Factors contributing to unintentional parathyroidectomy during thyroid surgery

Marissa Mencio, MD^a, Natalie Calcaterra, MD^a, Gerald Ogola, PhD^b, Stacey Mahady, DO^a , Michelle Shiller, DO^c, Erin Roe, MD^d, Scott Celinski, MD^a, John Preskitt, MD^a , and Christine Landry, MD^a

^aDepartment of Surgery, Baylor University Medical Center, Dallas, Texas; ^bCenter for Clinical Effectiveness, Baylor Scott and White Health, Dallas, Texas; ^cDepartment of Pathology, Baylor University Medical Center, Dallas, Texas; ^dDivision of Endocrinology, Baylor University Medical Center, Dallas, Texas

ABSTRACT

Unintentional parathyroidectomy during thyroid surgery has an incidence ranging between 1% and 31% across institutions. Many studies have identified malignancy and central neck dissection as risk factors for losing parathyroid glands, but few studies have evaluated the impact of other factors such as lymphocytic thyroiditis, hyperthyroidism, or concomitant primary hyperparathyroidism. The purpose of this study was to investigate which factors contribute to parathyroid loss during thyroid surgery. Charts of 269 patients undergoing thyroid surgery at a tertiary care medical center from 2010 to 2013 were retrospectively reviewed. Sixty-six patients (24.5%) experienced unintentional parathyroidectomy. Bivariate analysis showed no significant differences in patient characteristics. Patients with unintentional parathyroid removal had a significantly smaller largest thyroid nodule size ($P=0.002$), higher rate of central neck dissection (30.3% vs 7.9%, $P<0.0001$), and higher rate of malignancy (50% vs 36.0%, $P=0.04$). Multivariable analysis showed that the strongest risk factor for unintentional parathyroidectomy was central neck dissection ($P=0.0008$; odds ratio 4.72, confidence interval 1.91–11.71). In conclusion, central neck dissection for thyroid malignancy is the strongest risk factor for unintentional thyroidectomy. The presence of concomitant primary hyperparathyroidism, lymphocytic thyroiditis, or hyperthyroidism did not appear to increase the risk of unintentional parathyroidectomy.

KEYWORDS Central neck dissection; hypoparathyroidism; lymphocytic thyroiditis; parathyroidectomy; thyroid surgery; thyroidectomy

Hypoparathyroidism is one of the most common complications of total thyroidectomy, and it results from devascularization of, direct injury to, or unintentional removal of parathyroid gland tissue. In fact, hypoparathyroidism accounts for over half of hospital readmissions in patients after thyroidectomy.¹ Transient hypocalcemia lasting <6 months after surgery occurs in 6% to 59% of cases, while permanent hypoparathyroidism may persist in as many as 5.5% of patients.^{2–5} Unintentional parathyroidectomy occurs in 1% to 31% of cases even in the hands of experienced surgeons.^{3–25} While only one functional gland is needed to maintain eucalcemia, unplanned parathyroid removal should be minimized, as subsequent neck explorations and/or radiation therapy may threaten the function of the remaining glands.^{26–28} Known risk factors for unintentional loss of parathyroid tissue include presence of malignancy, concurrent central neck dissection, extent of

thyroidectomy, and reoperative status.^{3,5–7,13–18,29–32} We hypothesized that factors complicating dissection, namely conditions associated with inflammation and hypervascular states, would increase unintentional parathyroidectomy rates.^{17,33} Furthermore, the presence of concomitant primary hyperparathyroidism or large goiters may lead to a loss of parathyroid tissue.³⁴

METHODS

A retrospective review was performed on 269 patients who underwent thyroid surgery between 2010 and 2013 at Baylor University Medical Center at Dallas. Information on patient demographics, preoperative and postoperative diagnoses, presence of concomitant hyperparathyroidism and hyperthyroidism, type of thyroid surgery, performance of a central neck dissection, and final pathology was collected. Patients undergoing total, subtotal, or partial thyroidectomy

Corresponding author: Christine Landry, MD, 3410 Worth Street, Ste. 235, Dallas, TX 75246 (e-mail: christine.landry@bswhealth.org)

Received June 26, 2019; Revised October 3, 2019; Accepted October 10, 2019.

for benign or malignant disease were included. Patients who underwent isolated isthmusectomy or concomitant subtotal parathyroidectomy for hyperparathyroidism were excluded. Operative and pathology reports were reviewed to determine location of the parathyroid glands removed, whether parathyroid tissue was biopsied prior to autotransplantation, and whether incidental parathyroid tissue was present in the final pathologic specimen. All parathyroid tissue described on the final pathology report that was not accounted for in the operative note was classified as unintentional parathyroidectomy. Tissue submitted separately for pathologic confirmation via frozen section was deemed intentional removal.

Patients who did or did not lose parathyroid tissue were compared using independent sample *t* test/median test and chi-square test/Fisher's exact test for continuous and categorical variables, respectively. Multivariable logistic regression with backward variable selection was fitted to determine risk factors associated with unintentional parathyroidectomy. Independent variables considered in the multivariable model development included age, sex, race, total number of central lymph nodes, largest thyroid nodule size, largest thyroid lobe size, concomitant central neck dissection, concurrent lymphocytic thyroiditis, parathyroid autotransplantation, and malignancy. Variables with a significance level <0.20 were retained in the backward selection iteration. The final model consisted of age, central neck dissection, largest thyroid nodule size, and parathyroid autotransplantation. Statistical analysis was conducted using SAS 9.4 (SAS Institute, Cary, NC) software. *P* values <0.05 were considered statistically significant.

RESULTS

Among the 269 patients who underwent thyroid surgery, 72% were white and 80% were women; the patients ranged from 16 to 91 years old (mean 52.1 years) (Table 1). A total of 143 patients (53%) underwent total/subtotal thyroidectomy, while 111 (41.3%) underwent thyroid lobectomy and (5.6%) underwent completion thyroidectomy. Malignancy was present in 106 cases (39.4%); 24 of the 106 cases were incidental papillary thyroid cancer. Central neck dissection was performed in 36 of 269 (13.4%) cases. Thirty-four (12.6%) patients had four or more level VI lymph nodes removed. Of the 34 patients, 29 (85.3%) underwent formal central node dissection.

Sixty-six patients (24.5%) had unintentional removal of parathyroid tissue. There were no patient demographic differences between those who did and did not have removal of parathyroid tissue. On bivariate analysis, malignancy ($P=0.04$), smaller dominant thyroid nodule size ($P=0.002$), performance of central neck dissection ($P<0.0001$), and removal of four or more central lymph nodes ($P<0.0001$) were significantly associated with unintentional parathyroidectomy (Table 1). The rate of unintentional parathyroidectomy was not affected by the presence of hyperthyroidism ($n=17$, $P=0.26$), lymphocytic thyroiditis ($n=61$, $P=0.72$), or

concomitant hyperparathyroidism ($n=4$, $P=0.25$). A follow-up analysis comparing individual malignancy types showed no significant differences between patients with follicular thyroid carcinoma ($P=0.72$) or medullary thyroid carcinoma ($P=0.99$). Significant differences were observed for patients with both incidental ($P=0.03$) and known ($P=0.01$) papillary thyroid cancer; both were found to have increased risk of unintentional parathyroidectomy.

Multivariable analysis showed that central neck dissection had the strongest influence on parathyroid loss (odds ratio 4.72 [confidence interval 1.91–11.71], $P=0.0008$) (Table 2).

DISCUSSION

The occurrence of unintentional parathyroidectomy ranges widely across studies. This finding is likely due to a number of institution-related variables. For instance, there is variation in the pathological interpretation of parathyroid tissue on a specimen; some pathologists report the presence of parathyroid tissue in the specimen, while others report the actual size of parathyroid tissue lost. Also, because parathyroid gland size is variable, it is impossible to discern if a whole gland is removed based on the recorded weight or size of the pathologic specimen. Our unintentional parathyroidectomy rate of 24.5% is at the higher end of the reported spectrum, but our data included all parathyroid tissue lost even if it was a small fragment. The multi-institutional study by Applewhite et al reported an unintentional parathyroidectomy rate of 16.2%. However, their study included only patients with pathology reports documenting the removal of an entire gland.³⁵

We suspected that patients with primary hyperparathyroidism might be at greater risk for parathyroid tissue loss since the remaining suppressed parathyroid tissue may be smaller and harder to identify.³⁴ Our findings did not show this relationship, but only 4 of 269 (1.5%) patients in our study had an established preoperative diagnosis of primary hyperparathyroidism. Lin et al found that patients with hyperparathyroidism had a higher rate of ectopic parathyroid glands, including intrathyroidal locations.^{14,36,37} Autopsy studies report a 0.2% rate of intrathyroidal parathyroid gland location.³⁸ This incidence increased to 2% to 5% in the setting of primary hyperparathyroidism.^{39,40} Other studies reported a 40% to 50% rate of intrathyroidal parathyroid glands.^{3,5,9,41} Most authors have agreed that in the case of intrathyroidal parathyroid glands, unintentional parathyroidectomy is unavoidable, even in the hands of an experienced surgeon.^{3–5,8,14,21,30} Knowing that parathyroid excision can occur despite meticulous surgical technique is another reason why careful preservation of the remaining extracapsular parathyroid glands is crucial to preserve calcium homeostasis. Unfortunately, our pathologists did not always designate whether parathyroid tissue was intrathyroidal versus on the capsule of the thyroid.

Our results did not find relationships between unintentional loss of parathyroid tissue and Graves' disease,

Table 1. Bivariate analysis of risk factors for unintentional parathyroidectomy in 269 patients

Variable	Overall	Unintentional parathyroidectomy		P value
		Parathyroid lost (n = 66)	No parathyroid lost (n = 203)	
Age (years): mean ± SD	52.1 ± 15.1	49.5 ± 15.7	52.9 ± 14.7	0.11 ^c
Gender				
Female	215 (79.9%)	55 (83.3%)	160 (78.8%)	0.43 ^a
Male	54 (20.0%)	11 (16.7%)	43 (21.2%)	
Race				
White	193 (71.7%)	51 (77.3%)	142 (70.0%)	0.38 ^a
Black	57 (21.2%)	10 (15.2%)	47 (23.2%)	
Other	19 (7.1%)	5 (7.6%)	14 (6.8%)	
Largest thyroid nodule size (cm): mean ± SD	3.5 ± 1.7	2.9 ± 1.5	3.7 ± 1.7	0.002 ^c
Largest lobe size (cm): mean ± SD	5.9 ± 1.8	5.6 ± 1.5	6.0 ± 1.8	0.11 ^c
Thyroidectomy type				
Completion thyroidectomy	15 (5.6%)	4 (6.1%)	11 (5.4%)	0.20 ^b
Thyroid lobectomy	111 (41.3%)	21 (31.8%)	90 (44.3%)	
Total or near-total or total with lateral neck	143 (53.2%)	41 (62.1%)	102 (50.3%)	
Central neck dissection	36 (13.4%)	20 (30.3%)	16 (7.9%)	<0.0001 ^a
Total CLN (n): medial (IQR)	0 (0–1)	0.5 (0–4)	0 (0–1)	0.0002 ^d
Total CLN (n): categorical				
0	185 (68.8%)	33 (50.0%)	152 (74.9%)	<0.0001
1	26 (9.7%)	6 (9.1%)	20 (9.9%)	
2–3	24 (8.9%)	10 (15.2%)	14 (6.9%)	
≥4	34 (12.6%)	17 (25.8%)	17 (8.4%)	
Concomitant PHPT	4 (1.5)	2 (3.0%)	2 (1.0%)	0.25 ^b
Thyroid function				
Euthyroid	252 (93.7)	64 (97.0%)	188 (92.6%)	0.26 ^b
Hyperthyroid	17 (6.3)	2 (3.0%)	15 (7.4%)	
Type of hyperthyroidism				
Graves'	7 (41.2%)	1 (50.0%)	6 (40.0%)	1.00 ^b
Plummer disease	10 (58.8%)	1 (50.0%)	9 (60.0%)	
Malignancy	106 (39.4%)	33 (50.0%)	73 (36.0%)	0.04 ^a
Follicular thyroid carcinoma	10 (3.7%)	2 (6.1%)	8 (11.0%)	0.72 ^b
Incidental papillary thyroid carcinoma	24 (8.9%)	3 (9.1%)	21 (28.8%)	0.03 ^a
Medullary thyroid carcinoma	4 (1.5%)	1 (3.0%)	3 (4.1%)	0.99 ^b
Papillary thyroid carcinoma	68 (25.3%)	27 (81.8%)	41 (56.2%)	0.01 ^a
Lymphocytic thyroiditis	61 (22.7%)	16 (24.2%)	45 (56.2%)	0.72 ^b
Parathyroid reimplanted	27 (1.0%)	6 (9.1%)	21 (10.3%)	0.77 ^a

P value based on ^achi-square test; ^bFisher exact test; ^cindependent Student *t* test; ^dmedian test.

CLN indicates central lymph nodes; IQR, interquartile range; PHPT, primary hyperparathyroidism.

Table 2. Multivariable analysis of risk factors for parathyroid loss

Risk factor	Odds ratio (95% CI)	P value
Age (years)	0.99 (0.96–1.01)	0.16
Central neck dissection	4.72 (1.91–11.71)	0.0008
Largest thyroid nodule	0.81 (0.65–1.02)	0.08
PG autotransplantation	0.41 (0.11–1.49)	0.17

PG indicates parathyroid gland.

Plummer disease, or lymphocytic thyroiditis. Several other studies, one of which had 386 patients with Hashimoto's thyroiditis, failed to identify a relationship between unintentional parathyroidectomy and Hashimoto's thyroiditis.^{4,7,11,20,24} Graves' disease is associated with inflammation and hypervascularity, which can make close capsular dissection a challenge. Two large studies reported an increased incidence of transient and permanent hypoparathyroidism following total thyroidectomy for Graves' disease, but no significant correlation was found with respect to unintentional parathyroidectomy.^{30,42} Only 7 of 269 (2.6%) patients in our study had Graves' disease, which could account for the lack of significance. Three other studies, with comparably low numbers of Graves' disease, also failed to show an association, while a study of 1068 patients with 220 Graves' diagnoses found an increased rate of unintentional parathyroidectomy in this patient population.^{9,17,24,43}

Both malignancy and smaller thyroid nodule size were risk factors for unintentional parathyroidectomy on univariable, but not multivariable, analysis. Malignancy has been identified on univariate analysis in many other studies as a risk factor for inadvertent parathyroidectomy.^{7,16,18,24,31} Thyroid nodule size, independent of gland weight, is a less studied variable. Sorgato and colleagues⁴¹ found a significant association between patients with a smaller thyroid lesion, in relation to the weight of the gland, and an increased incidence of unintentional parathyroidectomy. Because patients with thyroid cancer often have smaller thyroid glands when compared to patients with goiters, the more aggressive dissection required for thyroid cancers could explain the relationship between smaller thyroid nodule size and loss of parathyroid tissue.^{24,41} Alternatively, parathyroid glands in patients with smaller thyroid glands may be in closer juxtaposition to the thyroid when compared to a larger multinodular goiter that displaces parathyroid tissue.²⁴

Central neck dissection is the most consistently recognized risk factor for unintentional parathyroidectomy, and the reported incidence of postoperative permanent hypoparathyroidism is as high as 16.2%.⁴⁴ Thyroid cancer characteristically spreads to lymph nodes, and as many as 75% of papillary thyroid cancer recurrences occur in cervical lymph nodes, most commonly in the central compartment.^{45,46} The more aggressive surgical approach for cancer requiring

nodal dissection puts the parathyroid glands at risk not only for unintentional removal, but also for trauma and devascularization from a more extensive dissection. During development, the inferior parathyroid glands can migrate caudally toward the thymus in up to 42% of cases.⁴⁷ As a result, the inferior glands are at particular risk for loss during central neck dissection and should be identified and preserved, if possible.^{37,47,48} Several studies are concordant with our findings that malignancy and central neck dissection are associated with increased risk of unintentional parathyroidectomy.^{7,16,18,24,31} The patient population in the study by Zhou et al was comparable to ours (malignancy rate 20%, concomitant central neck dissection 10%); their reported rate of unintentional parathyroidectomy was 20%.²⁴

In conclusion, the greatest risk factor for unintentional parathyroidectomy is the performance of a central neck dissection. Patients with lymphocytic thyroiditis, hyperthyroidism, or concomitant primary hyperparathyroidism do not appear to be at increased risk for unintentional parathyroidectomy.

ORCID

Stacey Mahady <http://orcid.org/0000-0002-2966-2441>

John Preskitt <http://orcid.org/0000-0002-5283-2170>

Christine Landry <http://orcid.org/0000-0003-1816-6378>

1. Iannuzzi JC, Fleming FJ, Kelly KN, et al. Risk scoring can predict readmission after endocrine surgery. *Surgery*. 2014;156:1432–1440. doi:10.1016/j.surg.2014.08.023.
2. Edafe O, Prasad P, Harrison BJ, et al. Incidence and predictors of post-thyroidectomy hypocalcaemia in a tertiary endocrine surgical unit. *Ann R Coll Surg Engl*. 2014;96:219–223. doi:10.1308/003588414X13814021679753.
3. Gourgiotis S, Moustafellos P, Dimopoulos N, et al. Inadvertent parathyroidectomy during thyroid surgery: the incidence of a complication of thyroidectomy. *Langenbecks Arch Surg*. 2006;391:557–560. doi:10.1007/s00423-006-0079-8.
4. Sakorafas GH, Stafyla V, Bramis C, et al. Incidental parathyroidectomy during thyroid surgery: an underappreciated complication of thyroidectomy. *World J Surg*. 2005;29:1539–1543. doi:10.1007/s00268-005-0032-y.
5. Sasson AR, Pingpank JFJ, Wetherington RW, et al. Incidental parathyroidectomy during thyroid surgery does not cause transient symptomatic hypocalcemia. *Arch Otolaryngol Head Neck Surg*. 2001;127:304–308. doi:10.1001/archotol.127.3.304.
6. Bergamaschi R, Becouarn G, Ronceray J, et al. Morbidity of thyroid surgery. *Am J Surg*. 1998;176:71–75. doi:10.1016/S0002-9610(98)00099-3.
7. Rajinikanth J, Paul MJ, Abraham DT, et al. Surgical audit of inadvertent parathyroidectomy during total thyroidectomy: incidence, risk factors, and outcome. *Medscape J Med*. 2009;11:29.
8. Abboud B, Sleilaty G, Braidry C, et al. Careful examination of thyroid specimen intraoperatively to reduce incidence of inadvertent parathyroidectomy during thyroid surgery. *Arch Otolaryngol Head Neck Surg*. 2007;133:1105–1110. doi:10.1001/archotol.133.11.1105.
9. Manouras A, Markogiannakis H, Lagoudianakis E, et al. Unintentional parathyroidectomy during total thyroidectomy. *Head Neck*. 2008;30:497–502. doi:10.1002/hed.20728.

10. Manatakis DK, Balalis D, Soulou VN, et al. Incidental parathyroidectomy during total thyroidectomy: risk factors and consequences. *Int J Endocrinol.* 2016;2016:1. doi:[10.1155/2016/7825305](https://doi.org/10.1155/2016/7825305).
11. Youssef T, Gaballah G, Abd-Elal E, et al. Assessment of risk factors of incidental parathyroidectomy during thyroid surgery: a prospective study. *Int J Surg.* 2010;8:207–211. doi:[10.1016/j.ijso.2009.12.008](https://doi.org/10.1016/j.ijso.2009.12.008).
12. Song CM, Jung JH, Ji YB, Min HJ, et al. Relationship between hypoparathyroidism and the number of parathyroid glands preserved during thyroidectomy. *World J Surg Onc.* 2014;12:200. doi:[10.1186/1477-7819-12-200](https://doi.org/10.1186/1477-7819-12-200).
13. Hone RWA, Tikka T, Kaleva AI, et al. Analysis of the incidence and factors predictive of inadvertent parathyroidectomy during thyroid surgery. *J Laryngol Otol.* 2016;130:669–673. doi:[10.1017/S0022215116008136](https://doi.org/10.1017/S0022215116008136).
14. Lin DT, Patel SG, Shaha AR, et al. Incidence of inadvertent parathyroid removal during thyroidectomy. *Laryngoscope.* 2002;112:608–611. doi:[10.1097/00005537-200204000-00003](https://doi.org/10.1097/00005537-200204000-00003).
15. Page C, Strunski V. Parathyroid risk in total thyroidectomy for bilateral, benign, multinodular goitre: report of 351 surgical cases. *J Laryngol Otol.* 2007;121:237–241. doi:[10.1017/S0022215106003501](https://doi.org/10.1017/S0022215106003501).
16. Sippel RS, Ozgöl O, Hartig GK, et al. Risks and consequences of incidental parathyroidectomy during thyroid resection. *ANZ J Surg.* 2007;77:33–36. doi:[10.1111/j.1445-2197.2006.03972.x](https://doi.org/10.1111/j.1445-2197.2006.03972.x).
17. Prazenica P, O'Driscoll K, Holy R. Incidental parathyroidectomy during thyroid surgery using capsular dissection technique. *Otolaryngol Head Neck Surg.* 2014;150:754–761. doi:[10.1177/0194599814521365](https://doi.org/10.1177/0194599814521365).
18. Zheng J, Song H, Cai S, et al. Evaluation of clinical significance and risk factors of incidental parathyroidectomy due to thyroidectomy: a single-center retrospective clinical study. *Medicine (Baltimore).* 2017;96:e8175. doi:[10.1097/MD.00000000000008175](https://doi.org/10.1097/MD.00000000000008175).
19. Ozogul B, Nuran Akcay M, Kisaoglu A, et al. Incidental parathyroidectomy during thyroid surgery: risk factors, incidence, and outcomes. *Turk J Med Sci.* 2014;44:84–88. doi:[10.3906/sag-1211-56](https://doi.org/10.3906/sag-1211-56).
20. Christakis I, Zacharopoulou P, Galanopoulos G, et al. Inadvertent parathyroidectomy risk factors in 1,373 thyroidectomies—male gender and presence of lymphadenopathy, but not size of gland, independently increase the risk. *Gland Surg.* 2017;6:666–674. doi:[10.21037/g.2017.07.06](https://doi.org/10.21037/g.2017.07.06).
21. Lee NJ, Blakey JD, Bhuta S, et al. Unintentional parathyroidectomy during thyroidectomy. *Laryngoscope.* 1999;109:1238–1240. doi:[10.1097/00005537-199908000-00010](https://doi.org/10.1097/00005537-199908000-00010).
22. Muller PE, Jakoby R, Heinert G, et al. Surgery for recurrent goitre: its complications and their risk factors. *Eur J Surg.* 2001;167:816–821. doi:[10.1080/11024150152717634](https://doi.org/10.1080/11024150152717634).
23. McGoldrick DM, Majeed M, Achakzai AA, et al. Inadvertent parathyroidectomy during thyroid surgery. *Ir J Med Sci.* 2017;186:1019–1022. doi:[10.1007/s11845-017-1560-9](https://doi.org/10.1007/s11845-017-1560-9).
24. Zhou HY, He JC, McHenry CR. Inadvertent parathyroidectomy: incidence, risk factors, and outcomes. *J Surg Res.* 2016;205:70–75. doi:[10.1016/j.jss.2016.06.019](https://doi.org/10.1016/j.jss.2016.06.019).
25. Ondik MP, McGinn J, Ruggiero F, et al. Unintentional parathyroidectomy and hypoparathyroidism in secondary central compartment surgery for thyroid cancer. *Head Neck.* 2010;32:462–466. doi:[10.1002/hed.21205](https://doi.org/10.1002/hed.21205).
26. Winslow CP, Meyers AD. Hypocalcemia as a complication of radioiodine therapy. *Am J Otolaryngol.* 1998;19:401–403. doi:[10.1016/S0196-0709\(98\)90045-X](https://doi.org/10.1016/S0196-0709(98)90045-X).
27. Glazebrook GA. Effect of decicurie doses of radioactive iodine 131 on parathyroid function. *Am J Surg.* 1987;154:368–373. doi:[10.1016/0002-9610\(89\)90006-8](https://doi.org/10.1016/0002-9610(89)90006-8).
28. Lo Galbo AM, Kuik DJ, Lips P, et al. A prospective longitudinal study on endocrine dysfunction following treatment of laryngeal or hypopharyngeal carcinoma. *Oral Oncol.* 2013;49:950–955. doi:[10.1016/j.oraloncology.2013.03.450](https://doi.org/10.1016/j.oraloncology.2013.03.450).
29. Sitges-Serra A, Ruiz S, Girvent M, et al. Outcome of protracted hypoparathyroidism after total thyroidectomy. *Br J Surg.* 2010;97:1687–1695. doi:[10.1002/bjs.7219](https://doi.org/10.1002/bjs.7219).
30. Erbil Y, Barbaros U, Ozbey N, et al. Risk factors of incidental parathyroidectomy after thyroidectomy for benign thyroid disorders. *Int J Surg Lond Engl.* 2009;7:58–61. doi:[10.1016/j.ijso.2008.10.012](https://doi.org/10.1016/j.ijso.2008.10.012).
31. Spiliotis J, Vaxevanidou A, Sergouniotis F, et al. Risk factors and consequences of incidental parathyroidectomy during thyroidectomy. *Am Surg.* 2010;76:436–441.
32. Youngwirth L, Benavidez J, Sippel R, et al. Postoperative parathyroid hormone testing decreases symptomatic hypocalcemia and associated emergency room visits after total thyroidectomy. *Surgery.* 2010;148:841–846. doi:[10.1016/j.surg.2010.07.038](https://doi.org/10.1016/j.surg.2010.07.038).
33. Khairy GA, Al-Saif A. Incidental parathyroidectomy during thyroid resection: incidence, risk factors, and outcome. *Ann Saudi Med.* 2011;31:274–278. doi:[10.4103/0256-4947.81545](https://doi.org/10.4103/0256-4947.81545).
34. Rosol TJ, DeLellis RA, Harvey PW, et al. Endocrine system. In: Haschek WM, Rousseaux CG, Wallig MA, eds. *Haschek and Rousseaux's Handbook of Toxicologic Pathology*. 3rd ed. Boston, MA: Academic Press; 2013:2391–2492.
35. Applewhite MK, White MG, Xiong M, et al. Incidence, risk factors, and clinical outcomes of incidental parathyroidectomy during thyroid surgery. *Ann Surg Oncol.* 2016;23:4310–4315. doi:[10.1245/s10434-016-5439-1](https://doi.org/10.1245/s10434-016-5439-1).
36. Phitayakorn R, McHenry CR. Incidence and location of ectopic abnormal parathyroid glands. *Am J Surg.* 2006;191:418–423. doi:[10.1016/j.amjsurg.2005.10.049](https://doi.org/10.1016/j.amjsurg.2005.10.049).
37. Feliciano DV. Parathyroid pathology in an intrathyroidal position. *Am J Surg.* 1992;164:496–500. doi:[10.1016/S0002-9610\(05\)81188-2](https://doi.org/10.1016/S0002-9610(05)81188-2).
38. Akerström G, Malmaeus J, Bergström R. Surgical anatomy of human parathyroid glands. *Surgery.* 1984;95:14–21.
39. Thompson NW, Eckhauser FE, Harness JK. The anatomy of primary hyperparathyroidism. *Surgery.* 1982;92:814–821.
40. Bruining H, van Houten H, Juttman JR, et al. Results of operative treatment of 615 patients with primary hyperparathyroidism. *World J Surg.* 1981;5:85–89. doi:[10.1007/BF01657843](https://doi.org/10.1007/BF01657843).
41. Sorgato N, Pennelli G, Boschin IM, et al. Can we avoid inadvertent parathyroidectomy during thyroid surgery? *In Vivo.* 2009;23:433–439.
42. Feroci F, Rettori M, Borrelli A, et al. A systematic review and meta-analysis of total thyroidectomy versus bilateral subtotal thyroidectomy for Graves' disease. *Surgery.* 2014;155:529–540. doi:[10.1016/j.surg.2013.10.017](https://doi.org/10.1016/j.surg.2013.10.017).
43. Cavicchi O, Piccin O, Caliceti U, et al. Transient hypoparathyroidism following thyroidectomy: a prospective study and multivariate analysis of 604 consecutive patients. *Otolaryngol Head Neck Surg.* 2007;137:654–658. doi:[10.1016/j.otohns.2007.03.001](https://doi.org/10.1016/j.otohns.2007.03.001).
44. Giordano D, Valcavi R, Thompson GB, et al. Complications of central neck dissection in patients with papillary thyroid carcinoma: results of a study on 1087 patients and review of the literature. *Thyroid.* 2012;22:911–917. doi:[10.1089/thy.2012.0011](https://doi.org/10.1089/thy.2012.0011).
45. Lombardi D, Accorona R, Paderno A, et al. Morbidity of central neck dissection for papillary thyroid cancer. *Gland Surg.* 2017;6:492–500. doi:[10.21037/g.2017.05.07](https://doi.org/10.21037/g.2017.05.07).
46. Goyal N, Pakdaman M, Kamani D, et al. Mapping the distribution of nodal metastases in papillary thyroid carcinoma: Where exactly are the nodes? *Laryngoscope.* 2017;127:1959–1964. doi:[10.1002/lary.26495](https://doi.org/10.1002/lary.26495).
47. Wang C. The anatomic basis of parathyroid surgery. *Ann Surg.* 1976;183:271–275. doi:[10.1097/0000658-197603000-00010](https://doi.org/10.1097/0000658-197603000-00010).
48. Åkerström G, Rudberg C, Grimelius L, et al. Causes of failed primary exploration and technical aspects of re-operation in primary hyperparathyroidism. *World J Surg.* 1992;16:562–568. doi:[10.1007/BF02067321](https://doi.org/10.1007/BF02067321).