

Research Article

Observational Assessment of Recurrent Laryngeal Nerve Dysfunction and Postoperative Complications Following Thyroidectomy with Intraoperative Nerve Monitoring

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ABSTRACT

Background: Recurrent laryngeal nerve dysfunction remains an important complication of thyroidectomy because it may lead to voice change, aspiration, ineffective cough, or airway compromise. Intraoperative nerve monitoring provides real-time functional assessment of the recurrent laryngeal nerve and may assist in identifying patients at risk of postoperative nerve dysfunction.

Aim: To assess recurrent laryngeal nerve dysfunction and postoperative complications following thyroidectomy performed with intraoperative nerve monitoring.

Material and Methods: This prospective observational study included 64 patients undergoing thyroidectomy at a tertiary care hospital. Demographic characteristics, thyroid pathology, type of surgery, intraoperative nerve-monitoring signals, postoperative recurrent laryngeal nerve function, and surgical complications were recorded. Postoperative complications included hypocalcaemia, neck haematoma, seroma, wound infection, respiratory distress, and need for re-exploration. Data were analysed using SPSS version 23.0, and a p-value <0.05 was considered statistically significant.

Results: The mean age was 46.78±12.64 years, and 78.13% of patients were female. Multinodular goitre was the most common diagnosis (43.75%), while total thyroidectomy was performed in 53.13%. Abnormal intraoperative nerve-monitoring signals were observed in 8 patients (12.50%). Postoperative recurrent laryngeal nerve dysfunction occurred in 6 patients (9.38%), including 5 of 8 patients (62.50%) with abnormal signals compared with 1 of 56 patients (1.79%) with normal signals (p<0.001). Reoperative surgery (p=0.009) and retrosternal extension (p=0.044) were significantly associated with RLN dysfunction. Overall hypocalcaemia occurred in 20.31%, with significantly higher occurrence after total, near-total, or completion thyroidectomy (p=0.013).

Conclusion: Intraoperative nerve monitoring was useful for functional assessment of the recurrent laryngeal nerve and abnormal signals were strongly associated with postoperative dysfunction. Reoperative surgery and retrosternal extension increased the risk of RLN dysfunction, while hypocalcaemia remained the most frequent postoperative complication.

Keywords: Thyroidectomy, Recurrent Laryngeal Nerve, Intraoperative Nerve Monitoring, Hypocalcaemia, Postoperative Complications.

INTRODUCTION

Thyroidectomy is one of the most frequently performed endocrine surgical procedures and is indicated for a wide spectrum of benign and malignant thyroid disorders, including multinodular goitre, solitary or suspicious thyroid nodules, Graves' disease, toxic nodular disease, compressive goitre, and thyroid carcinoma. Although advances in operative technique, anaesthesia, and perioperative care have improved the safety of thyroid surgery, injury to the recurrent laryngeal nerve remains one of its most important complications.

Preservation of the recurrent laryngeal nerve is therefore a major objective during thyroidectomy because impairment may lead to hoarseness, weak voice, ineffective cough, aspiration, or, when bilateral, serious airway compromise.¹ The recurrent laryngeal nerve has a close anatomical relationship with the thyroid gland and may show variations in its course, branching pattern, relationship to the inferior thyroid artery, and position around the ligament of Berry. These characteristics may make identification and preservation difficult, particularly in patients with large goitres,

retrosternal extension, inflammatory thyroid disease, malignancy, or previous thyroid surgery. Direct visual identification remains an essential component of safe thyroidectomy, but visual inspection provides information about anatomical continuity rather than functional integrity. Intraoperative nerve monitoring has therefore been incorporated as an adjunct to visual identification in many centres.² Intraoperative nerve monitoring uses electrical stimulation of the vagus nerve or recurrent laryngeal nerve together with electromyographic recording from the vocal cord musculature. This technique allows functional information to be obtained before, during, and after thyroid dissection. A reproducible electromyographic response can support identification of neural tissue and confirm functional continuity. Changes in signal amplitude or complete loss of signal may alert the surgical team to possible traction, compression, thermal injury, ligation, or other mechanisms of nerve impairment before the operation is completed.³ The technique may be particularly useful when anatomy is distorted or the nerve follows an uncommon course.⁴ The clinical value of intraoperative nerve monitoring extends beyond simple nerve identification. Monitoring may help localize functional disturbance and provide information relevant to intraoperative decision-making. In bilateral thyroid surgery, loss of a reliable signal on the first side may influence the decision to proceed with contralateral dissection, especially when bilateral nerve dysfunction would pose a major airway risk. Standardized interpretation of stimulation responses and careful attention to electrode position, equipment function, anaesthetic factors, and stimulation technique are important because technical problems can also produce abnormal or absent signals.⁵ Despite nerve monitoring, postoperative laryngeal dysfunction can still occur. Mechanisms of injury include excessive traction, compression, thermal spread, ischemia, entrapment in ligatures, transection, and difficult dissection. Patient- and disease-related factors such as advanced thyroid pathology, reoperative surgery, anatomical nerve branching, and extensive procedures may further increase surgical complexity. Careful postoperative assessment is therefore necessary even when the recurrent laryngeal nerve appears anatomically intact. Laryngoscopic evaluation provides an objective method for documenting vocal cord mobility and differentiating transient from persistent

dysfunction.⁶ Post-thyroidectomy morbidity is not limited to recurrent laryngeal nerve dysfunction. Hypocalcaemia resulting from temporary or permanent impairment of parathyroid function is another major postoperative concern, particularly after bilateral or extensive thyroid surgery. Other complications include neck haematoma, seroma, wound infection, respiratory difficulty, and re-exploration. Preservation of parathyroid vascularity, meticulous haemostasis, and structured postoperative surveillance are therefore essential. Newer intraoperative technologies have also been explored alongside neural monitoring to improve identification and preservation of structures at risk during total thyroidectomy.⁷

MATERIALS AND METHODS

The present study was conducted as a hospital-based prospective observational study at a tertiary care hospital to assess recurrent laryngeal nerve dysfunction and postoperative complications following thyroidectomy performed with intraoperative nerve monitoring. A total of 64 consecutive patients undergoing thyroid surgery and fulfilling the predefined eligibility criteria were included in the study. All patients underwent a standardized preoperative assessment, thyroidectomy with intraoperative nerve monitoring, and postoperative evaluation for recurrent laryngeal nerve function and other surgery-related complications. A total of 64 patients scheduled for thyroidectomy for benign or malignant thyroid disorders were enrolled. Patients undergoing total thyroidectomy, near-total thyroidectomy, hemithyroidectomy, or completion thyroidectomy were considered eligible. Demographic and clinical parameters including age, sex, presenting complaints, duration of thyroid swelling, symptoms of compression, previous thyroid treatment, associated comorbidities, thyroid functional status, indication for surgery, and type of thyroidectomy were recorded in a structured proforma.

Inclusion Criteria

Patients aged 18 years or above undergoing elective thyroidectomy with intraoperative recurrent laryngeal nerve monitoring were included. Patients with benign multinodular goitre, solitary thyroid nodule, toxic nodular disease, Graves' disease, or suspected or confirmed thyroid malignancy requiring surgical treatment were considered eligible. Only

patients who provided informed consent and had documented preoperative vocal cord mobility were included.

Exclusion Criteria

Patients with pre-existing vocal cord palsy or documented recurrent laryngeal nerve dysfunction, previous major laryngeal surgery, advanced malignancy with known direct invasion of the recurrent laryngeal nerve, emergency thyroid surgery, severe medical illness precluding standard evaluation, and patients in whom intraoperative nerve monitoring could not be adequately performed were excluded. Patients with incomplete clinical or postoperative follow-up data were also excluded from final assessment.

Preoperative Assessment

All patients underwent detailed clinical examination with particular attention to the size and consistency of the thyroid swelling, retrosternal extension, cervical lymphadenopathy, pressure symptoms, and features suggestive of thyroid malignancy. Thyroid function tests, serum calcium, complete blood count, renal function tests, and other routine preoperative investigations were performed. Ultrasonography of the neck was used to characterize the thyroid lesion and cervical lymph nodes. Fine-needle aspiration cytology was performed wherever clinically indicated. Preoperative indirect or flexible fiberoptic laryngoscopy was carried out to document vocal cord mobility and establish baseline recurrent laryngeal nerve function.

Surgical Procedure and Intraoperative Nerve Monitoring

Thyroidectomy was performed under general anaesthesia using a standardized surgical technique. Intraoperative nerve monitoring was carried out using an electromyography-based monitoring system with appropriately positioned endotracheal tube electrodes. Before thyroid dissection, the monitoring system was checked to confirm adequate electrode contact and baseline signal. The vagus nerve and recurrent laryngeal nerve were identified and stimulated when feasible. Baseline nerve stimulation, recurrent laryngeal nerve identification, intraoperative electromyographic signal amplitude, signal response after thyroid lobe dissection, and final nerve stimulation response were documented. Any reduction or loss of signal during surgery was recorded, along with the operative step at which it occurred and whether the signal subsequently

recovered. Visual identification and preservation of the recurrent laryngeal nerve were attempted in all cases.

Assessment of Recurrent Laryngeal Nerve Dysfunction

Postoperative recurrent laryngeal nerve function was evaluated clinically and by laryngoscopic examination. Patients were assessed for hoarseness, altered voice quality, weak voice, aspiration symptoms, ineffective cough, and respiratory difficulty. Vocal cord mobility was examined postoperatively, particularly in patients with voice changes or abnormal intraoperative monitoring signals. Recurrent laryngeal nerve dysfunction was categorized as unilateral or bilateral and as transient or persistent according to recovery during postoperative follow-up. The relationship between intraoperative loss of signal and postoperative vocal cord dysfunction was also evaluated.

Postoperative Complications and Outcome Parameters

Patients were observed for postoperative complications including recurrent laryngeal nerve palsy, transient or persistent hypocalcaemia, postoperative haemorrhage or neck haematoma, wound infection, seroma, respiratory distress, need for re-exploration, and other surgery-related morbidity. Serum calcium levels and clinical manifestations of hypocalcaemia such as perioral numbness, paresthesia, muscle cramps, or carpopedal spasm were recorded. The primary outcome was the incidence of postoperative recurrent laryngeal nerve dysfunction. Secondary outcomes included intraoperative loss of nerve-monitoring signal, association between signal loss and postoperative vocal cord palsy, incidence of hypocalcaemia, haemorrhage, wound complications, and overall postoperative morbidity. Outcomes were also assessed according to age, sex, thyroid pathology, extent of thyroidectomy, primary versus reoperative surgery, and malignant versus benign disease.

Statistical Analysis

The collected data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 23.0. Continuous variables were expressed as mean with standard deviation or median with interquartile range according to data distribution, while categorical variables were presented as frequencies and percentages. The Shapiro-Wilk test was used to assess normality

of continuous data. The independent-samples t-test or Mann-Whitney U test was used for comparison of continuous variables, whereas the chi-square test or Fisher's exact test was used for categorical variables. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of intraoperative nerve-monitoring signal changes for predicting postoperative recurrent laryngeal nerve dysfunction were calculated wherever applicable. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1. Demographic and Baseline Clinical Characteristics

A total of 64 patients were included in the study. The mean age of the study population was 46.78 ± 12.64 years. The largest proportion of patients belonged to the 41–50-year age group, comprising 18 patients (28.13%). This was followed by 14 patients (21.88%) in the 31–40-year age group and 13 patients (20.31%) in the 51–60-year age group. Ten patients (15.63%) were aged between 18 and 30 years, while 9 patients (14.06%) were older than 60 years. With regard to sex distribution, females constituted the majority, accounting for 50 patients (78.13%), whereas 14 patients (21.88%) were males. Assessment of thyroid functional status showed that 50 patients (78.13%) were euthyroid, 9 patients (14.06%) were hyperthyroid, and 5 patients (7.81%) were hypothyroid. Compressive symptoms were present in 12 patients (18.75%), while associated comorbidities were documented in 22 patients (34.38%).

Table 2. Thyroid Pathology and Operative Characteristics

Multinodular goitre was the most common primary diagnosis and was observed in 28 patients (43.75%). Solitary thyroid nodule was present in 14 patients (21.88%), while thyroid malignancy was diagnosed in 11 patients (17.19%). Graves' disease was present in 6 patients (9.38%), and toxic multinodular goitre was recorded in 5 patients (7.81%). On categorization according to pathology, 53 patients (82.81%) had benign thyroid disease, whereas 11 patients (17.19%) had malignant disease. Total thyroidectomy was the most commonly performed procedure and was carried out in 34 patients (53.13%). Hemithyroidectomy was performed in 18 patients (28.13%), near-total thyroidectomy in 8 patients (12.50%), and completion

thyroidectomy in 4 patients (6.25%). Primary thyroid surgery accounted for 58 cases (90.63%), whereas 6 patients (9.38%) underwent reoperative thyroid surgery. Retrosternal extension was identified in 10 patients (15.63%). Visual identification of the recurrent laryngeal nerve was achieved in all 64 patients, corresponding to 100.00% of the study population.

Table 3. Association between Intraoperative Nerve-Monitoring Findings and Postoperative RLN Dysfunction

A normal intraoperative nerve-monitoring signal was recorded in 56 patients (87.50%), whereas an abnormal signal was documented in 8 patients (12.50%). Among the 56 patients with a normal intraoperative signal, postoperative recurrent laryngeal nerve dysfunction developed in only 1 patient (1.79%), while 55 patients (98.21%) maintained normal postoperative recurrent laryngeal nerve function. In contrast, among the 8 patients with an abnormal intraoperative nerve-monitoring signal, 5 patients (62.50%) developed postoperative recurrent laryngeal nerve dysfunction, while 3 patients (37.50%) retained normal postoperative nerve function. Overall, postoperative recurrent laryngeal nerve dysfunction occurred in 6 of 64 patients (9.38%), whereas 58 patients (90.63%) showed normal postoperative recurrent laryngeal nerve function. The association between abnormal intraoperative nerve-monitoring signals and postoperative recurrent laryngeal nerve dysfunction was statistically significant, with a p-value of <0.001 .

Table 4. Association of Selected Clinical and Operative Factors with Postoperative RLN Dysfunction

Postoperative recurrent laryngeal nerve dysfunction was assessed in relation to selected demographic, pathological, and operative variables. Among 22 patients aged more than 50 years, 4 patients (18.18%) developed RLN dysfunction, while 18 patients (81.82%) did not. Among 42 patients aged 50 years or below, RLN dysfunction was observed in 2 patients (4.76%), whereas 40 patients (95.24%) had no dysfunction. The difference according to age was not statistically significant ($p=0.170$). Among males, 2 of 14 patients (14.29%) developed RLN dysfunction compared with 4 of 50 females (8.00%), with no statistically significant association between sex and RLN dysfunction ($p=0.604$).

Among patients with malignant thyroid disease, 3 of 11 patients (27.27%) developed postoperative RLN dysfunction, while 8 patients (72.73%) did not. Among 53 patients with benign disease, RLN dysfunction occurred in 3 patients (5.66%), whereas 50 patients (94.34%) remained unaffected. The difference between benign and malignant disease approached but did not reach statistical significance ($p=0.058$). Among the 6 patients undergoing reoperative thyroid surgery, 3 patients (50.00%) developed RLN dysfunction and 3 patients (50.00%) had normal nerve function. In comparison, among 58 patients undergoing primary thyroid surgery, RLN dysfunction occurred in 3 patients (5.17%), while 55 patients (94.83%) had no dysfunction. This association was statistically significant ($p=0.009$).

Among the 10 patients with retrosternal extension, postoperative RLN dysfunction was observed in 3 patients (30.00%), while 7 patients (70.00%) had normal nerve function. Among the 54 patients without retrosternal extension, RLN dysfunction occurred in 3 patients (5.56%), whereas 51 patients (94.44%) remained unaffected. The association between retrosternal extension and postoperative RLN dysfunction was statistically significant ($p=0.044$). Among 46 patients undergoing total, near-total, or completion thyroidectomy, 5 patients (10.87%) developed RLN dysfunction and 41 patients (89.13%) did not. In the hemithyroidectomy group, 1 of 18 patients (5.56%) developed RLN dysfunction, whereas 17 patients (94.44%) maintained normal nerve function. This difference was not statistically significant ($p=0.667$).

Table 5. Postoperative Complications According To Extent of Thyroidectomy

Postoperative complications were assessed according to the extent of thyroid surgery. Any form of hypocalcaemia was observed in 13 of 46 patients (28.26%) undergoing total, near-total, or completion thyroidectomy, whereas no case was recorded among the 18 patients undergoing hemithyroidectomy. Overall, hypocalcaemia occurred in 13 patients (20.31%), and the difference between the two operative groups was statistically significant

($p=0.013$). Transient hypocalcaemia was observed in 11 patients (23.91%) in the total, near-total, or completion thyroidectomy group and in none of the hemithyroidectomy patients. Overall, 11 patients (17.19%) developed transient hypocalcaemia, with a statistically significant difference between groups ($p=0.026$). Persistent hypocalcaemia occurred in 2 patients (4.35%) in the more extensive thyroidectomy group and in none of the hemithyroidectomy group, giving an overall incidence of 3.13%; this difference was not statistically significant ($p=1.000$).

Postoperative RLN dysfunction was observed in 5 of 46 patients (10.87%) undergoing total, near-total, or completion thyroidectomy and in 1 of 18 patients (5.56%) undergoing hemithyroidectomy. The overall incidence was 9.38%, and the difference was not statistically significant ($p=0.667$). Neck haematoma developed in 2 patients (4.35%) in the more extensive thyroidectomy group and in none of the hemithyroidectomy group, giving an overall incidence of 3.13% ($p=1.000$). Seroma occurred in 2 patients (4.35%) in the total, near-total, or completion group and in 1 patient (5.56%) in the hemithyroidectomy group, with an overall incidence of 4.69% ($p=1.000$).

Wound infection was recorded in 1 patient (2.17%) undergoing total, near-total, or completion thyroidectomy and in 1 patient (5.56%) undergoing hemithyroidectomy, resulting in an overall frequency of 3.13% ($p=0.487$). Respiratory distress was documented in 2 patients (4.35%) in the more extensive thyroidectomy group and in none of the hemithyroidectomy patients, with an overall incidence of 3.13% ($p=1.000$). Re-exploration was required in 1 patient (2.17%) in the total, near-total, or completion thyroidectomy group and in no patient after hemithyroidectomy, giving an overall rate of 1.56% ($p=1.000$). At least one postoperative complication occurred in 16 of 46 patients (34.78%) undergoing total, near-total, or completion thyroidectomy and in 2 of 18 patients (11.11%) undergoing hemithyroidectomy. Overall, 18 patients (28.13%) experienced one or more postoperative complications, although the difference between the two operative groups was not statistically significant ($p=0.070$).

Table 1. Demographic and Baseline Clinical Characteristics of the Study Population (N=64)

Parameter	Number (n)	Percentage (%)
Age (years), Mean $\pm$ SD	46.78 $\pm$ 12.64	—
18–30 years	10	15.63
31–40 years	14	21.88

41–50 years	18	28.13
51–60 years	13	20.31
>60 years	9	14.06
Sex		
Male	14	21.88
Female	50	78.13
Thyroid functional status		
Euthyroid	50	78.13
Hyperthyroid	9	14.06
Hypothyroid	5	7.81
Compressive symptoms present	12	18.75
Associated comorbidity present	22	34.38

Table: 2. Thyroid Pathology and Operative Characteristics of Patients (N=64)

Parameter	Number (n)	Percentage (%)
Primary diagnosis		
Multinodular goitre	28	43.75
Solitary thyroid nodule	14	21.88
Graves' disease	6	9.38
Toxic multinodular goitre	5	7.81
Thyroid malignancy	11	17.19
Pathological category		
Benign disease	53	82.81
Malignant disease	11	17.19
Type of thyroidectomy		
Total thyroidectomy	34	53.13
Near-total thyroidectomy	8	12.50
Hemithyroidectomy	18	28.13
Completion thyroidectomy	4	6.25
Primary thyroid surgery	58	90.63
Reoperative thyroid surgery	6	9.38
Retrosternal extension present	10	15.63
Visual identification of RLN achieved	64	100.00

Table: 3. Association between Intraoperative Nerve-Monitoring Findings and Postoperative Recurrent Laryngeal Nerve Dysfunction

Intraoperative nerve-monitoring status	Total n (%)	Postoperative RLN dysfunction n (%)	Normal postoperative RLN function n (%)	p-value
Normal signal	56 (87.50)	1 (1.79)	55 (98.21)	
Abnormal signal*	8 (12.50)	5 (62.50)	3 (37.50)	<0.001
Total	64 (100.00)	6 (9.38)	58 (90.63)	

*Abnormal signal included significant reduction in electromyographic response or complete loss of signal. Fisher's exact test was applied.

Table: 4. Association of Selected Clinical and Operative Factors with Postoperative RLN Dysfunction

Risk factor	Total patients	RLN dysfunction n (%)	No RLN dysfunction n (%)	p-value
Age >50 years	22	4 (18.18)	18 (81.82)	0.170
Age ≤50 years	42	2 (4.76)	40 (95.24)	
Male sex	14	2 (14.29)	12 (85.71)	0.604
Female sex	50	4 (8.00)	46 (92.00)	
Malignant disease	11	3 (27.27)	8 (72.73)	0.058
Benign disease	53	3 (5.66)	50 (94.34)	

Reoperative surgery	6	3 (50.00)	3 (50.00)	0.009
Primary surgery	58	3 (5.17)	55 (94.83)	
Retrosternal extension present	10	3 (30.00)	7 (70.00)	0.044
Retrosternal extension absent	54	3 (5.56)	51 (94.44)	
Total/near-total/completion thyroidectomy	46	5 (10.87)	41 (89.13)	0.667
Hemithyroidectomy	18	1 (5.56)	17 (94.44)	

Table: 5. Postoperative Complications According To Extent of Thyroidectomy

Postoperative complication	Total/near-total/completion thyroidectomy (n=46), n (%)	Hemithyroidectomy (n=18), n (%)	Overall (n=64), n (%)	p-value
Any hypocalcaemia	13 (28.26)	0 (0.00)	13 (20.31)	0.013
Transient hypocalcaemia	11 (23.91)	0 (0.00)	11 (17.19)	0.026
Persistent hypocalcaemia	2 (4.35)	0 (0.00)	2 (3.13)	1.000
RLN dysfunction	5 (10.87)	1 (5.56)	6 (9.38)	0.667
Neck haematoma	2 (4.35)	0 (0.00)	2 (3.13)	1.000
Seroma	2 (4.35)	1 (5.56)	3 (4.69)	1.000
Wound infection	1 (2.17)	1 (5.56)	2 (3.13)	0.487
Respiratory distress	2 (4.35)	0 (0.00)	2 (3.13)	1.000
Re-exploration	1 (2.17)	0 (0.00)	1 (1.56)	1.000
Patients with ≥1 postoperative complication	16 (34.78)	2 (11.11)	18 (28.13)	0.070

DISCUSSION

The present study included 64 patients with a mean age of 46.78 ± 12.64 years, and the largest proportion belonged to the 41–50-year age group (28.13%). Females constituted 78.13% of the study population, giving a marked female predominance. Most patients were euthyroid (78.13%), whereas 14.06% were hyperthyroid and 7.81% were hypothyroid. These demographic findings were comparable with those reported by Christou et al. (2019),⁸ who prospectively evaluated 1,329 patients undergoing total thyroidectomy and reported a median age of 51.17 years, with women constituting 80.00% of the study population. Hyperthyroidism was present in 20.00% of their patients. Thus, the female predominance observed in the present study was almost identical to their 80.00% rate, while the proportion of hyperthyroid patients in the present study was comparatively lower at 14.06%.

In the present study, multinodular goitre was the most frequent diagnosis, accounting for 28 patients (43.75%), followed by solitary thyroid nodule in 14 (21.88%), thyroid malignancy in 11 (17.19%), Graves' disease in 6 (9.38%), and toxic multinodular goitre in 5 (7.81%). Benign

disease therefore constituted 82.81% of all cases. Total thyroidectomy was the most frequently performed operation (53.13%), followed by hemithyroidectomy (28.13%), near-total thyroidectomy (12.50%), and completion thyroidectomy (6.25%). Zakaria et al. (2011)⁹ evaluated 418 patients and similarly found multinodular goitre to be the predominant indication, accounting for 253 cases (60.53%), while solitary thyroid nodules accounted for 69 cases (16.51%), hyperthyroidism for 68 (16.27%), and recurrent goitre for 23 (5.50%). Their operative pattern differed, with bilateral subtotal thyroidectomy performed in 68.40%, unilateral subtotal thyroidectomy in 12.40%, unilateral total thyroidectomy in 5.90%, bilateral total thyroidectomy in 5.30%, and completion thyroidectomy in 5.50%. The present series therefore demonstrated a substantially greater use of total thyroidectomy, while multinodular goitre remained the predominant underlying thyroid disorder in both studies.

Intraoperative nerve-monitoring findings showed a particularly strong relationship with postoperative recurrent laryngeal nerve function. Of 56 patients with a normal intraoperative signal, only 1 (1.79%) developed postoperative RLN dysfunction, whereas 5 of the

8 patients (62.50%) with an abnormal signal developed postoperative dysfunction ($p < 0.001$). Based on these findings, abnormal monitoring had a sensitivity of 83.33%, specificity of 94.83%, positive predictive value of 62.50%, negative predictive value of 98.21%, and overall accuracy of 93.75%. Calò et al. (2016)¹⁰ studied 1,356 patients operated with intraoperative neuromonitoring and documented loss of signal in 37 cases, including 29 true-positive, 1,317 true-negative, 8 false-positive, and 2 false-negative results. They reported a sensitivity of 93.55%, specificity of 99.40%, positive predictive value of 78.38%, negative predictive value of 99.85%, and accuracy of 99.26%. The very high negative predictive value in both studies was particularly comparable, being 98.21% in the present study and 99.85% in their series.

Overall postoperative RLN dysfunction occurred in 6 of 64 patients (9.38%) in the present study, while 58 patients (90.63%) retained normal postoperative nerve function. The rate observed in the present series was higher than that reported in the monitored group of the randomized trial conducted by Barczyński et al. (2009).¹¹ In their study, 1,000 nerves at risk in the neuromonitoring group demonstrated 19 transient and 8 permanent RLN injuries, corresponding to rates of approximately 1.90% and 0.80%, respectively, whereas the group managed without nerve monitoring had 38 transient and 12 permanent injuries among 1,000 nerves at risk. Neuromonitoring significantly decreased transient RLN paresis among high-risk patients by 2.90% ($p = 0.011$). The numerical difference from the present study should be viewed with consideration of the different denominators, as the current study reported dysfunction per patient whereas Barczyński et al. reported injury according to nerves at risk.

Evaluation of patient- and disease-related factors in the present study showed RLN dysfunction in 18.18% of patients aged > 50 years compared with 4.76% among those aged ≤ 50 years ($p = 0.170$). Dysfunction occurred in 14.29% of males and 8.00% of females ($p = 0.604$). A more marked difference was observed according to pathology, with RLN dysfunction occurring in 27.27% of patients with malignant disease compared with 5.66% of those with benign disease ($p = 0.058$). Similarly, dysfunction occurred in 10.87% following total, near-total, or completion thyroidectomy compared with 5.56% following hemithyroidectomy ($p = 0.667$). Gunn et al.

(2020)¹² analysed 11,370 thyroid operations and documented an overall RLN injury rate of 6.00%. Injury occurred in 9.00% of patients operated on for differentiated thyroid cancer compared with 4.30% of those undergoing surgery for a single nodule ($p < 0.01$), and in 6.90% following total thyroidectomy compared with 4.30% after lobectomy ($p < 0.01$). Their multivariate analysis also identified age ≥ 65 years (OR 1.6), total thyroidectomy (OR 1.4), and thyroid malignancy (OR 2.1) as independent factors associated with RLN injury. These observations followed the same numerical pattern as the present study, in which older age, malignant pathology, and more extensive thyroid surgery showed higher frequencies of dysfunction, although several comparisons did not achieve statistical significance.

Reoperative thyroid surgery showed one of the strongest associations with postoperative RLN dysfunction in the present study. Three of the 6 patients undergoing reoperative surgery (50.00%) developed RLN dysfunction compared with only 3 of 58 patients (5.17%) undergoing primary surgery, and the difference was statistically significant ($p = 0.009$). Chiang et al. (2005)¹³ similarly identified reoperative thyroid surgery as an important setting for RLN palsy. Among 521 patients, the overall temporary and permanent RLN palsy rates were 5.10% and 0.90%, respectively; however, in reoperative cases the temporary and permanent palsy rates increased to 10.80% and 8.10%, respectively. By comparison, corresponding rates in patients undergoing surgery for primary benign thyroid disease were only 4.00% and 0.20%. In their series, 94.60% of patients with postoperative palsy in whom nerve integrity had been maintained intraoperatively subsequently recovered nerve function. The significantly greater rate of dysfunction after reoperative surgery in the present study was therefore consistent with the increased nerve morbidity observed in their reoperative group.

Retrosternal extension was present in 10 patients (15.63%) in the present study and was significantly associated with postoperative RLN dysfunction. Dysfunction occurred in 3 of 10 patients with retrosternal extension (30.00%) compared with 3 of 54 patients without retrosternal extension (5.56%; $p = 0.044$). Testini et al. (2011)¹⁴ evaluated 19,662 patients undergoing total thyroidectomy, including 1,055 patients with cervicomedastinal goitre and 18,607 with cervical goitre. Overall postoperative morbidity was significantly greater among patients with cervicomedastinal goitre than

those with cervical goitre (35.00% versus 23.70%, $p < 0.001$), increasing to 53.50% among patients requiring manubriectomy. They also demonstrated significantly higher rates of both transient and permanent RLN palsy, transient and permanent hypocalcaemia, and seroma/haematoma in patients with mediastinal extension. The present finding of 30.00% RLN dysfunction in patients with retrosternal extension versus 5.56% without extension was therefore in accordance with the increased morbidity reported in patients with mediastinal goitre.

Postoperative hypocalcaemia was the most frequent complication in the present study, occurring in 13 patients (20.31%); 11 patients (17.19%) had transient and 2 (3.13%) had persistent hypocalcaemia. Hypocalcaemia occurred exclusively after total, near-total, or completion thyroidectomy, affecting 28.26% of these patients compared with 0.00% after hemithyroidectomy ($p = 0.013$). Other complications included RLN dysfunction in 9.38%, seroma in 4.69%, neck haematoma in 3.13%, wound infection in 3.13%, respiratory distress in 3.13%, and re-exploration in 1.56%. Overall, at least one complication occurred in 28.13% of patients. Rosato et al. (2004)¹⁵ analysed 14,934 thyroid operations and reported temporary hypoparathyroidism in 8.30% and persistent hypoparathyroidism in 1.70% of patients. Transient RLN palsy occurred in 2.00%, permanent RLN palsy in 1.00%, postoperative haemorrhage in 1.20%, and wound infection in 0.30%. Total thyroidectomy constituted 64.30% of their operations. Although the absolute complication frequencies in the present smaller cohort were higher, both studies demonstrated hypocalcaemia/hypoparathyroidism and RLN dysfunction among the principal complications encountered following thyroid surgery.

CONCLUSION

Intraoperative nerve monitoring provided valuable functional assessment of the recurrent laryngeal nerve during thyroidectomy and showed a significant association between abnormal intraoperative signals and postoperative nerve dysfunction. Reoperative thyroid surgery and retrosternal extension were associated with a higher frequency of recurrent laryngeal nerve dysfunction. Hypocalcaemia was the most common postoperative complication, particularly after more extensive thyroidectomy. Intraoperative nerve monitoring, combined with careful nerve identification and postoperative

surveillance, can support safer thyroid surgery and early recognition of complications.

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