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The Identification of Recurrent Laryngeal Nerve by Injection of Methylene Blue Dye into the Inferior Thyroid Artery in Comparison to The Conventional Technique during Thyroidectomy, Comparative study.

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ABSTRACT

Background: Thyroidectomy is a common surgical procedure for managing thyroid disorders, with recurrent laryngeal nerve (RLN) injury being a major concern. Identifying the RLN during surgery is crucial for preventing complications such as vocal cord dysfunction. Conventional methods rely on anatomical landmarks, but these can be challenging in cases of anatomical distortion. Methylene blue (MB) dye has been explored as an adjunct technique to enhance RLN visualization.

Objective: to evaluate the efficacy and safety of methylene blue injection into the inferior thyroid artery for RLN identification during thyroidectomy. The primary objectives were to assess whether MB injection reduces RLN identification time, minimizes intraoperative blood loss, and lowers the risk of postoperative complications compared to conventional dissection techniques.

Methods: A prospective comparative study was conducted on 40 patients undergoing thyroidectomy, equally divided into two groups: MB injection technique group (n=20) and conventional technique group (n=20). The study analyzed RLN identification time, intraoperative blood loss, and postoperative complications, including vocal cord dysfunction and airway compromise. Statistical analysis was performed to determine the significance of differences between the two groups.

Results: MB injection significantly reduced RLN identification time (7.65 ± 1.5 minutes) compared to the conventional method (14.9 ± 2.75 minutes, $p < 0.001$). Additionally, blood loss was lower in the MB injection group (67.5 ± 13.03 mL) compared to the conventional group (103.5 ± 21.95 mL, $p < 0.001$). Postoperative complications, including vocal cord dysfunction and stridor, were comparable between the two groups, with no statistically significant difference in RLN injury rates. However, dye extravasation was observed in 20% of cases in the MB group, emphasizing the need for precise injection techniques.

Conclusions: Methylene blue injection into the inferior thyroid artery is an effective and safe technique for RLN identification during thyroidectomy. It significantly reduces blood loss and shortens RLN identification time without increasing postoperative complications. This technique may serve as a valuable adjunct in thyroid surgery, particularly in cases where RLN visualization is challenging. Further research with larger sample sizes and long-term follow-up is recommended to validate these findings and refine MB injection protocols.

KEYWORDS: Thyroidectomy, Recurrent laryngeal nerve, Methylene blue injection, RLN identification, Surgical safety, Intraoperative nerve visualization, Postoperative complications.

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INTRODUCTION

Thyroidectomy remains one of the most commonly performed endocrine surgeries worldwide, especially in regions with a high prevalence of benign thyroid disorders such as multinodular goiter, solitary thyroid nodules, and toxic goiters **(1)**. Despite advancements in surgical techniques, recurrent laryngeal nerve (RLN) injury continues to be a significant and feared complication of thyroid surgery, with reported rates of transient and permanent injuries ranging from 0.4% to 7.2% and 0% to 5.2%, respectively. RLN injury can result in hoarseness, aspiration, vocal fatigue, or even life-threatening airway obstruction if bilateral. Thus, safe identification and preservation of the RLN is a critical component of successful thyroid surgery **(2,3)**.

Traditionally, RLN identification relies on visual recognition of anatomical landmarks, including its course near the inferior thyroid artery and the tracheoesophageal groove **(4)**. However, variations in anatomy or distorted surgical planes due to pathology may compromise the accuracy of this method **(5, 6)**. In response, several adjunct techniques have been introduced to improve RLN localization, such as intraoperative neuromonitoring, yet these methods may be expensive, require specialized equipment, or offer limited reliability **(7)**.

This study proposes a novel, simple, and cost-effective method for RLN identification using methylene blue dye injection into the inferior thyroid artery. The rationale lies in the differential uptake of the dye: while the thyroid parenchyma absorbs the dye, the RLN remains unstained and visually distinct. This technique may offer an accessible alternative for RLN identification, particularly in low-resource

settings **(7)**.

The aim of our study is to evaluate the effectiveness of methylene blue dye injection into the inferior thyroid artery for enhancing the intraoperative visualization of the RLN during thyroidectomy. We also compare this method to conventional RLN identification techniques in terms of nerve identification time, blood loss, complication rates, and postoperative outcomes, while assessing the safety and feasibility of using methylene blue in thyroid surgery

PATIENTS AND METHODS

After ethical committee approval and written consents from the patients, this prospective comparative cohort study was performed on total 40 patients undergoing thyroidectomy, equally divided into two groups: MB injection technique group (n=20) and conventional technique group (n=20) at the General Surgery Department of Ain Shams University Hospitals in period between June 2023 and February 2025. This study was approved by the Institutional Review Board, and Research Ethics Committee, Faculty of Medicine, Ain Shams University according to the WMA Declaration of Helsinki (FWA 000017585): Approval Number MD17/2023. The study was registered on clinical trial (clinicaltrial.gov): NCT07067814.

Study population: The study included 40 patients with indications for thyroidectomy due to benign thyroid conditions. Patients were randomly assigned into two equal groups:

- **Group A**: 20 patients underwent injection of methylene blue dye into the inferior thyroid artery to aid in identifying the recurrent laryngeal nerve (RLN).
- **Group B**: 20 patients underwent conventional RLN identification during thyroidectomy.

Inclusion criteria encompassed patients aged 18–60 years undergoing primary surgery (no prior neck surgery) with simple nodular goiter, solitary thyroid nodules, Graves' disease with failed medical treatment or controlled 2ry toxic goiter that were indicated for surgery and fit for general anesthesia. Only primary (first-time) thyroid surgeries were included.

Exclusion criteria included prior thyroid surgery, malignant goiter, major systemic diseases (e.g., cardiac or renal), methylene blue allergy, pregnancy, refusal to participate, and any preoperative vocal cord pathology or dysphonia.

All participants underwent comprehensive preoperative evaluation, which included:

- **Detailed medical history** focusing on thyroid disease duration, compressive symptoms, voice changes, medication use, and any history of prior neck surgery or radiation.
- **General physical examination** including vital signs and systemic review.
- **Neck examination** to assess thyroid size, consistency, mobility, and presence of nodules or retrosternal extension.

Special attention was paid to signs of thyrotoxicosis or local compressive symptoms such as dysphagia, dyspnea, or hoarseness

Preoperative Investigations

All patients underwent the following investigations:

- **Laboratory tests:**
  - Thyroid function tests (TSH, FT3, FT4)
  - Complete blood count (CBC), liver and kidney function tests
  - Coagulation profile
- **Imaging studies:**
  - Neck ultrasound to evaluate thyroid nodularity, size, vascularity, and lymph nodes
  - Indirect laryngoscopy to assess baseline vocal cord mobility and exclude pre-existing RLN palsy
- **Fine-needle aspiration cytology (FNAC)** was performed in indicated cases to confirm benign pathology

Intervention and Surgical Technique:

All operations were performed under general anesthesia by the same team and in the same setting in a standardized fashion. After standard exposure and dissection:

- In Group A, after ligation of the superior pole, 0.5-1 ml of sterile methylene blue dye was injected into the inferior thyroid artery. The thyroid tissue absorbed the dye, while the RLN remained unstained, appearing as a white structure in the tracheoesophageal groove. This aided in its early and safe identification, reducing the risk of injury during dissection.
- In Group B, the RLN was identified based on conventional anatomical landmarks without the use of dye. The nerve was traced along its expected course near the inferior thyroid artery and ligament of Berry

Postoperative Assessment:

Patients were followed postoperatively for complications, particularly RLN injury. Any signs of vocal cord dysfunction or dye-related adverse effects were carefully monitored. Safety and feasibility of methylene blue dye were also evaluated.

Sample Size: The study involved 40 patients, divided equally into two groups: Group A (MB injection technique): 20 patients underwent thyroidectomy with intraoperative MB injection to visualize the RLN and Group B (Conventional technique): 20 patients underwent thyroidectomy using standard anatomical landmarks for RLN identification

Outcome measures:

Primary Outcomes

1. **Time to Identification of the Recurrent Laryngeal Nerve (RLN):**

The time (in minutes) taken to identify a single RLN after delivery of the thyroid lobe was recorded.

2. **Intraoperative Blood Loss:**

Measured in milliliters using suction bottle readings and sponge weight estimates, this outcome assessed whether methylene blue-assisted visualization impacted surgical hemostasis.

Secondary Outcomes

1. **Incidence of RLN Injury:**

Postoperative vocal cord mobility was evaluated clinically and with indirect laryngoscopy when needed.

2. **Postoperative Complications:**

- **Dye Extravasation:** Assessed visually in Group A for signs of leakage into surrounding tissues.
- **Stridor and Tracheostomy Requirement:** Any signs of airway compromise postoperatively were documented along with the need for emergency tracheostomy.

3. **Surgical Duration:**

Total operative time was noted.

Ethical Considerations: The patient data were anonymous. Data presentation was not by the patient's name but by diagnosis and patient confidentiality was protected. An informed consent was taken from all participants, it was in Arabic language and confirmed by date and time. Confidentiality was preserved by assigning a number to patients initials and only the investigator knew it

Statistical analysis: The collected data was revised, coded, tabulated and introduced to a PC using Statistical package for Social Science **(SPSS 27).** Data was presented and suitable analysis was done according to the type of data obtained for each parameter.

i.Descriptive statistics:

1. Mean, Standard deviation (± SD) and range for parametric numerical data, while Median and Interquartile range (IQR) for non-parametric numerical data.
2. Frequency and percentage of non-numerical data.

ii.Analytical statistics:

1. ***Student T*** Test was used to assess the statistical significance of the difference between two study group means.
2. ***Fisher's exact test*** **was** used to examine the relationship between two qualitative variables when the expected count is less than 5 in more than 20% of cells.

P- value: level of significance
-P>0.05: Non-significant (NS).
-P< 0.05: Significant (S).

RESULTS

This study was conducted on 40 patients underwent thyroidectomy to evaluate the value of injection of methylene blue dye into the inferior thyroid artery for help of the identification and dissection of RLN in comparison to conventional technique and to investigate any side effect of the methylene blue post-operative to prove its safety and feasibility to apply. The study group was divided equally into two subgroups (20 patients) in each group regarding the technique used in the identification and dissection of RLN (The methylene blue (MB) injection technique, and the conventional technique).

Table 1: Demographic data for the study group.

		Mean ± SD	Range
Age		45.08 ± 7.66	(30 - 59)
		N (%)	
Gender	Male	9 (22.5%)	
	Female	31 (77.5%)	
Diagnosis	MNG	28 (70%)	
	Solitary nodule	6 (15%)	
	Graves' with failed medical treatment	3 (7.5%)	
	Controlled 2ry toxic goiter	3 (7.5%)	
Groups	MB injection technique	20 (50%)	
	Conventional technique	20 (50%)	

The mean age was 45.08 ± 7.66 and ranged from 30 to 59-year-old, the male patients were 22.5% while 77.5% were females. Regarding diagnosis, multinodular goiter (MNG) was the most frequent condition, affecting 70%, followed by solitary nodules in 15%. Graves' disease with failed medical treatment and controlled secondary toxic goiter were observed in equal proportions of 7.5% ***table (1).***

Table 2: Intra-operative data for the study group.

		N (%)	
Type of surgery	Hemi-Thyroidectomy	6 (15%)	
	Total Thyroidectomy	34 (85%)	
		Mean ± SD	Range
Blood loss (ml)		85.5 ± 25.49	(50 - 150)
Time taken for identification of single RLN after delivery of the lobe (min)		11.28 ± 4.27	(6 - 20)

The surgical approach varied between hemi-thyroidectomy, performed in 15%, and total thyroidectomy, which was more common at 85%. The mean blood loss was 85.5 ± 25.49 mL, with a range of 50 to 150 ml. The time required for the identification of a single recurrent laryngeal nerve (RLN) after lobe delivery was recorded at an average of 11.28 ± 4.27 minutes, varying between 6- and 20-minutes ***table (2).***

Table 3: Post-operative complications for the study group.

		N (%)
Dye extravasation (MB injection technique group)	No	16 (80%)
	Yes	4 (20%)
Vocal cord affection	Negative	36 (90%)
	Temporary	3 (7.5%)
	Permanent	1 (2.5%)
Affected side	Unilateral	3 (75%)
	Bilateral	1 (25%)
Stridor	No	39 (97.5%)
	Yes	1 (2.5%)
Tracheostomy	No	39 (97.5%)
	Yes	1 (2.5%)

Among the MB injection technique group, dye extravasation occurred in 20%, while 80% had no such occurrence. Vocal cord affection was absent in 90%, while 7.5% (3 patients) experienced temporary vocal cord impairment and 2.5% (1 patient) suffered permanent vocal cord dysfunction. Among the affected individuals (4 patients), unilateral vocal cord involvement was seen in 75%, whereas bilateral involvement was observed in 25%. Stridor was rare, affecting only 2.5%, and similarly, the need for tracheostomy was limited to 2.5%, while 97.5% did not experience these complications ***table (3).***

Table 4: Demographic data between two study groups.

		Groups		Test of significance		
		MB injection technique (N= 20)	Conventional technique (N= 20)			
		Mean ± SD N (%)	Mean ± SD N (%)	value	p-value	Sig.
Age		44.45 ± 7.7	45.7 ± 7.76	***t*= -0.511**	0.612*	NS
Gender	Male	5 (25%)	4 (20%)	FE	1.00**	NS
	Female	15 (75%)	16 (80%)			
Diagnosis	MNG	14 (70%)	14 (70%)	FE	1.00**	NS
	Solitary nodule	3 (15%)	3 (15%)			
	Graves' with failed medical treatment	2 (10%)	1 (5%)			
	Controlled 2ry toxic goiter	1 (5%)	2 (10%)			

*Student t-test (t); **Fisher's Exact test (FE).

The comparison between the MB injection and conventional technique groups revealed no significant differences in demographic characteristics. The mean age was 44.45 ± 7.7 years for the MB injection group and 45.7 ± 7.76 years for the conventional technique (p-value= 0.612). Gender distribution was similar, with males representing 25% in the MB group and 20% in the conventional group; likewise, female patients constituted 75% in the MB group and 80% in the conventional group (p-value= 1.00). Diagnoses were evenly distributed, with 70% in both groups having MNG, 15% presenting with solitary nodules, and slight variations in Graves' disease (10% vs. 5%) and controlled secondary toxic goiter (5% vs. 10%) **table (4).**

Table 5: Intra-operative data between two study groups.

		Groups		Test of significance		
		MB injection technique (N= 20)	Conventional technique (N= 20)			
		N (%) Mean ± SD	N (%) Mean ± SD	value	p-value	Sig.
Type of surgery	Hemi-Thyroidectomy	3 (15%)	3 (15%)	FE	1.00*	NS
	Total Thyroidectomy	17 (85%)	17 (85%)			

Blood loss (ml)	67.5 ± 13.03	103.5 ± 21.95	***t*= -6.307**	<0.001**	S
Time taken for identification of single RLN after delivery of the lobe (min)	7.65 ± 1.5	14.9 ± 2.75	***t*= -10.353**	<0.001**	S

*Fisher's Exact test (FE); **Student t-test (t).

The type of surgery was consistent between groups, with 15% undergoing hemi-thyroidectomy and 85% receiving total thyroidectomy in both groups (p-value= 1.00). However, significant differences were noted in blood loss and RLN identification time. The MB injection group exhibited significantly lower blood loss (67.5 ± 13.03 ml) compared to the conventional technique group (103.5 ± 21.95 ml, with p-value <0.001). Similarly, the time required for RLN identification was significantly shorter in the MB injection group (7.65 ± 1.5 min) compared to the conventional group (14.9 ± 2.75 min, as p-value <0.001) **table (5).**

Table 6: Post-operative complications between two study groups.

		Groups		Fisher's Exact test	
		MB injection technique (N= 20)	Conventional technique (N= 20)		
		N (%)	N (%)	p-value	Sig.
Vocal cord affection	Negative	19 (95%)	17 (85%)	0.605	NS
	Temporary	1 (5%)	2 (10%)		
	Permanent	0 (0%)	1 (5%)		
Affected side	Negative	19 (95%)	17 (85%)	0.605	NS
	Unilateral	1 (5%)	2 (10%)		
	Bilateral	0 (0%)	1 (5%)		
Stridor	No	20 (100%)	19 (95%)	1.00	NS
	Yes	0 (0%)	1 (5%)		
Tracheostomy	No	20 (100%)	19 (95%)	1.00	NS
	Yes	0 (0%)	1 (5%)		

The incidence of vocal cord affection did not differ significantly between groups, with negative findings in 95% of the MB injection group Vs. 85% of the conventional group. Temporary vocal cord dysfunction was noted in 5% of the MB group and 10% in the conventional group, while permanent dysfunction was observed only in the conventional group 5%. Regarding the affected side, unilateral involvement was reported in 5% of the MB group and 10% of the conventional group, while bilateral affection was present in the conventional group only, affecting 5%. Stridor and tracheostomy were absent in the MB injection group, whereas both complications occurred in 5% of the conventional group, though the difference was not statistically significant (p-value= 1.00) for all parameters **table (6).**

DISCUSSION

Thyroidectomy is a common surgical procedure performed for various thyroid disorders, including multinodular goiter, solitary thyroid nodules, and Graves' disease. Despite advances in surgical techniques, injury to the recurrent laryngeal nerve (RLN) remains a significant concern, as it can lead to vocal cord dysfunction, airway complications, and a reduced quality of life for patients ***(8)***. Traditional methods of RLN identification rely on direct visualization and anatomical knowledge, but these approaches can be challenging in cases where the nerve is difficult to locate due to anatomical variations, fibrosis, or distorted surgical planes. To enhance RLN identification and minimize complications, various adjunct techniques have been explored, including the use of methylene blue (MB) dye ***(9)***.

Methylene blue (MB), a well-established dye with diagnostic and therapeutic applications, has emerged as a promising tool for intraoperative RLN visualization. Unlike electrophysiological nerve monitoring, which requires specialized equipment and expertise, MB staining is a simple, cost-effective technique that can be widely implemented. Previous studies have explored MB for different intraoperative purposes, including the identification of the parathyroid glands, midline structures, and vascular territories. However, its role in facilitating precise and efficient RLN identification during thyroidectomy remains an area of ongoing research ***(10)***.

Our study introduced and evaluated the novel approach of injecting methylene blue dye into the inferior thyroid artery to facilitate RLN identification during thyroidectomy. Unlike conventional visualization methods, this technique aims to enhance contrast between the nerve and surrounding tissues, making it easier to locate and preserve the RLN. This method is hypothesized to reduce surgical time, lower intraoperative blood loss, and decrease the risk of nerve injury, ultimately leading to a safer and more efficient thyroidectomy procedure

By addressing gaps in prior research and offering a comparative analysis with established methods, our study represents an important step toward refining intraoperative techniques in thyroid surgery.

Consequently, this comparative clinical study was conducted on 40 patients undergoing thyroidectomy to evaluate the efficacy and safety of injecting methylene blue (MB) dye into the inferior thyroid artery to facilitate identification and dissection of the recurrent laryngeal nerve (RLN) and to determine whether methylene blue injection posed any postoperative risks or adverse effects, ensuring its feasibility for routine surgical application.

Regarding Demographic Characteristics of the Study Population, our study included 40 patients undergoing thyroidectomy, with an equal division between two groups: 20 patients in the methylene blue (MB) injection technique group and 20 in the conventional technique group. The mean age was 45.08 ± 7.66 years, and most patients were female (77.5%), a trend consistent with thyroid diseases being more prevalent among women. The most common diagnosis was multinodular goiter (MNG) (70%), followed by solitary nodules (15%), Graves' disease (7.5%), and controlled secondary toxic goiter (7.5%). The demographic characteristics between the MB injection and conventional groups were statistically comparable, ensuring that any observed differences in surgical outcomes were attributable to the technique used rather than patient-related factors.

Regarding Surgical Approach and Intraoperative Data, our study revealed that total thyroidectomy was the predominant procedure (85%), with 15% undergoing hemi-thyroidectomy. The mean blood loss was significantly lower in the MB injection group (67.5 ± 13.03 mL) compared to the conventional group (103.5 ± 21.95 mL, $p < 0.001$). Additionally, the time required for RLN identification was significantly reduced in the MB injection group (7.65 ± 1.5 minutes) compared to the conventional group (14.9 ± 2.75 minutes, $p < 0.001$).

The findings of our study are consistent with those of **AHMED MK et al. (11),** who demonstrated that MB spray-assisted RLN identification led to a reduction in surgical stress and facilitated easier nerve visualization. However, their study noted that the total thyroidectomy duration was slightly prolonged in the MB spray group, averaging 51.4 ± 2.3 minutes compared to 46.7 ± 2.2 minutes in the control group. **Farghaly et al. (12)** also confirmed the benefits of MB spraying in reducing surgical complications and improving RLN identification, with their study reporting that RLN remained unstained while all surrounding tissues absorbed the dye, facilitating nerve localization.

Additionally, these findings align with **Salah et al. (13)**, who reported a significant reduction in blood loss in the MB group (85 ± 22 mL) compared to the conventional group (105 ± 37 mL, $p = 0.01$). Additionally, RLN identification time was also shorter in the MB group (9 ± 2 minutes) compared to the conventional technique group (14 ± 3 minutes, $p = 0.008$).

Similarly, **Basavaraj et al. (8)** demonstrated that methylene blue spraying significantly improved RLN identification, reducing time to locate the RLN and blood loss compared to conventional methods. **Ahmed AM et al. (11)** also showed that methylene blue helped in rapid RLN identification, as the dye did not stain the nerve, allowing clear visualization.

Lakshmanan et al. (10) used MB spray instead of injection and found that the technique effectively identified RLN and parathyroid glands while reducing intraoperative complications. However, unlike our study, which used arterial injection, their approach involved surface spraying. This may have implications for MB dye diffusion and absorption, potentially affecting RLN identification time and safety.

In contrast, **Kataria et al. (9)** applied MB in a different context, using it for midline identification in endoscopic thyroidectomy. Their study highlighted the effectiveness of MB in improving anatomical precision, which aligns with our findings on its utility in enhancing intraoperative visualization.

Regarding Postoperative Complications and Safety Evaluation, Postoperative complications are a major concern in thyroidectomy, particularly vocal cord dysfunction and RLN injury. In our study, dye extravasation occurred in 20% of patients in the MB group, while 80% had no leakage issues. Vocal cord affection was noted in 10% of cases, but only 2.5% of patients had permanent dysfunction. Stridor and the need for tracheostomy were rare, occurring in only 2.5% of cases. These results suggest that while RLN injury remains a potential risk in thyroidectomy, MB injection does not increase this risk compared to the conventional technique.

Comparatively, **AHMED MK et al. (11)** found no significant differences in RLN injury rates between their MB spray and control groups, with no permanent vocal cord palsy detected postoperatively. Similarly, **Farghaly et al. (12)** reported that their MB spraying group had no cases of RLN injury, whereas the conventional group experienced one case of transient bilateral vocal cord paralysis. **Salah et al. (13)** reported a slightly higher rate of dye extravasation (2 out of 30 cases, ~6.7%) but still confirmed that MB dye was a safe and effective tool for RLN identification.

Additionally, **Abdelrahman et al. (15)** highlighted that methylene blue spraying allowed clearer differentiation between RLN and surrounding tissues. These findings align with our results, reinforcing the safety and feasibility of using MB for RLN identification during thyroidectomy.

In contrast, **Chhetri et al. (16)** found no statistically significant advantage of MB dye over conventional RLN identification methods, suggesting that other anatomical markers remain crucial for safe dissection. However, their study was limited to 30 patients, making it smaller than ours and less comparable in terms of broad applicability.

Regarding Comparison Between Study Groups, our study revealed that the MB injection and conventional technique groups

were well-matched in terms of demographic characteristics, eliminating patient-related variability. However, our study observed that MB injection led to significantly lower blood loss and faster RLN identification without increasing postoperative complications, confirming that MB dye does not introduce additional risks. The MB injection group exhibited a mean blood loss of 67.5 mL, significantly lower than the 103.5 mL observed in the conventional group. Additionally, the mean time required for RLN identification was almost half in the MB group compared to the conventional group, further demonstrating its clinical advantages.

These findings are consistent with the results of **AHMED MK et al. (11),** where MB spraying improved RLN visualization without causing significant adverse effects. Their study concluded that MB staining was a safe, cost-effective, and widely available method for facilitating RLN identification during thyroidectomy. Similarly, **Farghaly et al. (12)** reported that MB spraying significantly enhanced RLN identification while reducing the incidence of transient postoperative complications, such as vocal cord dysfunction. **Kataria et al. (9)** further supported the benefits of MB in thyroid surgery, albeit in the context of midline identification in endoscopic procedures. Their study suggested that MB could improve surgical orientation, potentially minimizing intraoperative complications.

Moreover, this aligns with findings from **Salah et al. (13)** and **Lakshmanan et al. (10)**, both of whom concluded that MB injection and spraying significantly enhance RLN identification while maintaining a similar safety profile to conventional techniques.

Basavaraj et al. (8) also demonstrated that MB dye was effective for RLN identification, but their study did not report any statistically significant reduction in complications. Similarly, **Chhetri et al. (16)** found that MB did not necessarily improve safety outcomes, reinforcing the need for careful surgical dissection regardless of the technique used.

Clinical Implications

The results of this study provided strong evidence supporting the use of MB injection for RLN identification during thyroidectomy. The key advantages include a significant reduction in intraoperative blood loss and faster RLN identification, both of which contribute to a safer and more efficient surgical procedure. Importantly, the postoperative complication rates were similar between the MB and conventional groups, confirming the safety and feasibility of this technique.

For surgeons, these findings suggest that MB injection could be a valuable adjunct in thyroid surgery, particularly in complex cases where RLN identification is challenging. The technique may help reduce surgical time, improve visualization, and minimize blood loss, ultimately leading to better patient outcomes.

Strength Points of the study:

Our study has several strengths that contribute to its significance in advancing thyroid surgery techniques. One of the key strengths is its comparative nature, allowing for a direct evaluation of methylene blue (MB) injection against the conventional approach. By assessing parameters such as blood loss, RLN identification time, and postoperative complications, we provide objective evidence supporting the efficacy of MB injection in thyroidectomy. Another notable strength is the randomized study design, which minimizes bias and ensures a fair comparison between the two techniques. Additionally, our study includes a diverse patient population, reflecting real-world clinical scenarios involving different thyroid pathologies, including multinodular goiter, solitary nodules, and Graves' disease.

Moreover, the novelty of our study lies in its focus on MB injection rather than conventional MB spraying or smearing techniques. While previous research has explored MB as a general staining agent, our study specifically examines its targeted application for RLN identification, enhancing precision while avoiding unnecessary tissue staining. The cost-effectiveness and accessibility of MB injection further highlight its potential as a practical alternative to nerve monitoring technologies, which may not be available in all healthcare settings.

Limitations of the study:

Despite its strengths, our study has certain limitations that should be acknowledged. One limitation is the relatively small sample size (40 patients), which, while sufficient to detect significant differences, may not fully capture the variability in surgical outcomes across larger populations. Additionally, the study was conducted at a single center, which may limit the generalizability of our findings to other institutions with different surgical protocols and patient demographics.

Additionally, long-term follow-up data on RLN function was not extensively analyzed, meaning that late complications beyond the immediate postoperative period were not fully assessed. Finally, while MB injection was effective in improving RLN visualization, a small percentage of patients experienced dye extravasation, highlighting the need for further refinement in application techniques**.**

CONCLUSION

Our study demonstrated that methylene blue injection is a safe, efficient, and cost-effective method for RLN identification during thyroidectomy. The MB injection group showed significantly lower blood loss, reduced RLN identification time, and comparable postoperative complication rates compared to the conventional technique. These findings align with existing literature, further validating the role of MB as an adjunct for improving surgical precision and safety.

When compared to other methods, MB injection offers several advantages, including better localization, reduced intraoperative bleeding, and ease of implementation without requiring additional equipment. While alternative approaches such as nerve monitoring can provide real-time functional feedback, they may not be feasible in all surgical settings due to cost and technical requirements. Our study supports the integration of MB injection as a practical and effective alternative, particularly in resource-limited environments.

Based on our findings, we recommend that MB injection should be considered as an adjunct technique for RLN identification in thyroidectomy, particularly in cases where nerve monitoring is unavailable.

ADDITIONAL INFORMATION

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosures

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Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.

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