

Research Article

Tubercle of Zuckerkandl and Endocrine Neck Surgery: Clinical Validation of a Classical Anatomical Landmark

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Abstract: **Introduction:** Injury to the recurrent laryngeal nerve (RLN) and the superior parathyroid gland (SPG) remains among the most feared complications of thyroid surgery. The tubercle of Zuckerkandl (TZ), a posterolateral projection of the thyroid lobe, has long been proposed as a constant anatomical landmark for both structures, yet comparative data across cadaveric and live surgical settings are limited. **Objective:** To validate the TZ as a landmark for the RLN and SPG by comparing its prevalence, morphometry, and anatomical relationships in human cadavers and in patients undergoing thyroid surgery. **Methods:** A comparative descriptive study of 60 specimens (30 thyroid surgery cases and 30 autopsy specimens) was conducted over 17 months at a tertiary-care teaching hospital. The TZ was identified, measured, and graded; its relationship to the RLN and its distance from the SPG were documented. Data were compared using unpaired t-test / Mann-Whitney U test and chi-square test, with $p < 0.05$ considered significant. **Results:** The TZ was present in 24/30 (80%) of cases in both groups ($p = 1.000$). Mean TZ size was comparable (surgical 0.72 ± 0.36 cm vs. autopsy 0.75 ± 0.49 cm; $p = 0.817$). The RLN lay posteromedial to the TZ in the majority of cases (66.7% surgical, 75% autopsy; $p = 0.817$), with the remainder posterior; no lateral or anterior course was observed. The mean SPG-TZ distance was significantly greater in surgical patients than in cadavers (1.20 ± 0.63 cm vs. 0.77 ± 0.41 cm; $p = 0.008$). No statistically significant sex-based differences were found in TZ presence, size, or relationships. **Conclusion:** The TZ is a consistently present, dimensionally stable structure in both cadaveric and live anatomy, with a predictable posteromedial/posterior relationship to the RLN and close proximity to the SPG. These findings clinically validate the TZ as a reliable dual-purpose landmark that may enhance nerve identification and parathyroid preservation during endocrine neck surgery.

Keywords: Tubercle of Zuckerkandl; thyroidectomy; recurrent laryngeal nerve; superior parathyroid gland; anatomical landmark; cadaveric study.

INTRODUCTION

Thyroidectomy, whether performed as a hemithyroidectomy or as a total procedure, is a cornerstone operation in otorhinolaryngology and head-and-neck surgical practice worldwide. Despite its frequency, the procedure carries significant perioperative risks, most notably injury to the recurrent laryngeal nerve (RLN) and inadvertent damage or devascularisation of the superior parathyroid gland (SPG), which may result in vocal-cord palsy or hypocalcaemia respectively [1,2]. These complications can produce serious functional impairment and long-term morbidity, underscoring the need for accurate anatomical landmarks that reliably guide safe dissection and preservation of vital structures.

Safe thyroid surgery therefore demands a thorough understanding of both the detailed anatomy and the embryological development of the neck. RLN injury may cause hoarseness, aspiration, and, in bilateral cases, life-threatening airway compromise [3], while parathyroid injury may lead to transient or permanent hypoparathyroidism requiring lifelong calcium and

vitamin-D supplementation [4]. Historically, several structures including Berry's ligament, the inferior thyroid artery, and the tracheo-oesophageal groove have been used to locate the RLN, but each has recognised limitations in variability and reproducibility.

The tubercle of Zuckerkandl (TZ) is a posterior or posterolateral projection of the lateral thyroid lobe that develops from the fusion of the ultimobranchial body with the median thyroid anlage. First characterised in detail by Pelizzo and colleagues, who described it as "an arrow pointing to the recurrent laryngeal nerve," it has since attracted interest as a constant landmark because the RLN characteristically passes deep and medial to it and the SPG lies in close proximity [5,6]. Reported prevalence varies widely between anatomical and surgical series, and a cadaveric dissection with meta-analysis has confirmed a predominantly posteromedial relationship of the nerve to the tubercle [7].

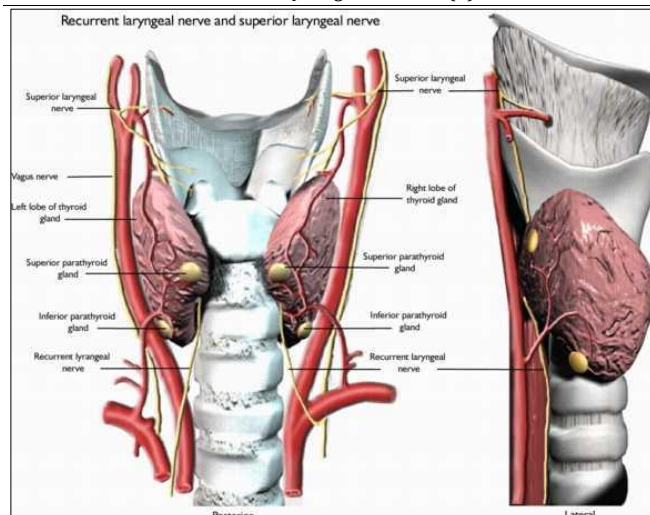


Figure 1: Anatomical relationship of the tubercle of Zuckerkandl to adjacent structures the recurrent laryngeal nerve, inferior thyroid artery, Berry's ligament, and superior parathyroid gland.

Although numerous studies have examined the TZ in either the operative or the cadaveric setting, comparative data directly juxtaposing the two are scarce. Differences in tissue turgor, vascularity, and surgical manipulation raise the question of whether cadaver-derived anatomical relationships translate reliably to the living operative field [8]. The present study was designed to address this gap by validating the TZ as a landmark for both the RLN and the SPG through a direct comparison of human cadavers and patients undergoing thyroid surgery, assessing its prevalence, morphometry, and spatial relationships in the two settings.

MATERIALS AND METHODS

2.1 Study design and setting

This comparative descriptive study was conducted jointly by the Departments of Otorhinolaryngology and Forensic Medicine at a tertiary-care teaching hospital over a 17-month period (April 2024 to August 2025). Ethical clearance was obtained from the Institutional Ethical Committee for Human Research before commencement, and written informed consent was obtained from surgical patients and from the relatives or the investigating officer for cadaveric specimens.

2.2 Participants and sample size

In the absence of any prior comparative (chimeric) study on this topic, and given the constraints of available time and resources, a convenience sample of 30 human cadavers and 30 patients undergoing thyroid surgery (total N = 60) was studied. Inclusion criteria comprised cadavers with intact neck anatomy brought for medicolegal autopsy, and patients presenting for thyroid or parathyroid surgery. Exclusion criteria comprised cadavers with distorted neck anatomy (ligature or

manual compression, neck trauma, sharp or blunt neck injury, or prior neck surgery) and patients unwilling to participate.

2.3 Procedure

In cadavers, a standard Y-shaped autopsy incision was made, a subplatysmal flap was elevated, and the strap muscles were retracted laterally to expose the thyroid gland, which was mobilised along the pretracheal fascia. In surgical cases, the same structures were assessed intraoperatively under standard aseptic conditions. In both settings the TZ was identified and its dimensions recorded, and it was graded according to the Pelizzo grading system (Figure 2). The relationship of the RLN to the TZ was classified as posteromedial or posterior, and the distance of the SPG from the TZ was measured.

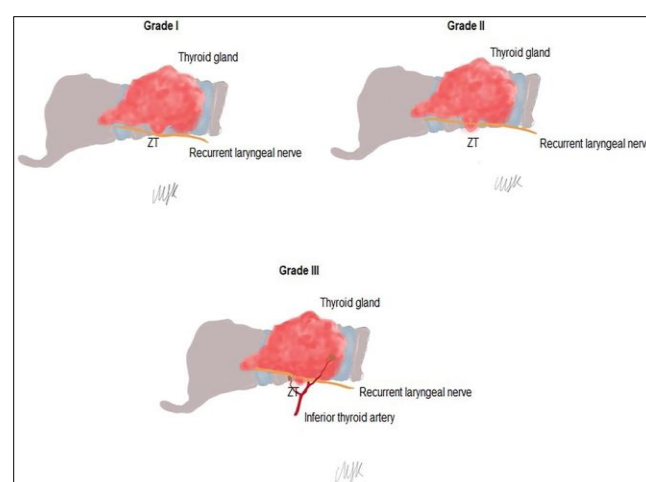


Figure 2: Pelizzo grading of the tubercle of Zuckerkandl (Grade 0–III) and its relationship to the recurrent laryngeal nerve. Adapted from published sources [5].

2.4 Outcome measures

The primary outcome measures were the identification of the TZ, the anatomical relationship of the RLN to the TZ, and the distance of the SPG from the TZ. The secondary outcome was intraoperative validation of these relationships by using the TZ to locate the RLN and SPG during thyroid surgery.

2.5 Statistical analysis

Data were entered in Microsoft Excel. Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) according to distribution, and categorical variables as frequencies and percentages. Between-group comparisons used the unpaired t-test or Mann–Whitney U test for continuous variables and the chi-square (or Fisher exact) test for categorical variables. A p-value < 0.05 was considered statistically significant.

RESULTS

The cohort comprised 60 specimens divided equally between the two groups: 30 thyroid-surgery patients (50%) and 30 autopsy specimens (50%) (Table 1). The mean age was 37.97 ± 11.00 years in the surgical group and 44.88 ± 15.42 years in the autopsy group; although the autopsy group was older, the difference was not statistically significant ($p = 0.081$). Sex distribution differed significantly between groups ($p = 0.009$): the surgical group was female-predominant (22/30, 73.33%) whereas the autopsy group was male-predominant (18/30, 60%) (Table 1).

Table 1: Demographic profile of the study cohort (N = 60).

Variable	Thyroid surgery (n=30)	Autopsy (n=30)	p-value
Group distribution	30 (50%)	30 (50%)	—
Mean age, years (SD)	37.97 (11.00)	44.88 (15.42)	0.081
Male	8 (26.66%)	18 (60%)	0.009
Female	22 (73.33%)	12 (40%)	

SD, standard deviation. Bold p-value denotes statistical significance ($p < 0.05$).

3.1 Prevalence and size of the tubercle of Zuckerkandl

The TZ was identified in 24 of 30 cases (80%) in each group, and was absent in the remaining 6 (20%) of each group an identical prevalence with no intergroup difference ($p = 1.000$). The mean size of the tubercle was comparable between the surgical (0.72 ± 0.36 cm) and autopsy (0.75 ± 0.49 cm) groups ($p = 0.817$), indicating dimensional stability irrespective of specimen origin (Table 2).

Table 2: Prevalence, size, and relationships of the TZ by group (N = 60).

Parameter	Thyroid surgery	Autopsy	p-value
TZ present	24 (80%)	24 (80%)	1.000
TZ absent	6 (20%)	6 (20%)	
Mean TZ size, cm (SD)	0.72 (0.36)	0.75 (0.49)	0.817
RLN posteromedial to TZ	16 (66.66%)	18 (75%)	0.817
RLN posterior to TZ	8 (33.33%)	6 (25%)	
Mean SPG–TZ distance, cm (SD)	1.20 (0.63)	0.77 (0.41)	0.008

TZ, tubercle of Zuckerkandl; RLN, recurrent laryngeal nerve; SPG, superior parathyroid gland. RLN counts refer to the 24 TZ-present cases in each group. Bold p-value denotes significance.

3.2 Relationship of the recurrent laryngeal nerve to the TZ

Among TZ-present cases, the RLN coursed posteromedial to the tubercle in 16/24 (66.66%) surgical and 18/24 (75%) autopsy cases, and posterior in the remainder (8/24, 33.33% surgical; 6/24, 25% autopsy). No lateral or anterior variants were encountered. The distribution did not differ significantly between groups ($p = 0.817$), demonstrating a consistent nerve–tubercle relationship across both settings (Table 2, Figure 3).

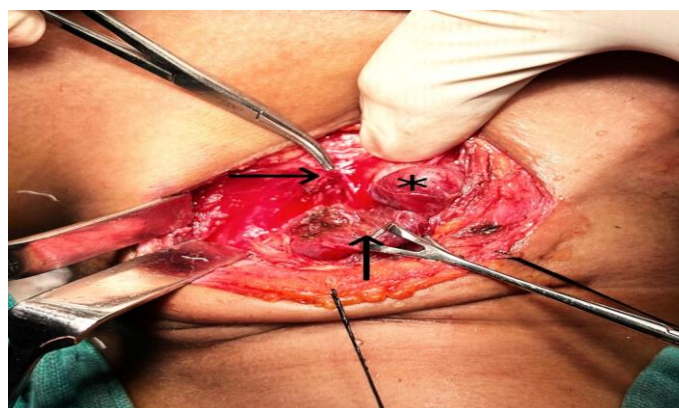


Figure 3: Intraoperative photograph during thyroid surgery localising the tubercle of Zuckerkandl (asterisk), with the recurrent laryngeal nerve lying posteromedial to it (lateral arrow) and the superior parathyroid gland in close proximity (upward arrow)

3.3 Distance of the superior parathyroid gland from the TZ

The mean SPG–TZ distance was significantly greater in the surgical group (1.20 ± 0.63 cm) than in the autopsy group (0.77 ± 0.41 cm; $p = 0.008$). Despite this difference, the gland lay in close proximity to the tubercle in both settings, with the majority of glands located within approximately 1.5 cm of the TZ (Table 2).

3.4 Sex-based analysis

When stratified by sex, the TZ was more frequently present and marginally larger in females in both groups, but none of these differences reached statistical significance (Table 3). Likewise, neither the RLN–TZ relationship nor the SPG–TZ distance differed significantly between the sexes in either group, indicating that the utility of the tubercle as a landmark is independent of patient sex.

Table 3: Sex-stratified TZ characteristics by group (N = 60).

Parameter / Group	Male	Female	p-value
TZ present Thyroid surgery	5 (62.5%)	19 (86.36%)	0.148
TZ present Autopsy	13 (72.22%)	11 (91.66%)	0.192
Mean TZ size (cm) Thyroid surgery	0.66 (0.29)	0.74 (0.39)	0.686
Mean TZ size (cm) Autopsy	0.65 (0.40)	0.87 (0.58)	0.273
RLN posteromedial Thyroid surgery	3 (60%)	13 (68.42%)	0.722
RLN posteromedial Autopsy	9 (69.23%)	9 (81.81%)	0.478
Mean SPG–TZ distance (cm) Thyroid surgery	1.34 (0.71)	1.16 (0.63)	0.589
Mean SPG–TZ distance (cm) Autopsy	0.81 (0.42)	0.73 (0.40)	0.609

Values are n (%) or mean (SD). None of the sex-based comparisons reached statistical significance.

DISCUSSION

In this comparative study of 60 specimens, the TZ proved to be a consistently identifiable and dimensionally stable structure, with a predictable relationship to the RLN and a close spatial association with the SPG in both cadaveric and live surgical settings. These findings reaffirm the tubercle's value as a dual-purpose landmark while also revealing an instructive difference in SPG proximity between postmortem and intraoperative anatomy.

4.1 Prevalence and morphometry

The observed prevalence of 80% in both groups sits comfortably within the published range. A cadaveric dissection and meta-analysis reported a pooled prevalence of roughly 70%, with most tubercles measuring under 1 cm [7], whereas Indian surgical series have documented rates as high as 90% with a predominance of Grade II tubercles [9], and a large single-surgeon series of 421 total thyroidectomies identified the tubercle in approximately 90% of cases [8]. Early surgical work by Gauger and colleagues similarly emphasised the frequent presence and surgical importance of the tubercle [6]. The comparable mean size across our two groups (0.72 vs. 0.75 cm; $p = 0.817$) supports the structural consistency of the tubercle regardless of whether it is examined in the living or the postmortem state.

4.2 Relationship to the recurrent laryngeal nerve

The predominantly posteromedial course of the RLN relative to the TZ that we observed (66.7% surgical, 75% autopsy) is consistent with the wider literature. The meta-analysis by Henry and colleagues placed the nerve posteromedial to the tubercle in the large majority of

cases, with lateral and anterior variants uncommon [7], and Gurluler reported the RLN medial to the tubercle in more than 80% of operations [8]. Other series, including that of Irawati and colleagues, found the nerve consistently posterior to the tubercle in an Indian surgical cohort [9], and cadaveric work has reinforced the reliability of the tubercle relative to other landmarks such as Berry's ligament and the inferior thyroid artery [10]. Clinically, using the tubercle as an entry point for dissection allows the nerve to be anticipated as lying deep and medial to it effectively a "safe zone" which is particularly valuable when standard planes are distorted by haemorrhage, malignancy, or reoperation. Operator-dependent variability remains, however, since the nerve is fully exposed only after mobilisation of the gland and control of the thyroid vessels.

4.3 Relationship to the superior parathyroid gland

The SPG lay significantly closer to the TZ in cadavers (0.77 cm) than in surgical patients (1.20 cm; $p = 0.008$). Several factors may explain this: postmortem soft-tissue contraction, loss of vascular turgor, and tissue retraction may draw the gland toward the tubercle in cadavers, whereas vascular engorgement, oedema, and surgical manipulation may increase the apparent distance in the living field. Higher-grade tubercles also tend to house the gland more closely [5]. Despite this difference, the gland remained within close reach of the tubercle in both groups a finding echoed by a Nepalese series in which the SPG was adherent to or within a few millimetres of the tubercle in most cases [11], and by work relating the RLN and SPG during thyroidectomy [12]. Comparative studies of parathyroid identification techniques have likewise supported the tubercle as a practical intraoperative marker for the gland [13]. This proximity

is clinically important because inadvertent removal or devascularisation of the SPG is a leading cause of postoperative hypocalcaemia.

4.4 Sex differences and clinical implications

We observed a non-significant trend toward a more prevalent and slightly larger tubercle in females, with no sex-based difference in the RLN or SPG relationships consistent with the sparse literature on sexual dimorphism of the tubercle [14]. The absence of significant sex effects supports a universal, demographic-independent dissection strategy. Taken together, the dual role of the tubercle in guiding RLN identification and SPG preservation suggests that a tubercle-focused approach may help reduce rates of nerve palsy and postoperative hypocalcaemia; indeed, higher-grade tubercles have been associated with increased rates of transient hypocalcaemia and nerve palsy, reinforcing the need for deliberate attention to this structure [15]. Intraoperative neuromonitoring and preoperative imaging recognition of the tubercle may further complement its use as a landmark [16,17].

4.5 Cadaveric versus surgical anatomy

The significant SPG–TZ distance difference highlights the interpretive caution required when extrapolating cadaveric measurements to the operative field: cadaver studies offer full exposure but lack physiological tissue tension, while living anatomy is shaped by inflammation, retraction, and pathology [18]. Nevertheless, the consistent detectability of the tubercle and the stability of its relationship to the RLN across both settings indicate a fundamental anatomical constancy, and support the use of cadaver-based learning and simulation as effective preparatory tools for endocrine neck surgery.

4.6 Limitations

This study is limited by its modest, convenience-based sample size drawn from a single centre, and by the significant baseline differences in age and sex distribution between the surgical and autopsy groups, which may confound comparisons. Grading and distance measurements were operator-dependent and not blinded, and imaging correlation was not performed. Larger, multicentre studies with standardised, blinded measurement and grade-stratified analysis would help confirm and refine these findings.

CONCLUSION

The tubercle of Zuckerkandl is a consistently present and dimensionally stable anatomical structure in both cadaveric and live surgical settings, with a predictable posteromedial or posterior relationship to the recurrent laryngeal nerve and close proximity to the superior parathyroid gland. Its characteristics were largely independent of patient sex. Although the superior parathyroid gland lay significantly closer to the tubercle in cadavers than in surgical patients, the relationship remained clinically useful in both groups. These results clinically validate the tubercle as a reliable, dual-purpose

landmark for identifying and protecting the recurrent laryngeal nerve and the superior parathyroid gland. Incorporating deliberate identification of the tubercle into operative protocols and surgical training may improve intraoperative safety and reduce complications, particularly in anatomically complex or high-risk thyroid surgery.

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