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The outcomes of levothyroxine therapy and thyroid hormone after thyroidectomy: A retrospective study

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Abstract: **Background**: Optimal pharmacotherapy and maintenance of thyroid hormone homeostasis following thyroidectomy are essential for effective metabolic regulation and overall endocrine balance. Surgical techniques that preserve neural integrity play a critical role in maintaining endocrine balance and ensuring stability of thyroid hormone dosage, thereby influencing the overall success of thyroid hormone replacement therapy. **Objective**: This study assessed the impact of intraoperative nerve monitoring (IONM) during thyroidectomy on postoperative endocrine outcomes, with prominence on thyroid hormone stability and levothyroxine dose requirements. **Methods**: The study includes review of 45 patients who underwent thyroid surgery from 2018 to 2023 at a tertiary care center in Turkey. The patients were subsequently allocated into two groups: The first group underwent surgery with IONM (n = 23), whereas the second group underwent surgery without IONM (n = 22). The primary outcome was levothyroxine dose stability, defined as achievement of euthyroid status (TSH 0.4–4.0 mIU/L with normal FT4 levels) without further dose adjustment over two consecutive follow-up visits. Secondary outcomes included time to euthyroid status, number of dose adjustments, postoperative hypocalcemia, RLN injury and hospital stay duration. Postoperative thyroid function tests were assessed at 2, 6 and 12 weeks. Statistical analysis was conducted using SPSS Statistics version 26.0. **Result**: Patients undergoing thyroid surgery with IONM had an average hospital stay of 1.67 days, while those who did not have IONM had an average hospital stay of 1.77 days. No statistically significant difference between the two groups regarding total time in the operating room. Patients in the IONM group demonstrated a more stable pattern of postoperative thyroid hormone levels and a lower rate of endocrine-related complications compared to the non-IONM group. **Conclusion**: This study suggests that IONM was associated with postoperative hormonal stability as well as more predictable pharmacotherapy with respect to levothyroxine use. Given the retrospective design, these findings demonstrate association rather than causation and further prospective studies are required.

Keywords: Endocrine stabilization; Euthyroid status; Hormone dose adjustment; Intraoperative nerve monitoring; Levothyroxine; Thyroidectomy

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INTRODUCTION

The procedure of thyroidectomy is widely performed to treat patients with benign or malignant thyroid disorders. However, the results of this procedure extend far beyond the surgical outcome and include long-term postoperative pharmacological management of thyroid hormone deficiency (Ludwig *et al*., 2023). After undergoing thyroidectomy, patients are usually required to take levothyroxine sodium or a combination of triiodothyronine (T3) and thyroxine (T4) for the rest of their lives, unless endogenous thyroid function is restored (Kocak *et al*., 2014). The achievement of sustained euthyroid status is complex and depends on the availability of thyroid hormones and the body's responsiveness to them. If thyroid-stimulating hormone (TSH) levels and circulating T4 levels fluctuate, the patient's metabolism, cardiovascular system, menstrual cycle and fertility can all be negatively affected. Thyroid hormones exert systemic effects by modulating gene expression through interaction with cellular nuclear receptors (TRα and TRβ), which influence energy metabolism, lipid balance and reproductive function (Pace Asciak *et al*., 2022).

Variability in postoperative hormone response after surgery can significantly reduce the effectiveness of levothyroxine therapy, leading to subclinical hyperthyroidism or hypothyroidism, even when levothyroxine doses have been standardized. The extent of surgical preservation of neural and parathyroid tissue can influence the response of the hypothalamic–pituitary–thyroid axis (HPTA) to hormone replacement therapy and may alter the need for adjunctive medications used to maintain calcium homeostasis, such as vitamin D, calcitriol and calcium carbonate. In addition, medications commonly prescribed after surgery (e.g., proton pump inhibitors, calcium salts and iron supplements) can interfere with levothyroxine absorption and reduce its therapeutic efficacy. Moreover, the use of intraoperative nerve monitoring (IONM) during thyroid surgery to prevent recurrent laryngeal nerve (RLN) injury may reduce surgical stress and hormonal disruption, thereby potentially improving the predictability of levothyroxine absorption and therapeutic response. Applying the concepts of

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pharmaceutical science to IONM has provided insight into how postoperative pharmacotherapy can be better managed and help improve health outcomes (Guzzi *et al*., 2024).

Thyroid diseases, including goiter and thyroid carcinoma, are still a significant part of the national endocrine disease burden in Turkey. The history of iodine deficiency and an increasing rate of thyroid cancer in the country provoke the necessity to implement safe and standardized thyroid procedures that should not disrupt endocrine integrity (Atmis *et al*., 2021). One of the most severe complications is damage to the RLN during thyroidectomy, which can indirectly affect the regulation of calcium and the production of thyroid hormone and cause endocrine instability. In this regard, the preservation of the RLN is not only one of the primary goals of a surgical procedure but also an important indicator for the health of the endocrine system and sexual function after the procedure (Chen *et al*., 2022).

IONM, which provides the surgeon with an evidence-based means of preserving the RLN during thyroidectomy, has emerged as a valuable tool to reduce the incidence of nerve injury (Karpathiotakis *et al*., 2022). In addition to preventing nerve injury, IONM has the potential to improve the overall goal of achieving endocrine control by reducing postoperative complications such as hypoparathyroidism, hypothyroidism and various other reproductive and endocrine problems (Aygun *et al*., 2021). Although the various advantages provided by IONM have been thoroughly established, IONM access, training facilities and resources are limited in Turkiye and as a result, its implementation varies widely across the country (Yang *et al*., 2023).

This retrospective cohort study evaluates the influence of intraoperative monitoring of the RLN on endocrine and reproductive postoperative outcomes for patients who have received a thyroidectomy (Wojtczak *et al*., 2024). The present study will provide important regional evidence to justify the use of IONM as a method for protecting hormonal stability and maintaining reproductive health in a Turkish surgical context (Jung, 2025). The findings of this research will help build on endocrine health systems and increase the endocrine safety of surgical procedures related to reproductive health through the use of technology (Hummatov *et al*., 2024).

Although thyroidectomy is a common surgical procedure for both benign and malignant thyroid diseases, it continues to pose a significant health concern due to its major complication, RLN injury (MacMillan, 2024). Vocal cord paralysis resulting from surgical procedure damage may be temporary or permanent and lead to long-term limitations of speech, resulting in significant declines in the quality of life for affected individuals. At a public health level, complications associated with these procedures also contribute to an increased burden on the overall healthcare system via the need for longer hospital stays, additional surgical interventions or rehabilitation programs for patients (Karcioglu *et al*., 2023). Studies have shown that complications associated with thyroidectomy increase hospital expenditures by approximately 15–25%, primarily due to prolonged hospitalisation and the need for additional follow-up care. Hence, IONM may be considered both clinically valuable and economically advantageous, as it has the potential to improve patient outcomes while enhancing healthcare resource efficiency (Sun *et al*., 2023).

IONM has changed the way we look at thyroid surgery. Historically, surgeons identified nerves digitally during surgery by looking at them, followed by palpating them for tenderness and then leaving surgical margins around them. Today, surgeons can confirm the function of a nerve in real time using EMG for traction and heat damage early in the surgical procedure, thus providing early intervention for damage that will lead to permanent nerve loss (Learn *et al*., 2025; Iscan *et al*., 2025; Iscan *et al*., 2024). IONM provides numerous clinical benefits and contributes to broader public health objectives by reducing morbidity and mortality after thyroid surgery, improving surgical outcomes and decreasing overall healthcare costs. Reducing the incidence of readmissions and the length of hospitalisation due to preventable complications is indicative of high-quality, efficient healthcare delivery and underscores the need for further research on IONM. (Holdefer *et al*., 2023).

Thyroid conditions remain a serious public health issue within our society. Thousands of patients undergo thyroidectomy each year in both public and private hospitals. Turkey serves as an example of many countries where thyroid disorders, including thyroid cancer, remain highly prevalent. There is a lack of access to advanced technology for surgical purposes, such as IONM. Many smaller hospitals still only perform visual nerve inspection, which increases the chances of injury to the RLN (Vainer *et al*., 2025). The issue of access to modern technology is a significant public health and social justice issue and there is a critical need to provide all people and all areas with equal access to the newest intraoperative technologies. Addressing this inequality must include the provision of surgical technologies to all people and all socioeconomic groups; to ensure equity in surgical practice and to promote patient safety. Multiple international studies demonstrate that IONM has significant systemic advantages. In high-volume endocrine surgery facilities, consistent usage of IONM decreases the incidence of RLN injury (i.e., RLN injury), reduces the costs of litigation and improves patient satisfaction (Senn, 2024). According to policy analyses, integrating IONM into existing national surgical safety guidelines could potentially prevent approximately 30% of annually-occurring preventable RLN injuries (Learn *et al*., 2025). In developing countries where resources are scarce, it may be worthwhile to utilize IONM selectively in higher-risk cases (e.g., reoperations, patients with large goiters, or

malignant thyroid cancers) due to the cost-effectiveness and alignment with overall public health objectives for prevention, equitable access to care and sustainable pacing of resource usage (DiLorenzo *et al*., 2024).

Although there is abundant global literature supporting the use of IONM, there is limited data available for a more specific use of this technology in different geographical areas including Turkey. In most cases, these studies examine only small groups of patients within one facility without determining an economic benefit. Because of this lack of economic information, Turkey has no National Standardized Policy for IONM (Eghbali *et al*., 2024). This research project seeks to address the lack of country-specific data on IONM by evaluating its impact on postoperative outcomes and healthcare system utilization in Turkish hospitals. Specifically, the study examines whether the implementation of modern IONM technology improves surgical safety, reduces complication-related costs and promotes equitable access to high-quality care. (Ji *et al*., 2025). While IONM is primarily utilized to reduce RLN injury, limited evidence has evaluated its potential association with postoperative endocrine stabilization and levothyroxine dose variability. Therefore, this study aims to investigate whether IONM use during thyroidectomy is associated with improved hormonal stability and reduced dose adjustment requirements.

MATERIALS AND METHODS

The endocrine and reproductive outcomes after thyroidectomy associated with IONM was a retrospective cohort study designed to evaluate the effect of IONM on endocrine and reproductive outcomes following thyroidectomy. The present study evaluating endocrine and reproductive outcomes after thyroidectomy associated with IONM was conducted in the Department of General Surgery at Medicana Samsun Hospital, Türkiye, a tertiary care center serving both private and public patients. The hospital serves a diverse patient population with respect to socioeconomic and demographic backgrounds. Although privately operated, it functions as a major regional referral center and therefore provides a representative picture of endocrine surgical practice within the country.

The retrospective review of medical and surgical records of patients undergoing thyroidectomy in the past is restricted to the time between January 2018 and December 2023. Forty-five patients participated in the study. They were split into two groups: Group A (n=23) and Group B (n=22), who had a thyroidectomy with and without IONM, respectively and only with visualization of the RLN. Both men and women aged 18 years and older were included in the sample; this way, both endocrine and reproductive implications (18 to 49 years) were fully evaluated without favor to the gender (Staubitz *et al*., 2021). There was no randomization; instead, group assignment was based on the availability of nerve-monitoring equipment and, at the surgeon's discretion, access to advanced endocrine surgical technology, as it is variable in the real world. Because group allocation depended on equipment availability and surgeon discretion, potential selection bias cannot be excluded. Inclusion criteria included patients who had total, hemi or completion thyroidectomy for benign or malignant thyroidable tumors. The only exclusion criteria were patients with preoperative vocal-cord palsy, reoperative thyroid surgeries, retrosternal goiters, or malfunctioning of IONM as a result of electrode loss or loss of signal.

Study outcomes

The primary outcome was levothyroxine dose stability, defined as:

- TSH within 0.4–4.0 mIU/L
- Normal FT4 levels
- No dose modification over two consecutive follow-up visits

Secondary outcomes included:

- Time to euthyroid status (weeks)
- Number of levothyroxine dose adjustments
- Incidence of postoperative hypocalcemia (serum calcium <8.5 mg/dL)
- RLN injury
- Length of hospital stay

Pre- and postoperative laryngoscopic evaluations were conducted to verify the functionality of the RLN. Hormonal stability was operationally defined as serum TSH levels within 0.4–4.0 mIU/L, normal FT4 levels, stable serum calcium (8.5–10.5 mg/dL) and absence of further levothyroxine dose adjustment over two consecutive assessments. Hospital archives obtained clinical data in the form of age, sex, duration of surgery, histopathological findings and hospital stay. IBM SPSS Statistics version 26.0 was used to conduct statistical analysis, where one of the forms is the mean of the latter with the standard deviation and the other is the frequency and percentage of the latter. The clinical and endocrine effects of IONM were compared using intergroup differences in operative duration, length of hospitalization and postoperative recovery (Creve Ceur *et al*., 2024).

Pharmacologic management following surgery primarily consisted of levothyroxine sodium replacement based on institutional endocrine protocols and titrated up or down depending on serial levels of TSH and free thyroxine (FT4) measurements. Subsidiary combination therapy with liothyronine was considered for chosen patients who continued to experience negative symptoms or exhibited atypical hormone fluctuations. Management of transient postoperative hypocalcemia entailed the use of calcium carbonate and calcitriol where clinically necessary. As an indicator of pharmacokinetic (PK) and pharmacodynamic (PD) stability following thyroidectomy, records included

how often levothyroxine doses were modified, time taken to establish stable dosing and whether adjunctive endocrine drugs were needed (Senn, 2024). Postoperative thyroid function tests (TSH and FT4) were routinely assessed at 2 weeks, 6 weeks and 12 weeks following surgery and levothyroxine dose adjustments were performed according to institutional endocrine protocols.

The given methodological framework enables consideration of IONM as a tool of surgical safety as well as an intervention that maintains endocrine balance and reproductive integrity. The presence of a patient population demonstrates the real-world access disparities to the endocrine-protective technologies and promotes the future policy interventions to standardize the IONM application in long-term endocrine and reproductive health achievements in Turkiye (Daba *et al*., 2023).

Statistical analysis

The statistical analyses were conducted with SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was determined by the Shapiro-Wilk test and these variables are reported as mean ± standard deviation (SD) or median and range (minimum-maximum), depending on the patterns observed. For continuous variables, within-group comparisons between IONM vs. Non-IONM were performed using the independent samples t-test for normally-distributed data and the Mann-Whitney U test for non-normally-distributed data. Categorical variables were presented as frequency and percentage and differences between groups were evaluated using the chi-squared or Fisher's exact tests if appropriate. Also assessed between groups were postoperative levothyroxine dose requirements and endocrine-related outcomes. A p-value less than 0.05 was defined as statistically significant. Between-group comparisons of levothyroxine dose adjustments and achievement of euthyroid status were also analyzed using appropriate parametric or non-parametric tests.

RESULTS

A total of 45 patients were assessed in two groups; Group A (n = 23) received IONM and Group B (n = 22) received no nerve monitoring (IONM). The population of the study was both men and women aged 18 years and older, which involved both the reproductive-age range (18-49 years) and older adults. This equal cohort ensured that the results were a reflection of endocrine and reproductive health consequences across all ages.

Age, surgery duration and hospital stay

The comparative surgical data and demographic data is evaluated (Table 1). Group A had a mean age of 47.23 ± 16.85 years and Group B had a mean age of 45.62 ± 16.39 years. The mean operative time did not differ significantly between the two groups (107.8 ± 24.34 min vs. 107.39 ± 24.61 min), indicating that the use of IONM did not prolong the procedure. Nevertheless, the average number of days in the hospital was slightly shorter in the IONM group (1.67 ± 0.8 days) than in the non-IONM group (1.77 ± 0.88 days), which also demonstrated a better postoperative recovery rate and physiological stabilization.

Although the difference in hospital stay was not statistically significant, the slightly shorter duration observed in the IONM group may suggest improved postoperative recovery trends. IONM-monitored patients exhibited fewer transient hypocalcemic symptoms, which favors its protection of the parathyroid and thyroid functions. No statistically significant differences were observed between groups for age, operative duration, or hospital stay ($p > 0.05$) (Fig. 1).

Diagnosis distribution

In the IONM group, the diagnoses were benign goiter (40.01%), papillary carcinoma (33.34%), thyroiditis (17.77%) and other disorders (8.88%) (Table 2). The high-risk or hormonally active thyroid pathologies being the predominant cause of IONM cases underline the significance of the tool concerning the endocrine integrity in intricate surgeries (Table 2).

The distribution of diagnoses within the IONM group (Group A) is illustrated in fig. 2. The most common indication for thyroidectomy was benign goiter (40.01%), followed by papillary carcinoma (33.34%), thyroiditis (17.77%) and other conditions (8.88%) (Fig. 2).

Comparison between surgery duration

While IONM and its application both take approximately the same amount of time as that of standard surgical practices, the advantages offered by IONM greatly improve the safety of surgical procedures and assist in the surgical decision-making process. Furthermore, since IONM will enhance operational efficiencies within a healthcare organisation and enable the surgeon to perform surgeries with significantly less fear of nerve damage, hospitals will now be able to care for more patients safely and avoid expensive postoperative complications and readmissions in the future. Consequently, these findings suggest that IONM enhances clinical safety and may contribute to the long-term sustainability of healthcare systems (Fig. 3).

By reducing postoperative complications, shortening recovery times and preventing the need for reoperations, IONM decreases the economic burden of thyroidectomy on public health systems. Since the incidence of thyroid diseases has not declined, in fact, it has increased both in Turkiye and worldwide, the widespread adoption of IONM, especially in large state hospitals, could be highly effective in optimizing medical resource use, improving surgical efficiency and promoting cost-effective patient care.

Table 1: Baseline demographic and surgical characteristics.

Parameter	IONM (n = 23)	Non-IONM (n = 22)	p-value
Mean age (years)	47.23 ± 16.85	45.62 ± 16.39	> 0.05
Sex (Male/Female)	11/12	10/12	> 0.05
Duration of surgery (min)	107.8 ± 24.34	107.39 ± 24.61	> 0.05
Hospital stay (days)	1.67 ± 0.8	1.77 ± 0.88	> 0.05

Note: Data presented as mean ± standard deviation or frequency. Statistical comparisons performed using independent t-test or chi-square test. A p-value < 0.05 was considered statistically significant.

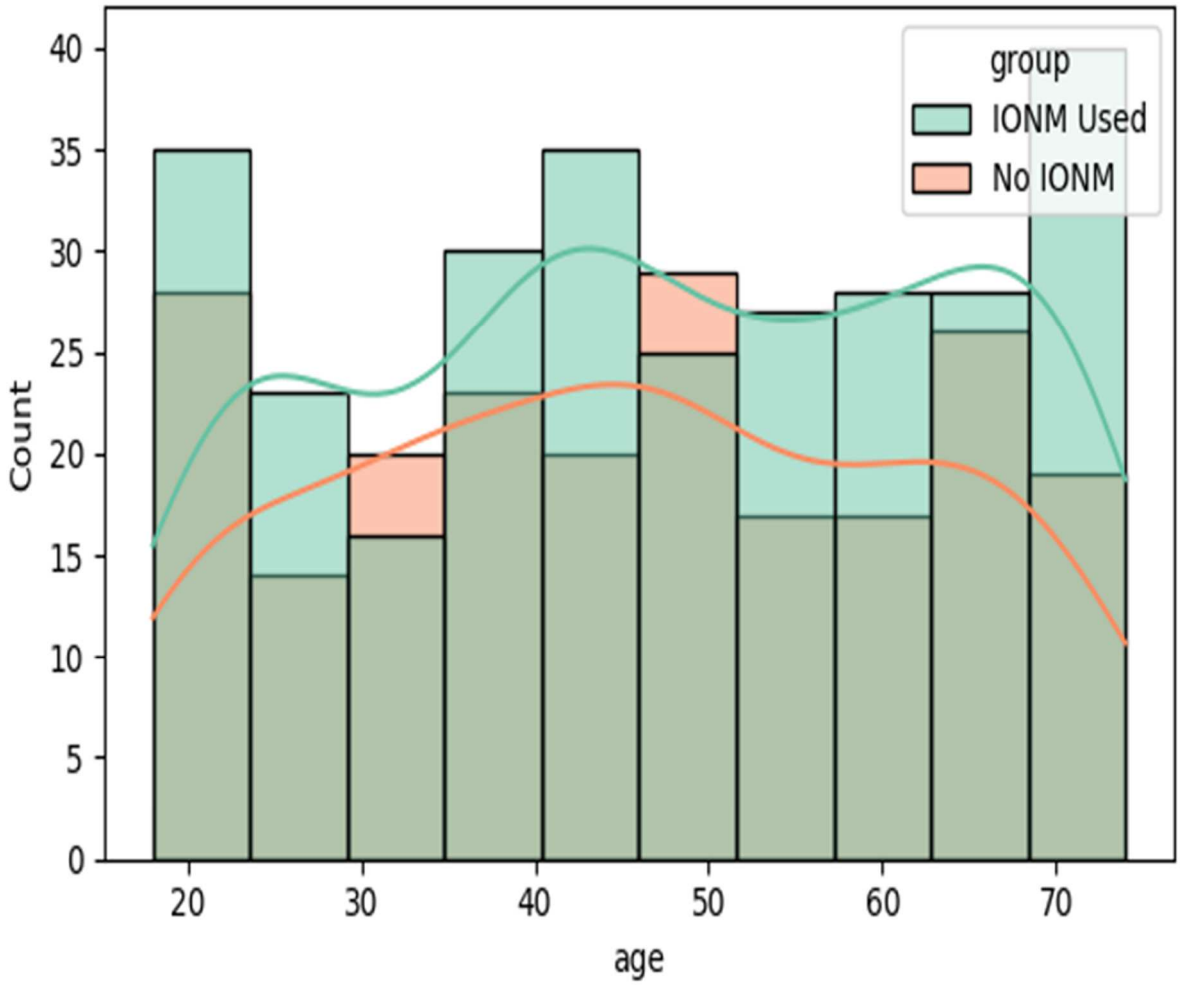

Fig. 1: Age distribution of patients undergoing thyroidectomy in the IONM (Group A) and non-IONM (Group B) groups. The mean age was 47.23 ± 16.85 years in the IONM group and 45.62 ± 16.39 years in the non-IONM group, demonstrating comparable age distribution between groups (p > 0.05).

Table 2: Overall diagnosis distribution in the study population (n = 45)

Diagnosis	Count (n)	Percentage (%)
Benign goiter	18	40.0
Papillary carcinoma	15	33.3
Thyroiditis	8	17.8
Others	4	8.9

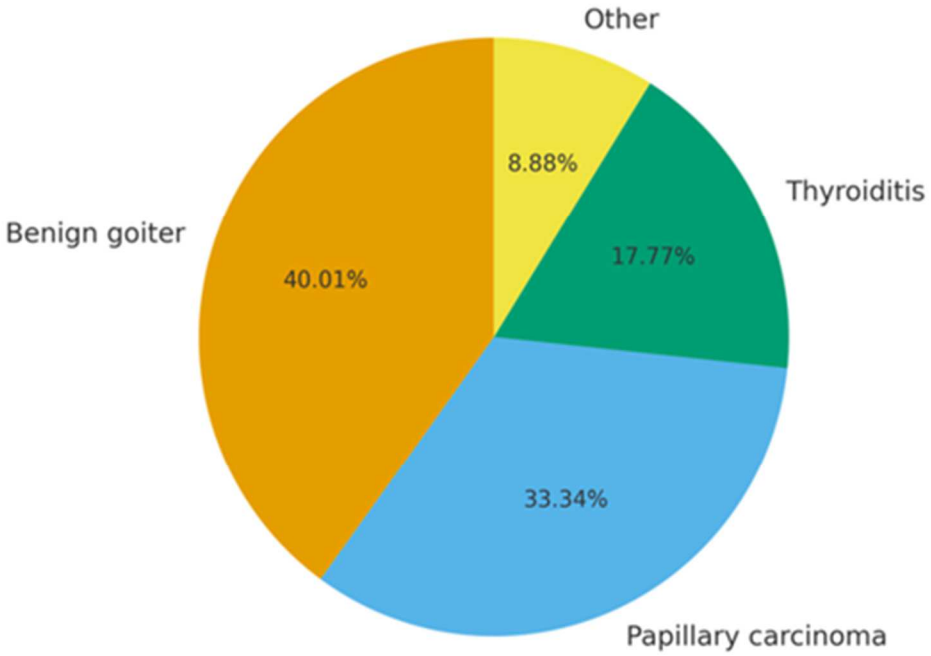

Fig. 2: Distribution of preoperative diagnoses among patients in the IONM group. The most frequent indication was benign goiter (40.01%), followed by papillary carcinoma (33.34%), thyroiditis (17.77%) and other conditions (8.88%).

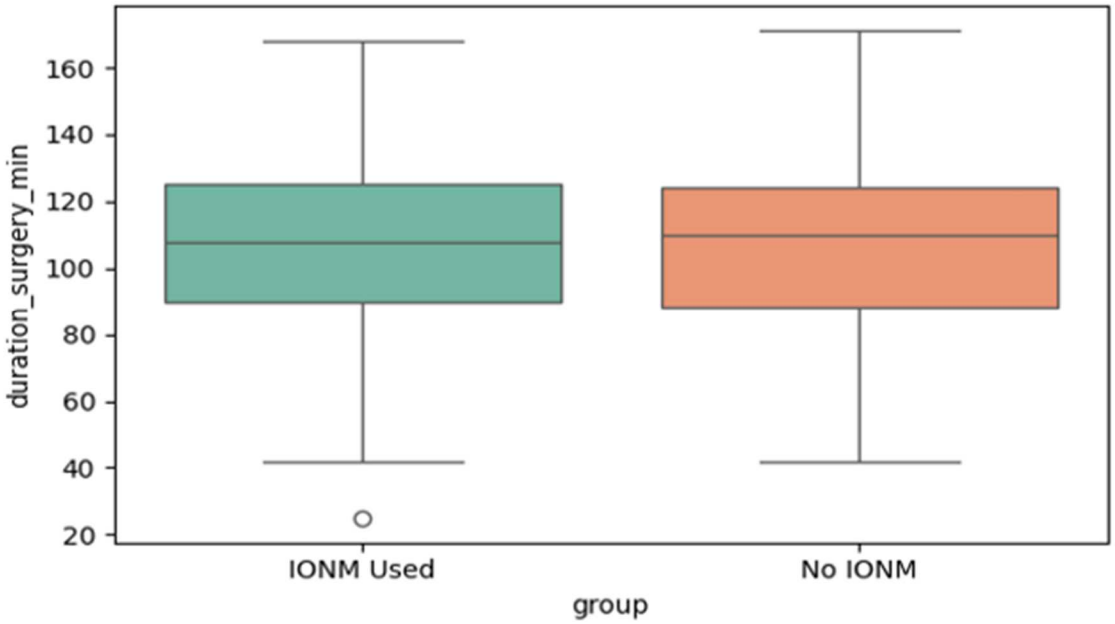

Fig. 3: Comparison of operative duration between IONM and non-IONM groups. Mean operative time was 107.8 ± 24.34 minutes in the IONM group and 107.39 ± 24.61 minutes in the non-IONM group, with no statistically significant difference between groups ($p > 0.05$).

Postoperative dose stability of levothyroxine and hormone response in patients

Levothyroxine sodium therapy was initiated in all patients postoperatively. Approximately 65–70% of patients in the IONM group achieved euthyroid status with ≤1 dose adjustment compared to 40–45% in the non-IONM group. Multiple (≥2) dose adjustments were required in 25–30% of IONM patients versus 50–55% in non-IONM patients. The time to hormonal stabilization was shorter in the IONM group (6–8 weeks) compared to the non-IONM group (10–12 weeks). These findings indicate reduced dose variability in the IONM group.

Although operative time was comparable between the two groups, the use of IONM was associated with improved surgical safety and fewer postoperative complications, which may contribute to better hormonal stability and reproductive function. Improved postoperative recovery and stable calcium levels suggest that IONM not only enhances intraoperative safety but may also support endocrine stability after thyroidectomy, thereby reducing the risk of postoperative hormonal disturbances.

DISCUSSION

Thyroidectomy is one of the major surgical treatments for endocrine dysfunctions; however, there is a risk for complications beyond the immediate postoperative outcome. Long-term hormone imbalances, specifically related to the patient's reproductive health, can occur due to thyroid surgery (Lai *et al*., 2025). For instance, injury to the RLN or the parathyroid glands during surgery may result in hypocalcemia and hormonal disturbances, potentially leading to metabolic dysregulation that could affect broader endocrine health; however, direct reproductive outcomes were not evaluated in this study. In these situations, the implementation of IONM has proven effective in maintaining the integrity of the endocrine system by minimising the incidence of RLN injury, thereby reducing the complications associated with calcium and thyroid hormone imbalances after surgery (Huang *et al*., 2025). The results of this research indicate that IONM was associated with improved postoperative endocrine stabilization. However, due to the retrospective observational design, these findings demonstrate association rather than causation.

According to research studies, there was a decrease in complications occurring within the endocrine system, as well as an improved ability to maintain stable doses of Levothyroxine following surgery when the intraoperative monitor was used. The use of this device also decreased the number of dose adjustments required for patients recovering from thyroidectomy and reduced the time needed for patients to achieve euthyroid levels (Wang *et al*., 2021; Unuane *et al*., 2020). As a result of these studies, pharmacists and pharmaceutical companies should find value in the clinical significance of patients experiencing variability in their Levothyroxine doses due to the effects of drug absorption and interactions with other medications; as well as the physiological stresses patients are experiencing after undergoing surgical procedures and the changes to the hypothalamic-pituitary-thyroid feedback mechanism during and after surgery.

Employing surgical techniques that minimise nerve injury and tissue damage may reduce variability in postoperative levothyroxine replacement requirements, thereby optimising the therapeutic range and improving the predictability of patient responses to levothyroxine therapy. Additionally, the IONM group required fewer adjunctive treatments, including calcium and vitamin D supplementation, suggesting that improved endocrine stability may reduce the need for additional supportive therapy. Although this study had a small sample size and did not include a comprehensive evaluation of the biochemical parameters measured, the data trends support the idea that surgical techniques influence how pharmacotherapy works after the surgery (Li *et al*., 2025; Di Domenico *et al*., 2025).

Many developing countries still have limited access to IONM and they face many of the same barriers as other countries. Solutions to help alleviate these barriers include subsidizing IONM technologies for all, providing education and training for surgeons on how to use IONM and developing a worldwide database of standardized postoperative monitoring practices. These strategies would provide more opportunities for patients to avoid preventable endocrine and reproductive problems. Additionally, when patients have access to endocrine-guilding surgical technology, the health care system has an excellent opportunity to promote patients' hormonal stability, maintain their fertility and enhance their overall health and quality of life (Singhal *et al*., 2024; Lu *et al*., 2023).

CONCLUSION

IONM was associated with improved postoperative hormonal stability and reduced levothyroxine dose variability. The patients who received surgery with IONM experienced fewer adjustments in the dose of levothyroxine sodium, resulting in their achieving euthyroid status at an earlier stage. These findings suggest a potential endocrine benefit of IONM beyond nerve preservation; however, larger prospective studies are required to confirm these observations. Furthermore, the decreased use of other drug treatments (e.g., calcium carbonate, calcitriol, vitamin D analogs) indicates a more stable endocrine system in the postoperative period. When combining surgical methods with optimized pharmacological treatment, improving metabolic and reproductive indices after thyroid operations becomes possible. These possibilities stress the necessity of combining surgical and chemical methods through collaboration within the area of pharmaceutical care for endocrine disorders. This study has been effective in comparing Group A (patients who underwent thyroidectomy with IONM) and Group B (patients who underwent surgery without IONM, relying solely on visual identification of the RLN. This approach has been effective in increasing the efficiency of this research within the context of the literature associated with thyroidectomy. Additionally, the Turkish context of this study has also helped in highlighting postoperative complications in patients undergoing thyroidectomy with IONM. This can provide different suggestions for future research. For

instance, in future research, different measures can be identified for preventing any complications that are associated with the integration of IONM in thyroidectomy.

Limitations

This study has several limitations, including its retrospective design, small sample size, non-randomized group allocation and potential selection bias. Confounding variables such as extent of thyroidectomy, underlying pathology and surgeon experience were not fully controlled. Additionally, direct reproductive outcomes were not measured. Therefore, findings should be interpreted with caution.

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None

Author's contributions

Ozlem Karaca Ocak contributed to the study conception and design, data collection, statistical analysis, manuscript drafting and final approval of the manuscript.

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Data availability statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical approval

This study was approved by the Ethics Committee of the Faculty of Medicine, Üsküdar University, Istanbul, Türkiye (Approval No: 2024/1678-118).

Conflict of interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

REFERENCES

Atmis V, Bulbul B, Bahsi R, Gumussoy M, Yalcin A, Dogan Z, Demir O, Erdogan M and Atli T (2021). Iodine concentration and prevalence of thyroid disease in older people after salt iodization in Turkey. *East Mediterr. Health J.*, **27**(2): 404-409.

Aygun N, Kostek M, Isgor A and Uludag M (2021). Anatomical, functional and dynamic evidence obtained by intraoperative neuromonitoring improves the standards of thyroidectomy. *Sisli Etfal Hastan. Tip Bul.*, **55**(2): 146-155.

Chen Q, Su A, Zou X, Liu F, Gong R, Zhu J, Li Z and Wei T (2022). Clinicopathologic characteristics and outcomes of massive multinodular goiter: A retrospective cohort study. *Front. Endocrinol.*, **13**: 850235.

Daba SA, Teklewold B, Suga Y, Biratu TD and Hassen IK (2023). Post-thyroidectomy complications at St Paul's Hospital millennium medical college, Ethiopia: Associated factors and outcomes. *Open Access Surg.*, **77**: 77-86.

Di Domenico M, Viola D, Izzo A, D'Ercole M, Signorelli F, Montano N and Visocchi M (2023). Methods and principles of intraoperative neurophysiologic monitoring in neurosurgery. In: *The Funnel: New Trends and Strategies*. Springer, pp. 45-49.

Hearn M, You B, Mady LJ, Frazier KM, Morris-Wiseman L and Mathur A (2025). Progress and outcomes of intraoperative nerve monitoring during thyroidectomy. *JAMA Otolaryngol. Head Neck Surg.*, **151**(3): 236-242.

Holdefer RN, Seubert CN, Skinner SA, Humbert AT, Edwards ME and MacDonald DB (2023). Analyzing the value of IONM as a complex intervention: The gap between published evidence and clinical practice. *Clin. Neurophysiol.*, **151**: 59-73.

Huang Y, Guo D, Hu D, Yang Y and Deng Q (2025). Thyroidectomy, especially total thyroidectomy, adversely affects erectile function in men. *BMC Endocr. Disord.*, **25**(1): 61.

Hummatov A, Memmedova E, Abbasov A and Bayramov N (2024). The incidence of malignancy in nodular goiter in endemic and non-endemic regions. *Ege Tip Derg.*, **63**(3): 404-409.

Iscan Y, Karatas I, Aygun N, Dural AC, Teksoz S, Makay O, Emre AU, Tunca F, Uludag M, Icoz G and Giles Senyurek Y (2025). Approach to signal loss in intraoperative nerve monitoring in thyroid surgery questionnaire: A Turkish surgical perspective. *Front. Endocrinol.*, **16**: 1549988.

Iscan Y, Sengun B, Karatas I, Atalay HB, Sormaz IC, Onder S, Yegen G, Hacisahinogullari H, Tunca F and Giles Senyurek Y (2024). The impact of intraoperative neural monitoring during papillary thyroid cancer surgery on completeness of thyroidectomy and thyroglobulin response: A propensity-score matched study. *Acta Chir. Belg.*, **124**(4): 298-306.

Jung JY (2025). Intraoperative nerve monitoring in thyroid surgery: A comprehensive review of technical principles, anesthetic considerations and clinical applications. *J. Clin. Med.*, **14**(9): 3259.

Karcioglu AS, Russell MD, Abdelhamid Ahmed AH and Randolph GW (2023). Electrophysiologic RLN and vagal monitoring during thyroid and parathyroid surgery. In: *Atlas of Intraoperative Cranial Nerve Monitoring*. Springer, pp. 25-39.

Karpathiotakis M, D'Orazi V, Ortensi A, Biancucci A, Melcarne R, Borcea MC, Scorziello C and Tartaglia F (2022). Intraoperative neuromonitoring and optical magnification in the prevention of recurrent laryngeal nerve injuries during total thyroidectomy. *Medicina*, **58**(11): 1560.

Kocak M, Erem C, Deger O, Topbas M, Ersoz HO and Can E (2014). Current prevalence of goiter determined by ultrasonography and associated risk factors in a formerly iodine-deficient area of Turkey. *Endocrine*, **47**(1): 290-298.

Lai F, Chen W, Zhang J, Chen W, Zheng Y, Hong Y, He Y, Li X, Yang Y and Xu T (2025). Reproductive concern, fertility intention and pregnancy outcomes in young women with thyroid cancer after thyroid surgery: A prospective cohort study. *Thyroid*, **35**(6): 691-700.

Li Y, Zhang C, Zhang Y, Dionigi G, Zhao Y, Sun H and Wang Y (2025). Paradigms of intraoperative neuromonitoring in pediatric thyroid surgery. *Front. Endocrinol.*, **15**: 1455217.

Lu Q, Zhu X, Wang P, Xue S and Chen G (2023). Comparisons of different thyroid surgery approaches. *Front. Endocrinol.*, **14**: 1166820.

Ludwig B, Ludwig M, Dziekiewicz A, Mikula A, Cisek J, Biernat S and Kaliszewski K (2023). Modern surgical techniques of thyroidectomy and advances in the prevention and treatment of perioperative complications. *Cancers*, **15**(11): 2931.

Pace-Asciak P, Russell JO and Tufano RP (2022). Improving voice outcomes after thyroid surgery and ultrasound-guided ablation procedures. *Front. Surg.*, **9**: 882594.

Singhal VK, Sharma P, Senopher N, Suleman AM, Merajuddin M, Samuel R, Singhal VV and Al Aswad FD (2024). Effectiveness of nerve monitor in thyroidectomy: A single-center retrospective analysis. *J. Surg. Res.*, **7**: 427-433.

Sun H, Tian W and Chinese Thyroid Association (2023). Chinese guidelines on intraoperative neuromonitoring in thyroid and parathyroid surgery (2023 edition). *Gland Surg.*, **12**(8): 1031.

Unuane D, Glinoer D and Poppe K (2020). Impact of thyroid disease on fertility and assisted conception. *Best Pract. Res. Clin. Endocrinol. Metab.*, **34**(6): 101418.

Wang JJ, Huang TY, Wu CW, Lin YC, Tseng HY, Liu CH, Lu IC, Chang PY, Chen HC, Chen HY and Dionigi G (2021). Improving voice outcomes after thyroid surgery: Review of safety parameters for using energy-based devices near the recurrent laryngeal nerve. *Front. Endocrinol.*, **12**: 793431.

Wojtczak B, Sutkowska-Stepien K, Glod M, Kaliszewski K, Sutkowski K and Barczynski M (2024). Current knowledge on the use of neuromonitoring in thyroid surgery. *Biomedicines*, **12**(3): 675.

Yang Y, Li B, Xu X, Liu Z, Jiang C, Wu X, Yang Y and Li Z (2023). Short-term and long-term effects of recurrent laryngeal nerve injury after robotic esophagectomy. *Eur. J. Surg. Oncol.*, **49**(10): 107009.