BMC Surgery

RESEARCH

Open Access

Impact of Intraoperative Nanocarbon Staining and parathyroid autotransplantation on parathyroid injury and recovery in adult thyroidectomy: a retrospective cohort study

Chen Chen[1], Xiaole Wang[2], Gang Liu[1] and Yi Huang[1*]

Abstract

Background Thyroid surgeries are intricate operations that carry the risk of damaging the parathyroid glands, which can result in hypocalcemia and potential long-term hypoparathyroidism. Innovative surgical techniques including Intraoperative Nanocarbon Staining (INS), aim to enhance the preservation of parathyroid glands. This study assesses the effectiveness of INS combined with parathyroid autotransplantation in reducing postoperative complications and preserving parathyroid function.

Methods This retrospective cohort study assessed patients aged ≥ 18 who underwent thyroid surgery at a tertiary care hospital from January 2017 to December 2022. We compared the incidence of postoperative parathyroid injury, recovery rates of parathyroid function, and the incidence of permanent hypoparathyroidism between groups. Data on patient demographics, diagnosis, surgical details, parathyroid hormone levels, and calcium levels were collected and analyzed using chi-square tests, t-tests, and logistic regression.

Results The study included 198 patients, with 101 in the intervention group and 97 in the control group. Baseline characteristics such as sex ratio, age, BMI, and preoperative calcium levels showed no significant differences between groups. The intervention group demonstrated a significantly shorter duration of intravenous calcium supplementation (median 2 vs. 3 days, $p < 0.001$) and higher calcium nadir levels (median 8.36 vs. 7.85 mg/dL, $p < 0.001$) compared to controls. Furthermore, the incidence of postoperative parathyroid injury and permanent hypoparathyroidism was lower in the intervention group (15.84% vs. 20.62%, $p = 0.045$ and 4.95% vs. 15.46%, $p = 0.003$, respectively). Multivariate analysis revealed factors such as Blood iPTH monitoring level (OR 1.053, 95% CI 1.009–1.099, $P = 0.018$) and surgery type (Near Total Thyroidectomy) (OR 0.447, 95% CI 0.202–0.990, $P = 0.047$) were positively associated with surgical success. The intervention group also showed higher surgery success rates (OR 2.054, 95% CI 1.017–4.150, $P = 0.045$).

Conclusion The application of INS and parathyroid autotransplantation during thyroidectomy significantly improves postoperative parathyroid gland function, reducing the incidence of permanent hypoparathyroidism. These findings support the incorporation of these techniques into standard surgical practice for thyroidectomy.

*Correspondence:
Yi Huang
sincl@163.com
Full list of author information is available at the end of the article

Keywords Thyroidectomy, Parathyroid function, Hypocalcemia, Intraoperative nerve monitoring, Parathyroid autotransplantation, Retrospective study

Introduction

Thyroid diseases encompass a wide range of disorders affecting millions worldwide, ranging from benign nodules and goiters to malignancies that require surgical intervention [1, 2]. The management of these conditions, especially when surgery is necessary, involves navigating intricate anatomical relationships and potential complications, with a primary focus on the integrity of the parathyroid glands. Despite their small size, these glands play a crucial role in calcium homeostasis [3], and their inadvertent injury or removal during thyroid surgery can lead to significant postoperative challenges, including hypocalcemia and the potential for long-term hypoparathyroidism [4, 5]. Such complications not only affect patient recovery and quality of life but also pose a substantial burden on healthcare systems.

The advancement in surgical methods has notably decreased the risks associated with thyroid surgeries, such as the application of near-infrared autofluorescence (NIR-AF) technology. NIR-AF has shown potential in assisting surgeons with the detection and preservation of the parathyroid glands [4] The work of Benmiloud et al. suggests that utilizing NIR-AF for identifying parathyroid glands can notably decrease the incidence of early postoperative hypocalcemia and enhance the likelihood of parathyroid preservation following total thyroidectomy [5]. However, recent clinical studies indicate that while the use of autofluorescence technology during thyroidectomies does reduce the morbidity in some patients, it does not decrease the incidence of postoperative low parathyroid hormone (PTH) levels [6].

Intraoperative Nanocarbon Staining (INS) is a new technique designed to improve the recognition and preservation of parathyroid glands. INS utilizes the characteristics of carbon nanoparticles to help surgeons accurately identify and preserve parathyroid glands, thereby mitigating the risk of postoperative complications such as hypocalcemia. Prior applications of nanocarbon negative imaging technology in patients suffering from secondary hyperparathyroidism (SHPT) have demonstrated a notable decrease in the recurrence rate of SHPT, alongside enhanced surgical results [7]. Compared with patients undergoing conventional endoscopic thyroid cancer surgery, nanocarbon technology allows patients to undergo clearer lymph node dissection [8] and facilitates the identification of parathyroid glands during thyroidectomy combined with central compartment lymph node dissection [9]. Multiple meta-analysis results also further showed that compared with the use of methylene blue or blank control, nanocarbon particles improved the degree of neck dissection, increased the scope and accuracy of neck dissection, and enhanced the protection of the normal anatomical structure and physiological function of the parathyroid glands during thyroid cancer surgery [10, 11]. Moreover, when in situ preservation of parathyroid glands is not feasible, autotransplantation of the parathyroid glands serves as a viable alternative to maintain their function by relocating them to a muscle bed, where they can continue to regulate calcium levels [12]. Although not a new strategy, it remains a crucial aspect of surgical treatment for thyroid conditions, especially in scenarios with a higher risk of parathyroid damage.

Although INS and parathyroid autotransplantation show potential benefits, their effectiveness and impact on patient outcomes in thyroid surgery remain unclear. This retrospective cohort study seeks to fill the existing gap in the literature by examining the incidence of postoperative parathyroid injury, the restoration of parathyroid function, and the occurrence of permanent hypoparathyroidism in patients who have undergone thyroid surgery with and without these interventions. Through this analysis, we aim to provide insights into the effectiveness of these techniques and advocate for their consideration in surgical practice to enhance patient outcomes after thyroid surgery.

Methods

Study design and population

In this retrospective cohort study, we focused on adult patients (aged 18 years and older) who underwent thyroidectomy at our tertiary care hospital from January 2017 to December 2022. Eligible participants had complete medical records, including preoperative assessments, intraoperative details, and postoperative follow-ups. We excluded patients with incomplete records, those who did not underwent surgery within the designated timeframe, those who had prior thyroid or parathyroid surgeries, or had concurrent malignant diseases (defined as active cancers other than thyroid cancer that could independently affect prognosis). The selection process is shown in Fig. 1. Ethical approval for this study was granted by the Institutional Review Board of the People's Hospital of Suzhou New District, with all procedures performed in accordance with ethical standards laid down in the 1964 Declaration of Helsinki and

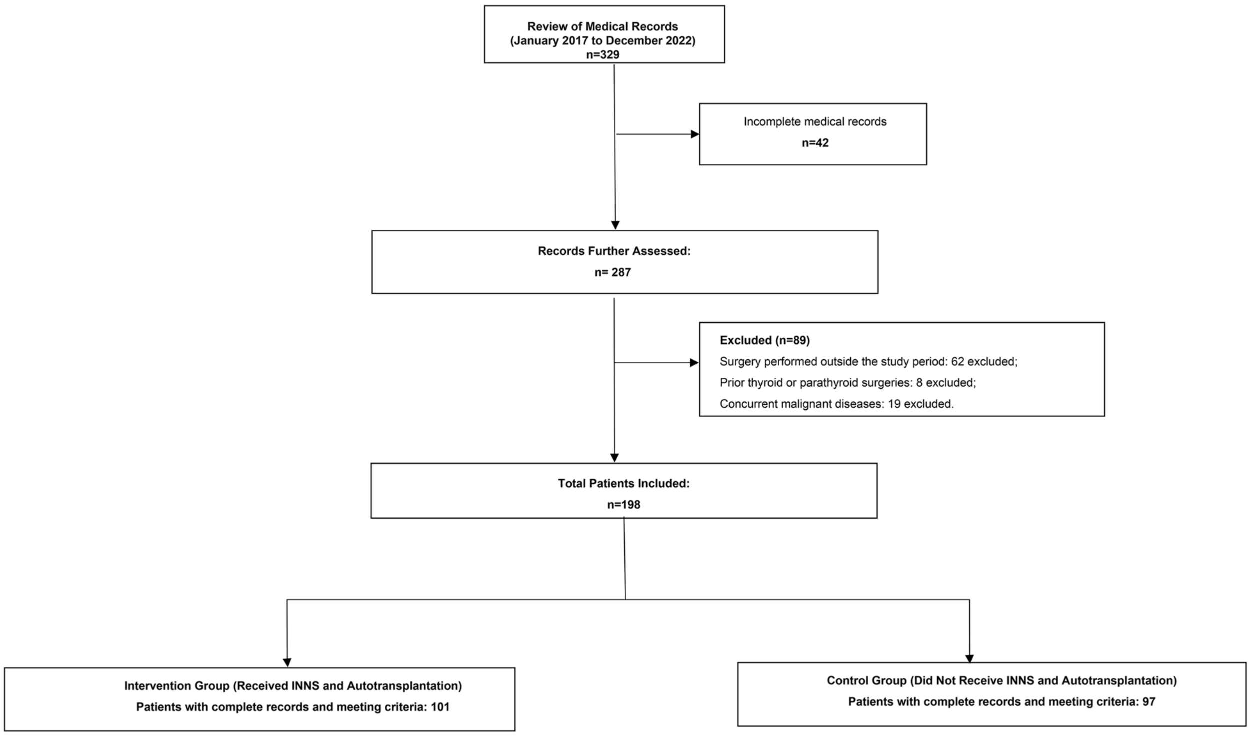

Fig. 1 Study flowchart depicting participant selection and analysis

its later amendments. Due to the retrospective nature of this study, the requirement for informed consent was waived, contingent upon the anonymization of patient data. A post-hoc power analysis was also conducted using G*Power to determine the power of the model in detecting significant predictors. The analysis revealed that the model had a high power (>80%) to detect the effects of the intervention group on permanent hypoparathyroidism, while the power for detecting an effect on postoperative parathyroid injury was moderate.

Data collection

All data were extracted from electronic medical records and paper charts by trained medical staff and entered into a secure, anonymized database designed specifically for this study. Rigorous data verification protocols were implemented to ensure accuracy and completeness of the data captured. Discrepancies were resolved through consensus among clinical experts.

Preoperative data collection

For each patient, demographic information including age, sex, and Body Mass Index (BMI) was recorded. Clinical data encompassing the diagnosis leading to thyroidectomy, any comorbid conditions, and preoperative serum calcium, surgery types and parathyroid hormone (PTH) levels were systematically collected. This preoperative assessment provided a baseline against which postoperative outcomes could be evaluated.

Intraoperative data collection

Detailed records of the surgical procedure were compiled, noting whether INNS and parathyroid gland autotransplantation were employed. Additional intraoperative parameters recorded included the total duration of surgery, any complications encountered (such as bleeding, damage to surrounding structures), and the number of parathyroid glands identified and preserved or autotransplanted.

Postoperative data collection

The postoperative phase involved monitoring and documenting recovery metrics, including serum calcium and PTH levels at various intervals, specifically on the first postoperative day and subsequently at 1, 3, and 6 months, and 1-year post-surgery. The incidence of hypocalcemia, its severity, and the duration were recorded, along with any treatments administered to manage this condition. Recovery of parathyroid function and any instances of permanent hypoparathyroidism were also monitored, alongside general recovery and any long-term complications or recurrence of the primary thyroid condition.

Statistical analysis

The statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, N.Y., USA). Continuous variables were first subjected to normality testing using the Shapiro-Wilk test. Variables conforming to a normal distribution were described using means and standard deviations (mean ± SD) and compared between groups using independent samples t-tests. For variables not following a normal distribution, medians and interquartile ranges (IQR) were used for descriptive statistics, and the Mann-Whitney U test was employed for group comparisons. Categorical variables were presented in terms of frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test, depending on the suitability of the data. The primary outcome of the study, the incidence of postoperative parathyroid injury, and secondary outcomes, including recovery rates of parathyroid function and incidence of permanent hypoparathyroidism, were evaluated between the intervention and control groups. A p-value < 0.05 was considered statistically significant. Multiple logistic regression was utilized to identify factors associated with surgical success, with covariates selected based on a P value < 0.20 in univariate analysis. All selected covariates underwent correlation analysis to detect significant collinearity and were included in the multivariate model without selection method application, assessing odds ratios (95% CI) for each. The specific covariates included in the multivariate analysis were sex, age, BMI, Blood iPTH monitoring level, Surgery Type, and Groups. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for each variable. The chi-square statistic was used to assess the overall model fit, while Cox and Snell, Nagelkerke, and McFadden's pseudo-R^2 values were calculated to estimate the proportion of variance explained by the model.

Result

Perioperative characteristics

The perioperative characteristics of the intervention group (INS + parathyroid autotransplantation) and control group were shown in Table 1. The comparison includes sex ratio, age, BMI, preoperative calcium levels, initial diagnosis, surgery type, lymph node dissection, autotransplanted parathyroids, duration of surgery, complications, weight of the specimen, size of the largest nodule, blood loss, and bone pain relief time. No significant differences were found between the two groups across all measured parameters, suggesting comparable baseline characteristics. The distribution of initial diagnoses was similar between groups, including thyroid carcinoma, multinodular goitre (MNG), toxic MNG, and Graves' disease. The mean duration of surgery and the incidence of complications such as recurrent laryngeal nerve palsy (RLNP), infection, and hematoma were also comparable, indicating a balanced comparison basis for further outcome analysis.

Intraoperative and postoperative outcomes

Intraoperative and postoperative outcomes focused on bone pain relief time, blood iPTH monitoring levels, venous calcium time, and calcium nadir. The results indicated that although bone pain relief time and blood iPTH levels were similar between groups, significant differences were found in intravenous calcium duration and calcium nadir levels (Table 2). The intervention group required intravenous calcium for fewer days and maintained higher calcium nadir levels than the control group, indicating a potential benefit of INS + Parathyroid Autotransplantation in mitigating postoperative hypocalcemia.

Postoperative parathyroid function and surgical outcomes

The comparison of postoperative outcomes highlights the operative duration, POD1 iPTH levels, 1-year iPTH levels, incidence of postoperative parathyroid injury, incidence of permanent hypoparathyroidism, and recurrence. No difference was observed in operative duration and immediate postoperative iPTH levels. However, a significant reduction in the incidence of postoperative parathyroid injury and permanent hypoparathyroidism in the intervention group suggests a protective effect of INS + Parathyroid Autotransplantation on parathyroid function (Table 3). Recurrence rates of the primary condition were similar between groups, indicating that the intervention does not impact the long-term management of the underlying thyroid condition. Hypocalcemia events were more commonly found in the control group than in the intervention group, but the difference is not statistically significant ($p = 0.064$).

Multivariate analysis of factors influencing surgical success

Postoperative parathyroid injury and permanent hypoparathyroidism were chosen to be the factors representing surgical success in the multivariate analysis. Blood iPTH monitoring levels were significantly associated with surgery success (OR 1.053, 95% CI 1.009–1.099, $P = 0.018$). Surgery Type (Near Total Thyroidectomy) was also significantly linked to an increased surgery success rate (OR 0.447, 95% CI 0.202–0.990, $P = 0.047$). Groups (Intervention vs. Control) were significantly associated with surgery success (OR 2.054, 95% CI 1.017–4.150, $P = 0.045$) (Table 4). These findings underscore the complex interplay of patient characteristics

Table 1 Perioperative characteristics of study subjects in INNS + Autotransplantation vs. Control Groups

Characteristic	Intervention Group (*n* = 101)	Control Group (*n* = 97)	*P*-value
Sex ratio (F/M)	63.37% / 36.63%	59.79% / 40.21%	0.662
Age (years, median [IQR])	52.00 [41.00, 58.00]	51.00 [43.00, 58.00]	0.821
BMI (kg/m^2, mean ± SD)	25.26 ± 4.09	24.29 ± 4.01	0.092
Preoperative calcium (mg/dL, median [IQR])	9.20 [9.00, 9.50]	9.20 [8.90, 9.50]	0.156
Initial diagnosis, n (%)			0.929
- Thyroid Carcinoma	48 (47.52%)	44 (45.36%)	
- MNG	26 (25.74%)	23 (23.71%)	
- Toxic MNG	14 (13.86%)	15 (15.46%)	
- Graves' disease	13 (12.87%)	15 (15.46%)	
Surgery Type, n (%)			0.532
- Total TTx	56 (55.45%)	47 (48.45%)	
- Near Total TTx	25 (24.75%)	25 (25.77%)	
- Lobectomy	20 (19.80%)	25 (25.77%)	
Lymph Node Dissection, n (%)			0.936
- Central Lymph Node Dissection (Bilateral)	26 (25.74%)	27 (27.83%)	
- Central Lymph Node Dissection (Unilateral)	19 (18.81%)	17 (17.53%)	
- None	56 (55.45%)	53 (54.64%)	
Autotransplanted Parathyroids, n (%)			0.696
− 0	33 (32.67%)	37 (38.14%)	
− 1	23 (22.77%)	16 (16.49%)	
− 2	31 (30.69%)	31 (31.96%)	
− 3	14 (13.86%)	13 (13.40%)	
Mean duration of surgery (min, mean ± SD)	120.65 ± 28.97	125.05 ± 27.98	0.279
Complications, n (%)			0.819
- RLNP	4 (3.96%)	2 (2.06%)	
- Infection	2 (1.98%)	1 (1.03%)	
- Hematoma	1 (0.99%)	1 (1.03%)	
Weight of the specimen (g, mean ± SD)	34.96 ± 14.04	37.36 ± 14.79	0.243
Size of the largest nodule (mm, mean ± SD)	26.20 ± 10.63	25.29 ± 10.43	0.544
Blood loss (mL, mean ± SD)	51.12 ± 26.53	52.94 ± 26.87	0.632
Bone pain relief time (days, median [IQR])	7.00 [3.00, 11.00]	8.00 [4.00, 11.00]	0.417

Data are presented as mean ± standard deviation (SD) for normally distributed variables and median [interquartile range (IQR)] for non-normally distributed variables. *P*-values are calculated using the independent samples t-test or Mann-Whitney U test for continuous variables and Chi-square test or Fisher's exact test for categorical variables, as appropriate. $P < 0.05$ are considered statistically significant and are marked with an asterisk (*). *RLNP* Recurrent Laryngeal Nerve Palsy, *MNG* Multinodular Goitre

Table 2 Comparison of intraoperative outcomes between groups

Characteristic	Intervention Group (*n* = 101)	Control Group (*n* = 97)	*P*-value
Bone pain relief time (days, median [IQR])	7.00 [3.00, 11.00]	8.00 [4.00, 11.00]	0.417
Blood iPTH monitoring level (pg/mL, median [IQR])	35.08 [20.17, 50.13]	37.65 [23.31, 51.56]	0.455
Intravenous calcium time (days, median [IQR])	2.00 [1.00, 3.00]	3.00 [2.00, 4.00]	< 0.001*
Calcium Nadir (mg/dL, median [IQR])	8.36 [7.76, 8.69]	7.85 [7.55, 8.35]	0.000*

Data are presented as mean ± standard deviation (SD) for normally distributed variables and median [interquartile range (IQR)] for non-normally distributed variables. *P*-values are calculated using the independent samples t-test or Mann-Whitney U test for continuous variables and Chi-square test or Fisher's exact test for categorical variables, as appropriate. $P<0.05$ are considered statistically significant and are marked with an asterisk (*)

and surgical techniques in determining the outcome of thyroid surgery. The post-hoc power analysis showed the model demonstrated a high power (> 80%) to detect the effects of the intervention group on permanent

Table 3 Comparison of postoperative outcomes between groups

Characteristic	Intervention Group ($n=101$)	Control Group ($n=97$)	*P*-value
Operative Duration (min, median [IQR])	121.50 [120.75, 122.25]	121.50 [120.75, 122.25]	0.213
POD1 iPTH (pg/mL, median [IQR])	36.37 [35.72, 37.01]	36.37 [35.72, 37.01]	0.455
1-year iPTH (pg/mL, median [IQR])	41.80 [41.37, 42.24]	41.80 [41.37, 42.24]	0.310
Incidence of Postoperative Parathyroid Injury, n (%)	16 (15.84%)	20 (20.62%)	0.045*
1-year iPTH (pg/mL, median [IQR])	40.93 [30.07, 54.40]	42.68 [33.31, 57.37]	0.200
Incidence of Permanent Hypoparathyroidism, n (%)	5 (4.95%)	15 (15.46%)	0.003*
Recurrence, n (%)	5 (4.95%)	5 (5.15%)	1.000
Hypocalcemia events, n (%)	17 (28.87%)	28 (28.87%)	0.064

Data are presented as mean ± standard deviation (SD) for normally distributed variables and median [interquartile range (IQR)] for non-normally distributed variables. *P*-values are calculated using the independent samples t-test or Mann-Whitney U test for continuous variables and Chi-square test or Fisher's exact test for categorical variables, as appropriate. $P<0.05$ are considered statistically significant and are marked with an asterisk (*). *SHPT* Secondary Hyperparathyroidism. *POD1 iPTH* Postoperative Day 1 intact Parathyroid Hormone levels. Persistent SHPT refers to persistent secondary hyperparathyroidism observed post-surgery. Recurrence indicates the recurrence of the primary thyroid condition necessitating surgery

Table 4 Analysis on factors influencing Surgical Success

Characteristics	Univariate analysis		Multivariate analysis	
	OR (95%CI)	*P*	OR (95%CI)	*P*
Sex				
Female	0.493 (0.242, 1.005)	0.052	2.375 (0.564–9.999)	0.238
Male	Reference		Reference	
Age	0.976 (0.948, 1.005)	0.101	0.976 (0.947–1.006)	0.119
BMI	0.937 (0.865, 1.015)	0.109	0.931 (0.852–1.017)	0.112
Blood iPTH monitoring level (pg/mL)	1.031 (1.009, 1.053)	0.006*	1.053 (1.009–1.099)	0.018*
Surgery Type				
Lobectomy	0.896 (0.383, 2.099)	0.100	0.738 (0.299–1.825)	0.511
Near Total Thyroidectomy	0.455 (0.215, 0.964)	0.040*	0.447 (0.202–0.990)	0.047*
Total Thyroidectomy	Reference		Reference	
Groups				
Intervention group	1.727 (0.898, 3.324)	0.102	2.054 (1.017–4.150)	0.045*
Control group	Reference		Reference	

$P<0.05$ are considered statistically significant and are marked with an asterisk (*). Persistent SHPT refers to persistent secondary hyperparathyroidism observed post-surgery. Recurrence indicates the recurrence of the primary thyroid condition necessitating surgery

hypoparathyroidism ($P=0.008$), confirming the robustness of this finding. However, the model's power for detecting an effect on postoperative parathyroid injury was moderate ($P=0.176$), suggesting that while there is a trend towards increased risk in the intervention group, the study may have been underpowered to detect smaller effect sizes for this outcome.

Discussion

This retrospective cohort study demonstrated the effectiveness of INS combined with parathyroid autotransplantation in reducing postoperative hypocalcemia and preserving parathyroid function after thyroidectomy. The significant decrease in the need for intravenous calcium and higher calcium nadir levels in the intervention group highlights the potential of INS + parathyroid autotransplantation to mitigate postoperative hypocalcemia, a common complication following thyroid surgery. This finding is particularly relevant given the morbidity associated with acute and chronic hypocalcemia, which can significantly impact patient quality of life. Postoperative hypocalcemia is the most common complication after thyroid surgery and a major obstacle to early discharge [13]. Studies have shown that female sex, surgery, and changes in perioperative serum calcium are factors influencing the development of early hypocalcemia [14]. Van et al. demonstrated that fluoroscopic visualization of the parathyroid glands during thyroid surgery appeared to reduce the occurrence of permanent hypocalcemia, with a 17.5% incidence of transient hypoparathyroidism [15]. This discrepancy may indicate that, although INS and parathyroid transplantation enhance overall parathyroid function, other unmeasured variables may still contribute to the risk of hypocalcemia. Further investigation of factors influencing the development of hypocalcemia after thyroidectomy is needed in the future.

Autofluorescence imaging has not yet been established as a standard technique in clinical practice. Our study suggests another feasible and effective way to label parathyroid glands. The effectiveness of nanocarbons in preventing parathyroid damage has been demonstrated using nanocarbon suspensions during total thyroidectomy [16]. In cases of inadvertent resection or revascularization during thyroid surgery, parathyroid autotransplantation may serve as the sole means of restoring parathyroid function [17]. The significant reduction in the incidence of postoperative parathyroid injury and permanent hypoparathyroidism further highlights the clinical utility of the intervention. This finding is consistent with prior studies that suggest accurate identification and, when necessary, autotransplantation of parathyroid glands can significantly improve functional preservation [18]. These techniques, by facilitating the real-time differentiation of parathyroid tissue from thyroid and other neck tissues, help in reducing accidental resection or devascularization of the glands.

The multivariate analysis sheds light on various factors influencing surgical success, offering insights into preoperative and intraoperative considerations that could enhance patient outcomes. Near-total thyroidectomy had a relatively good surgical success rate compared with other surgeries. This may be related to the characteristics of near-total thyroidectomy. The goal of this operation is to preserve some thyroid function while minimizing the risk of complications, particularly those related to parathyroid glands [19, 20]. In addition, blood iPTH monitoring levels were identified as an important risk factor. Studies have shown that intraoperative monitoring of blood iPTH levels can serve as a powerful indicator for evaluating parathyroid function and help identify high-risk patients [21, 22]. The protective effect of INS + Autotransplantation on the parathyroid glands corroborates with the literature emphasizing the evolution of surgical techniques towards minimizing complications and enhancing recovery [23, 24]. The application of INS improves intraoperative visualization of both thyroid and parathyroid glands, reducing the risk of missection and promoting vascularization, which aids in the recovery of parathyroid function. Moreover, while some studies suggest that parathyroid transplantation may lead to transient hypocalcemia, its long-term benefits include a lower incidence of permanent hypocalcemia, as transplanted glands can better reestablish blood supply and regulatory mechanisms for calcium metabolism. This dual approach not only increases surgical success rates but may also leverage distinct biological mechanisms to enhance patient recovery outcomes. The findings of Wang and colleagues align closely with our own, suggesting that carbon nanoparticles are instrumental in accurately identifying lymph nodes, reducing missection of parathyroid glands, and accelerating rapid recovery of parathyroid function [25]. However, there appears to be a divergence in perspectives regarding parathyroid transplantation when compared to our research. The study by Lu et al. reported a higher incidence of transient hypocalcemia in patients who received PTHAT compared with patients who did not receive PTHAT, but permanent hypocalcemia occurred only in patients who did not receive PTHAT [26]. This discrepancy may be attributed to the necessity for the transplanted parathyroid gland to restore its blood supply function.

This study advocates the wider use of INS and parathyroid transplantation during thyroidectomy, particularly in cases at high risk for parathyroid injury. However, the study is limited by its retrospective design, which inherently introduces the risk of selection bias and potential confounding factors. Furthermore, variations in surgical technique and surgeon experience, which were not systematically controlled, could have influenced the study outcomes. Patients with more complex thyroid conditions may have been more likely to undergo parathyroid autotransplantation, potentially skewing the results. Future research should focus on prospective, randomized controlled trials with larger sample sizes to address these limitations and better control for confounding variables. Such studies could also explore patient-centered outcomes, including long-term quality of life, and validate the findings in more diverse patient populations.

Conclusion

In conclusion, the integration of INS and parathyroid autotransplantation presents a promising approach to improving the outcomes of thyroid surgery. This study contributes valuable evidence to the ongoing efforts to refine surgical techniques for thyroid and parathyroid diseases, emphasizing the importance of preserving gland function and preventing postoperative complications.

Acknowledgements
None.

Reporting checklist
The authors have completed the STROBE reporting checklist.

Authors' contributions
C.C. comes up with the conception and design, and participates in data analysis and interpretation. X.W. provides administrative support, gathers study materials and patient information; G.L. collects and summarizes data: Gang Liu; Y.H. interprets data; All authors participated in the writing of the manuscript and reviewed the manuscript.

Funding
None.

Data availability
The data supporting the results of this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of the People's Hospital of Suzhou New District (approval number 2024-092), with all procedures performed in accordance with ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. No other ethical statement is required. Due to the retrospective nature of this study, the requirement for informed consent was waived, contingent upon the anonymization of patient data. Clinical trial number not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of General Surgery, The People's Hospital of Suzhou New District, No.95 Hua shan Road, Suzhou 215129, Jiangsu, China. [2]Medical Department, The Second Affiliated Hospital of Soochow University, Suzhou 215004, Jiangsu, China.

Received: 9 August 2024 Accepted: 18 November 2024
Published online: 29 November 2024

References

1. Jung CK, Bychkov A, Kakudo K. Update from the 2022 World Health Organization classification of thyroid tumors: a standardized Diagnostic Approach. Endocrinol Metab (Seoul). 2022;37(5):703–18.
2. Baloch ZW, Asa SL, Barletta JA, Ghossein RA, Juhlin CC, Jung CK, et al. Overview of the 2022 WHO classification of thyroid neoplasms. Endocr Pathol. 2022;33(1):27–63.
3. Lemoine S, Figueres L, Bacchetta J, Frey S, Dubourg L. Calcium homeostasis and hyperparathyroidism: nephrologic and endocrinologic points of view. Ann Endocrinol (Paris). 2022;83(4):237–43.
4. Wolf HW, Runkel N, Limberger K, Nebiker CA. Near-infrared autofluorescence of the parathyroid glands during thyroidectomy for the prevention of hypoparathyroidism: a prospective randomized clinical trial. Langenbecks Arch Surg. 2022;407(7):3031–8.
5. Benmiloud F, Godiris-Petit G, Gras R, Gillot JC, Turrin N, Penaranda G, et al. Association of Autofluorescence-based detection of the parathyroid glands during total thyroidectomy with postoperative hypocalcemia risk: results of the PARAFLUO Multicenter Randomized Clinical Trial. JAMA Surg. 2020;155(2):106–12.
6. Bergenfelz A, Barczynski M, Heie A, Muth A, Passler C, Schneider M, et al. Impact of autofluorescence for detection of parathyroid glands during thyroidectomy on postoperative parathyroid hormone levels: parallel multicentre randomized clinical trial. Br J Surg. 2023;110(12):1824–33.
7. Wu Y, Liu Y, Huang T, Jiang Y, Wang H, He Z. Application of nanocarbon negative imaging technology in surgery for secondary hyperparathyroidism. Gland Surg. 2021;10(8):2455–61.
8. Ma JJ, Zhang DB, Zhang WF, Wang X. Application of Nanocarbon in breast Approach endoscopic thyroidectomy thyroid Cancer surgery. J Laparoendosc Adv Surg Tech A. 2020;30(5):547–52.
9. Qian YC, Liu FZ, Yao WP, Zhao YB, Jiang Y, Zhang Y. [Application of carbon nano-particles in total thyroidectomy combined with lymphadenectomy in area VI]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2019;54(1):28–32.
10. Wang L, Yang D, Lv JY, Yu D, Xin SJ. Application of carbon nanoparticles in lymph node dissection and parathyroid protection during thyroid cancer surgeries: a systematic review and meta-analysis. Onco Targets Ther. 2017;10:1247–60.
11. Li Y, Jian WH, Guo ZM, Li QL, Lin SJ, Huang HY. A Meta-analysis of Carbon nanoparticles for identifying Lymph nodes and protecting parathyroid glands during surgery. Otolaryngol Head Neck Surg. 2015;152(6):1007–16.
12. Sitges-Serra A, Lorente-Poch L, Sancho J. Parathyroid autotransplantation in thyroid surgery. Langenbecks Arch Surg. 2018;403(3):309–15.
13. Lukinovic J, Bilic M. Overview of thyroid surgery complications. Acta Clin Croat. 2020;59(Suppl 1):81–6.
14. Del Rio P, Rossini M, Montana CM, Viani L, Pedrazzi G, Loderer T, et al. Postoperative hypocalcemia: analysis of factors influencing early hypocalcemia development following thyroid surgery. BMC Surg. 2019;18(Suppl 1):25.
15. Van Slycke S, Van Den Heede K, Brusselaers N, Vermeersch H. Feasibility of autofluorescence for parathyroid glands during thyroid surgery and the risk of Hypocalcemia: first results in Belgium and Review of the literature. Surg Innov. 2021;28(4):409–18.
16. Tian W, Jiang Y, Gao B, Zhang X, Zhang S, Zhao J, et al. Application of nano-carbon in lymph node dissection for thyroid cancer and protection of parathyroid glands. Med Sci Monit. 2014;20:1925–30.
17. Iorio O, Petrozza V, De Gori A, Bononi M, Porta N, De Toma G, et al. Parathyroid autotransplantation during thyroid surgery. Where we are? A systematic review on indications and results. J Invest Surg. 2019;32(7):594–601.
18. Gauger PG, Reeve TS, Wilkinson M, Delbridge LW. Routine parathyroid autotransplantation during total thyroidectomy: the influence of technique. Eur J Surg. 2000;166(8):605–9.
19. Li G, Wu L. Total or Near-total Thyroidectomy in treatment of thyroid Cancer. Pak J Med Sci. 2022;38(6):1662–7.
20. Cirocchi R, Trastulli S, Randolph J, Guarino S, Di Rocco G, Arezzo A, et al. Total or near-total thyroidectomy versus subtotal thyroidectomy for multinodular non-toxic goitre in adults. Cochrane Database Syst Rev. 2015;2015(8):CD010370.
21. Pickering JM, Giles WH. Improving intraoperative parathyroid hormone lab efficiency. Am Surg. 2022;88(5):915–21.
22. Xu F, Huang Y, Zeng M, Zhang L, Ren W, Qian H, et al. Diagnostic values of intraoperative (1–84) parathyroid hormone levels are Superior to intact parathyroid hormone for successful parathyroidectomy in patients with chronic kidney disease. Endocr Pract. 2021;27(11):1065–71.
23. Koimtzis G, Stefanopoulos L, Alexandrou V, Tteralli N, Brooker V, Alawad AA et al. The role of Carbon nanoparticles in Lymph Node dissection and parathyroid gland preservation during surgery for thyroid Cancer: a systematic review and Meta-analysis. Cancers (Basel). 2022;14(16):4016.
24. Liu Y, Li L, Yu J, Fan YX, Lu XB. Carbon nanoparticle lymph node tracer improves the outcomes of surgical treatment in papillary thyroid cancer. Cancer Biomark. 2018;23(2):227–33.
25. Wang B, Du ZP, Qiu NC, Liu ME, Liu S, Jiang DZ, et al. Application of carbon nanoparticles accelerates the rapid recovery of parathyroid function during thyroid carcinoma surgery with central lymph node dissection: a retrospective cohort study. Int J Surg. 2016;36(Pt A):164–9.
26. Lo CY, Lam KY. Postoperative hypocalcemia in patients who did or did not undergo parathyroid autotransplantation during thyroidectomy: a comparative study. Surgery. 1998;124(6):1081–6. discussion 6–7.

Publisher's Note