure of viscera.

## Surgical planning

*Extent of thyroid resection*

Total thyroidectomy is generally the operation performed for SSG, especially in those with bilateral enlargement. In the event that an SSG appears to involve just one lobe, and assuming the contralateral lobe is normal, then hemi-thyroidectomy may be considered as a viable option. This minimizes the risk of complications while relieving symptoms of concern. Precise handling of the cervical thyroid helps to impart traction on the attached SSG and aid in its dissection and delivery from the mediastinum. The main impediment to appropriate SSG dissection is instrument access in limited 3-dimensional space, with acknowledgement of restrictions in the anterior-posterior cross−sectional plane most crucial. Some authors describe early division of the isthmus and even dissection of the smaller lobe first, in order to increase the dimensions of the surgical field, allowing better visualization and more working room.

*Surgical approach*

Many techniques have been described over the evolution of contemporary surgical practice to address the SSG. Morcellation, with intracapsular fragmentation and suction of tissue and colloid from within the mass was popularized in the 1920s, with recent tangential undertakings invoking the use of a powered microdebrider in this technique. The toboggan technique, described by Charles Proye in 1981 [30], promotes early division of the isthmus from the tracheal attachments and the mobilization of the superior pole to facilitate removal of the SSG component (or inferior pole) from the mediastinum, with early identification and preservation of the RLN. The drawer maneuverer, involving the SSG being gripped by 2 hands from the neck and pulled like a drawer, has also been described as an adjunct. These techniques are all complementary to a transcervical approach to the SSG; their limitations raise the question of when this approach is no longer efficacious and when a sternotomy should be considered for access. Anatomy and morphology must be assessed in combination to accurately assess risk of need for a trans-sternal approach.

*Anatomical considerations*

To recognize the high-risk patients described by Simo et al. [20], assessment of radiological images in multiple planes focuses on identification of 4 significant anatomical landmarks; the carina of the trachea, the arch of the aorta, the pleura of the lungs bilaterally, and the esophagus.

Disease involving the carina would purvey potentially the highest risk for requirement of sternotomy for maintenance of safe airway patency [31]. While carinal disease may be the most inferior possible extension, it must be noted that the tracheobronchial complex has an inherent degree of mobility aiding in the possibility of surgical intervention.

Conversely the arch of the aorta is somewhat less amenable to safe mobility especially transcervically [32]. Extension beyond or around the aortic arch has been shown to significantly increase need for trans-sternal approach. The notion that a SSG encroaching on superior limit of the arch of the aorta can be safely dissected from the great vasculature is grossly compromised in the reoperative field of the recurrent disease setting.

Contact with the pleura of the lungs especially in the plane posterior to the trachea may limit surgical visibility and the meticulous dissection that may be needed to free the SSG from the lungs could require sternotomy for safety. Furthermore, the involved hemi-thorax may require lung deflation via selective ventilation to avoid iatrogenic injury, especially pneumothorax.

Tracing the esophagus inferiorly from its cervical component aids in establishing the involvement of the posterior mediastinum in the disease process. Poor vector of dissection and limited visualization makes the transcervical approach here perilous in nature.

*Morphological considerations*

Size of the SSG has been shown by Sancho et al. [31] to be an independent predictor of need for sternotomy on multivariate analysis, with volumes greater than 260 g being most at risk. Semi-automated thyroid volumetry using 3D CT has been shown in some Korean studies to be substantially close to thyroid specimen volume [33].

The shape of the SSG, as rigorously described by Simo et al., is an intrinsic property of the disease greatly impacting the possibility of delivery through a transcervical incision [22]. The lesion enlarging in the coronal and sagittal planes as it progresses in inferior extent is of concern for requiring a trans-sternal approach. The pyramidal nature of Simo's “iceberg” shape implies difficulty with retraction via a narrow apex, hazardous dissection of a base for freedom from underlying attachments, and an unhelpful relation to the shape of the potential passage for specimen delivery through the neck. Flati et al. suggest that such a shaped SSG with >70% of the volume of disease lying inferior to the thoracic inlet will almost inevitably require an extracervical approach [34]. Other rounded morphologies, while still in an at-risk category, are more likely to exhibit characteristics favorable to transcervical dissection.

*Extra-cervical approaches*

*Median sternotomy including partial*

The classic approach to an anterior mediastinal mass would be through a median sternotomy. However, division of the sternum adds a significant amount of morbidity to a treatment for benign disease. Complications of median sternotomy include deep space wound infections, dehiscence, arrhythmias, and sternal instability. Open chest surgery can also lead to injury of the internal mammary vessels and traction injury of the brachial plexus. Several alternative, minimally invasive techniques may also be employed as part of an extracervical approach.

*Cervical mediastinoscopy*

Cervical mediastinoscopy can aid in the removal of a SSG by allowing direct visualization of retrosternal portions of the gland. Crossing tributaries to the enlarged gland can be ligated with clips or cautery through the mediastinoscope. In certain cases of mild but difficult to control hemorrhage, inspection, and hemostasis with mediastinoscopy can help avoid median sternotomy [35]. This can be performed through the same transverse cervical incision, without the need for additional incision. This

allows visualization down to the carina, innominate anteriorly, and aortic arch and superior vena cava laterally. The risks of cervical mediastinoscopy include major hemorrhage from requiring median sternotomy, RLN injury specifically on the patient's left, thoracic duct injury. In specific cases, anterior mediastinoscopy (also referred to as Chamberlain's procedure) can help deliver a retrosternal goiter into the neck [36]. This involves removal of the costal cartilage of the second rib to allow insertion of the mediastinoscope. On the patient's left side, this leads to the aortopulmonary window. Risks include injury to the internal mammary vessels, injury of the pleura, and hemorrhage.

*Video/robotic assisted thoracoscopic surgery (VATS/RATS)*

VATS is also an excellent option for a less morbid extra-cervical approach compared to median sternotomy. Several ports are placed into the chest between the ribs, and the anterior mediastinum can be accessed. Depending on how midline the SSG is, VATS can be performed ipsilateral or bilateral. Whether ipsilateral or bilateral, patients who undergo VATS for anterior mediastinal masses have less blood loss, less pain, shorter duration of chest drains, and shorter length of stay compared to patients with median sternotomy [37]. VATS thyroidectomies are often successful, with only 8% requiring conversion to open surgery [38].

At the moment, there are no published studies for RATS thyroidectomy. Extrapolating from other anterior mediastinal masses, clinical outcomes for RATS vs VATS are equal, but the cost of RATS is much higher [39]. While the location of the ports used for RATS is different, the number and size of incisions remains the same as VATS.

## Summary

Surgical resection remains the standard of care for SSG and gravitates towards the severe end of the spectrum of complexity encountered by the thyroid surgeon. Intraoperative difficulties faced by the attending clinician manifest as increased risk of postoperative complications for the patient. With problematic exposure at the epicenter of the surgical challenge in SSG, the long-standing debate in the literature has revolved around the utility of a trans-sternal surgical approach as an addressing solution. Evolution of radiological imaging and surgical technique, including the evolution of IONM, has seen a significant narrowing of the therapeutic window where trans-sternal surgery is reliably indicated and beneficial. The risk of exposing the patient to the morbidity of sternotomy is questionably justifiable in the benign setting of SSG, especially with the advent of new minimally invasive, clinically efficacious technologies such as VATS and RATS. Classification systems based on preoperative, cross-sectional imaging aid in identifying anatomic locations and lesional morphologies increasing surgical complexity and consequentially elevating risk of a needing an extra-cervical strategy. Trans-sternal approach to SSG should generally be nominated pre-operatively, resulting from a detailed radiological assessment of the totality of a lesion espousing a combination of high-risk anatomic and morphological considerations and, as such, should be a rare intervention.

**Practice Points**

- Substernal goiter requires surgical resection which may be challenging in nature
- Preoperative evaluation should include multiplanar cross-sectional radiological imaging such as CT or MRI
- The vast majority of substernal goiters can be removed through a traditional transcervical surgical incision
- The risk of the surgeon requiring extracervical access, such as via a transsternal approach is identifiable on pre-operative imaging by careful assessment of the anatomical and morphological characteristics of the lesion
- Minimally invasive techniques and technologies have proved clinically effective and have a favourable morbidity profile compared to sternotomy
- Transsternal approach should be a rare undertaking and planned preoperatively with the patient appropriately consent

**Research Agenda**

- Outcomes of minimally invasive extracervical approaches compared to transcervical resection of large substernal goiters
- Indications for prophylactic resection of asymptomatic goiters

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## Conflicts of interest

All authors have no conflicts of interest to disclose.

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