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ORIGINAL RESEARCH

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Experience with the use of intraoperative continuous nerve monitoring in video-assisted neck surgery and external cervical incisions

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Abstract

Objectives: Recurrent laryngeal nerve (RLN) injury is one of the severe complications in thyroid surgery. Therefore, intraoperative nerve monitoring (IONM) has been widely used to identify the RLN and confirm its integrity. Recently, the usefulness of continuous IONM (CIONM) with automatic, periodic stimulation to the vagus nerve during thyroid surgery was reported. This study aimed to report our experience with minimally invasive video-assisted endoscopic endocrine neck surgery (VANS), during which, CIONM was successfully applied for the first time.

Methods: Consecutive patients who underwent thyroid surgery with CIONM, performed in our department using either external neck incision surgery or VANS between July 2017 and June 2019, were retrospectively analyzed.

Results: A total of 22 patients who underwent thyroid surgery with neck incision (14 cases; 7 men and 7 women; age, 21-75 years [mean, 52 years]) or VANS (8 cases; 8 women, age, 20-61 years [mean, 41 years]) were enrolled in this study. The addition of CIONM in VANS prolonged the operation's duration by approximately 30 minutes as the endoscopic surgery was technically more difficult. No intra- and postoperative incidence of transient or permanent RLN palsy was observed in any patient, except for three patients who underwent external neck incision surgery in whom combined resection was unavoidable due to tumor invasion of the RLN.

Conclusion: We reported the first successful application of CIONM during thyroidectomy using VANS. Future clinical trials should clarify the benefits of CIONM when compared to intermittent IONM in VANS.

Level of Evidence: 5.

KEYWORDS
continuous intraoperative nerve monitoring, intermittent intraoperative nerve monitoring, recurrent laryngeal nerve, video-assisted endoscopic endocrine neck surgery

1 | INTRODUCTION

In thyroid surgery, identification and preservation of the recurrent laryngeal nerve (RLN) are important. Unless the combined resection of this nerve with an infiltrating tumor is unavoidable, the course of the RLN should be confirmed, and the nerve integrity should be preserved to ensure that postoperative speech and swallowing functions are not impaired. However, even if the nerve appears to be preserved to the naked eye, postoperative functional RLN palsy occurs in about 3% of cases in which transient paralysis is involved.[1-3]

Considering the risk of bilateral paralysis during total thyroidectomy, postoperative paralysis, even transient paralysis, is one of the complications that should be avoided. Intraoperative nerve monitoring (IONM) can identify various causes of RLN palsy, such as clamping, compression, traction, and heat injury; however, these complications are rarely identified when IONM is performed intermittently. To overcome this problem, continuous IONM (CIONM) is characterized by continuous intraoperative stimulation of the vagus nerve, from which the RLN originates, allowing the surgeon to recognize the effects of intraoperative nerve manipulation real-time.[4-6]

We have experience with CIONM, originally developed by Shimizu et al, in external incisional surgery and minimally invasive video-assisted endoscopic endocrine neck surgery (VANS).[7] In this study, we confirmed the completeness of RLN using CIONM in a total of 22 patients, 14 with open thyroid surgery and 8 with VANS. To the best of our knowledge, this is the first detailed report describing the procedure to perform CIONM during VANS.

2 | PATIENTS AND METHODS

2.1 | Ethics

This study was approved by the Ethics Committee of Kanazawa Medical University Hospital, and the requirement for informed consent was waived because of the retrospective study design.

2.2 | Study design

Retrospective observational study.

2.3 | Patients

Consecutive patients who underwent an initial surgery for thyroid carcinoma or Graves' disease between July 2017 and June 2019 were retrospectively included in this study. Only patients with sufficient organ function at the time of surgery were included. Patients were excluded based on the following criteria: preoperative RLN paresis, clinically evident disease of the central nervous system, arrhythmia, or a history of neck surgery.

2.4 | VANS

The operative position was supine with the neck extended with a shoulder pillow as in usual thyroid surgery. The skin incision was made 7 cm laterally from the midline of the sternum and 3 cm along the Langer dermatome line about 2 transverse fingers below the clavicle. A wound protector (wrap protector TMS type 3.5 cm, for type 3.5 cm, Hakko, Japan) was applied to the incision to prevent damage to the wound margin. The skin flap was created using electrocautery under direct visualization with a headlight. The flap was created from the subclavian wound to the subclavian muscle, with the lateral area extending to the medial margin of the sternal branch of the sternocleidomastoid muscle on the healthy side, the medial area extending to the lateral margin of the sternocleidomastoid branch on the affected side, and the cephalic area extending to the superior border of the thyroid cartilage. To lift the skin valve, a skin valve lifting hook (Mist-Less VANS retractor set, Hakko, Japan) was used. The lifting hooks were secured to a post using a wire retractor (Kent traction device, Takasago Medical Industry, Japan). The endoscope was a 0°24 cm long rigid speculum (Carlstorz, Japan) inserted via a scope guide into a 5-mm skin incision in the affected lower neck and secured to a locking arm (System JB, Japan). In addition, a muscle hook (Sonne Medical, Japan) trailing the sternocleidomastoid muscle and scaphoid muscle outward was fixed with an iron assist (Unimedic, Japan) (Figure 1).

2.5 | CIONM

In this study, the NIM-Response 3.0 Nerve Monitoring System (Medtronic, Tokyo, Japan) was used to perform CIONM. Repeated pulse stimulation of the vagus nerve, located centrally to the RLN, was applied every second via an automatic periodic stimulation (APS) electrode (Medtronic), as shown in Figure 2A. The NIM TriVantage EMG endotracheal tube (Medtronic) was inserted intraoperatively to continuously monitor the electromyogram (EMG) of the vocal cord, as well as the potential amplitude and latency in response to the external stimulation pulse (Figure 3).

Since the APS electrode was originally designed for external neck surgery, we had to devise the following measures to place it endoscopically on the vagus nerve. First, similar to the procedure employed for the external incision approach, the carotid sheath was incised at the cricoid cartilage level to expose the vagus nerve. Then, the vagus nerve was taped and retracted with a vessel loop to facilitate the APS electrode placement (Figure 2B). We inserted the lead wire of the APS electrode into the Lap Protector (Hakko Co., Japan), which was placed at the incision site, by passing the wire through a silicone tube (Figure 4A,B) because the insertion of the APS electrode wire directly through the Lap Protector would have interfered with the forceps. Second, the APS electrode was threaded between the clavicular and sternal heads of the sternocleidomastoid muscle to prevent interference with the forceps and other instruments (Figure 4C).

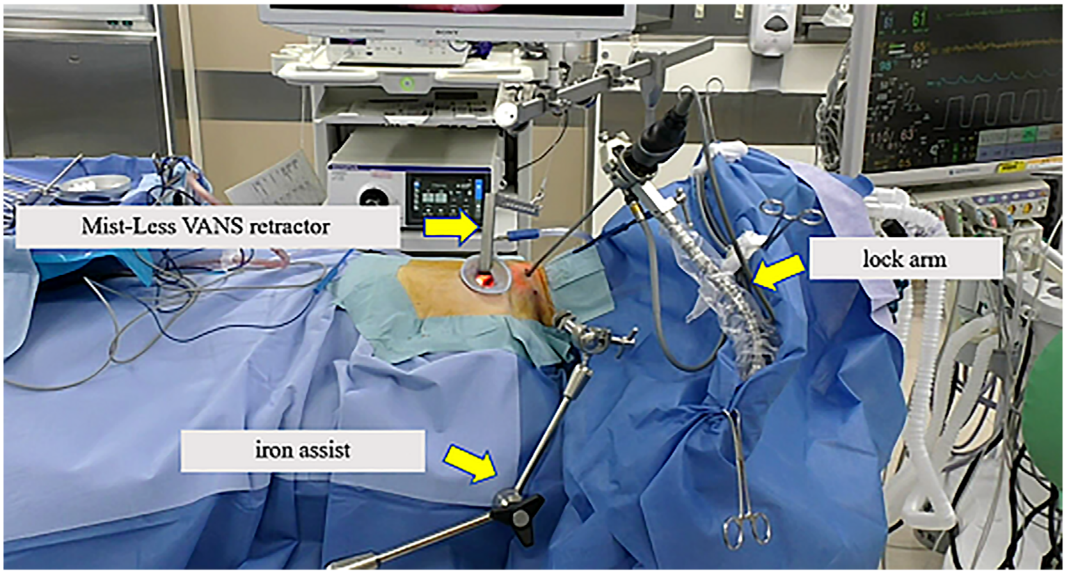

FIGURE 1 Setting up VANS in our department. VANS, video-assisted endoscopic endocrine neck surgery

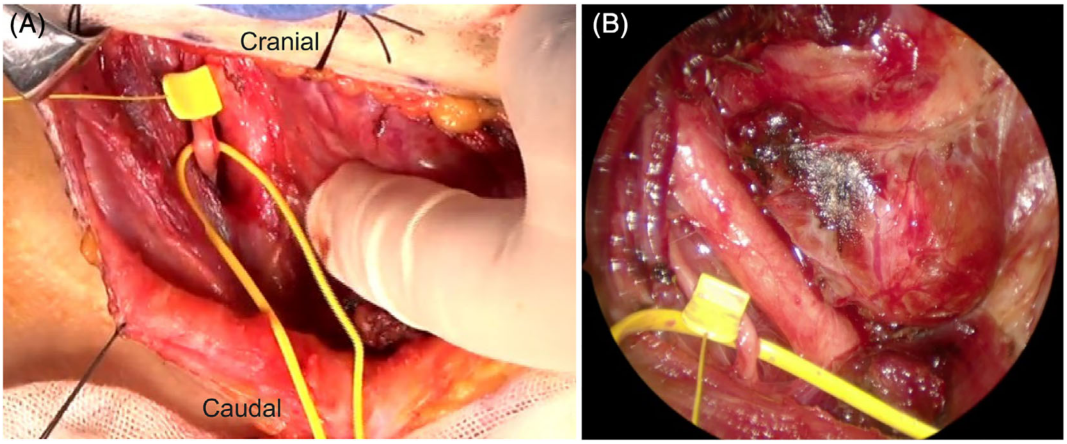

FIGURE 2 APS electrodes attached to the vagus nerves (taped). A, Images showing the external neck incision approach. B, Endoscopic images of the neck during VANS. The vagus nerve is exposed and taped for atraumatic retraction. APS, automatic periodic stimulation; VANS, video-assisted endoscopic endocrine neck surgery

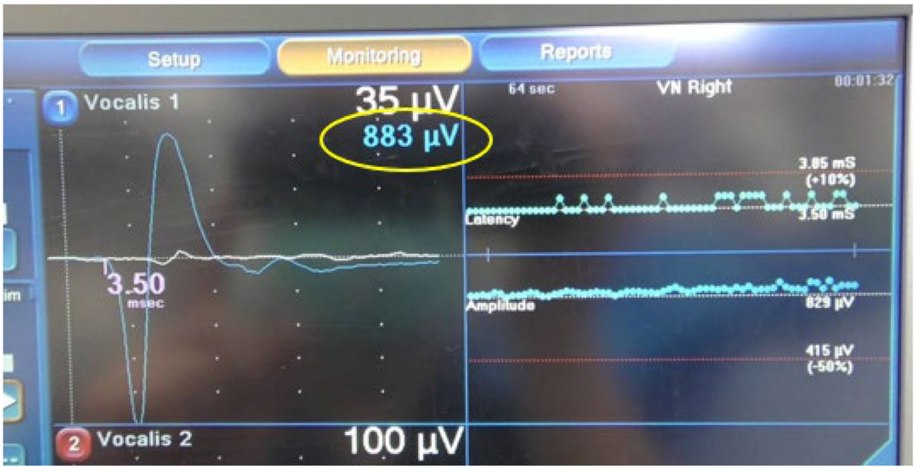

FIGURE 3 Electromyogram (left) with a waveform amplitude of 883 μV and a latency of 3.50 ms. In all enrolled cases, baseline amplitudes exceeded 500 μV

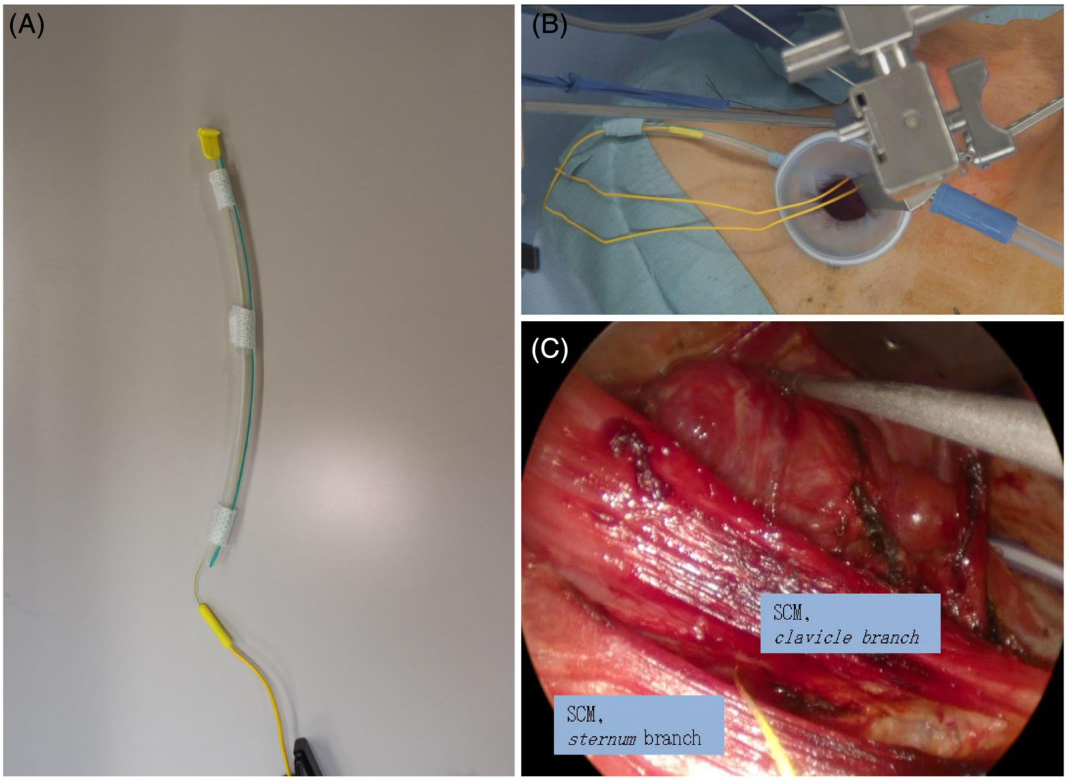

FIGURE 4 Positioning of the APS electrode in VANS. A, The lead wire of the APS electrode is passed through a silicone tube. B, The tube is inserted outside the Lap Protector at the incision port to avoid interference with forceps and other equipment. C, The clavicular and sternal heads of the SCM are separated, and the APS electrode is placed between them. APS, automatic periodic stimulation; SCM, sternocleidomastoid muscle; VANS, video-assisted endoscopic endocrine neck surgery

TABLE 1 Characteristics of patients who underwent thyroid surgery using the external neck incision approach

					RLN palsy	
Case no	Age (years)	Sex	Clinical presentation	Surgical approach	Intraoperative	Postoperative
1	38	M	Medullar cancer T3N1bM0	Total thyroidectomy+ M	–	–
2	44	M	Recurrent papillary thyroid cancer rT0N1bM0	M	+	+*
3	59	F	Papillary thyroid cancer T3N1bM0	Total thyroidectomy+ M	–	–
4	45	F	Papillary thyroid cancer T3N1bM0	Lobectomy + M	–	–
5	74	M	Papillary thyroid cancer T3N1aM0	Lobectomy + C	–	–
6	69	F	Mediastinal goiter	Lobectomy	–	–
7	57	F	Mediastinal goiter	Lobectomy	–	–
8	71	M	Clear cell carcinoma (metastasis of a renal cell carcinoma)	Lobectomy	+	+*
9	44	F	Papillary thyroid cancer T3N1aM0	Total thyroidectomy	–	–
10	47	M	Graves' disease	Total thyroidectomy	–	–
11	21	F	Papillary thyroid cancer T1bN1bM0	Total thyroidectomy + M	–	–

(Continues)

TABLE 1 (Continued)

Case no	Age (years)	Sex	Clinical presentation	Surgical approach	RLN palsy	
					Intraoperative	Postoperative
12	23	F	Papillary thyroid cancer T2N1bM0	Lobectomy + M	–	–
13	62	M	Papillary thyroid cancer T1bN1bM0	Total thyroidectomy + M	–	–
14	75	M	Papillary thyroid cancer T1bN1bM0	Total thyroidectomy + M	+	+*

Abbreviations: C, central node dissection; F, female; M, male; M, modified radical neck dissection; RLN, recurrent laryngeal nerve.
*Resection of the recurrent laryngeal nerve due to tumor invasion.

TABLE 2 Characteristics of patients who underwent thyroid surgery using VANS

Case no	Age (years)	Sex	Clinical presentation	Surgical approach	RLN palsy	
					Intraoperative	Postoperative
1	61	F	Papillary thyroid cancer T3N0M0	Lobectomy + C	–	–
2	30	F	Papillary thyroid cancer T1bN0M0	Lobectomy + C	–	–
3	56	F	Papillary thyroid cancer T1bN0M0	Lobectomy + C	–	–
4	45	F	Papillary cancer T1bN0M0	Lobectomy + C	–	–
5	40	F	Bilateral papillary thyroid cancer T1bN0M0	Total thyroidectomy + C	–	–
6	38	F	Graves' disease	Total thyroidectomy	–	–
7	20	F	Graves' disease	Total thyroidectomy	–	–
8	38	F	Graves' disease	Total thyroidectomy	–	–

Abbreviations: C, central node dissection; F, female; RLN, recurrent laryngeal nerve; uni, unilateral; VANS, video-assisted neck surgery.

The addition of CIONM to VANS increased the duration of the surgical procedure by approximately 30 minutes.

3 | RESULTS

A total of 22 patients underwent thyroid surgery in our department, either with an external neck incision approach (14 cases) or VANS (8 cases), between July 2017 and June 2019. Neck incision surgery was performed in 7 men and 7 women aged 21 to 75 years, with an average age of 52 years. Among them, 12 patients were diagnosed with papillary carcinomas, 1 patient had Graves' disease, and 1 patient had a giant follicular lesion. A total of 7 patients underwent total resection, 6 underwent lobectomy, and 1 underwent only cervical dissection. Three patients underwent resection of the RLN due to tumor invasion, as advanced cancer is more common in patients treated with an external incision approach. The remaining 11 patients who did not require combined resection showed neither transient nor permanent RLN palsy (Table 1). In contrast, in VANS, 5 patients had papillary carcinoma, and 3 were diagnosed with Graves' disease. The 8 patients were all women aged 20 to 61 years, with an average age of 41. Of them, 4 patients underwent total resection, and 4 underwent lobectomy. None of the patients treated with VANS had RLN palsy, including transient palsy (Table 2).

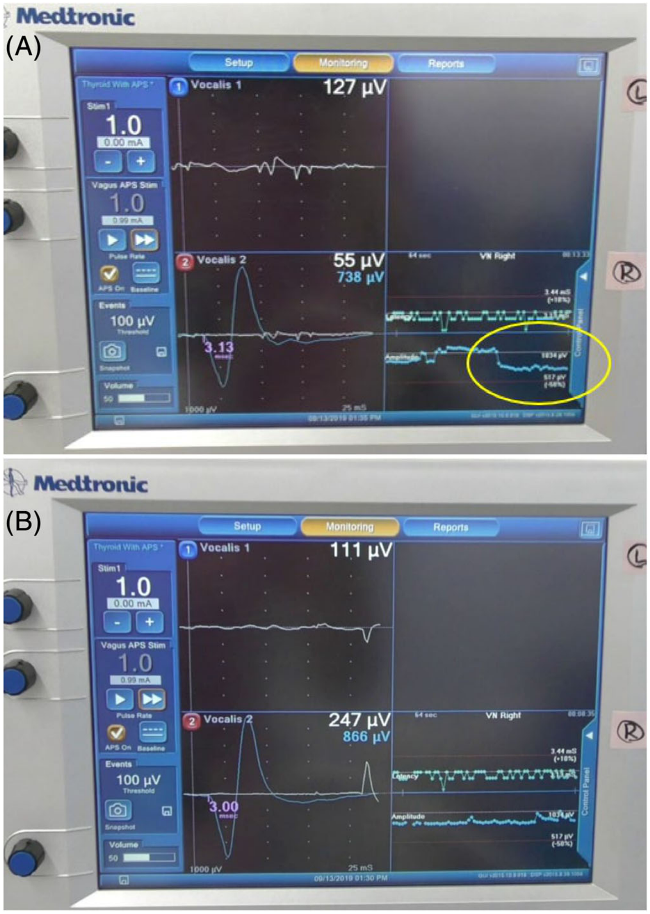

FIGURE 5 Intraoperative electromyogram findings in case 5, Table 2. A, A distinct decrease in electromyogram amplitude at the time of the thyroid prolapse. B, After the thyroidectomy, the amplitude returned to near baseline values

Case 5 in Table 2 is presented in more detail as it is a representative case for VANS. The patient was a 40-year-old woman with stage IB bilateral papillary thyroid cancer (T1bN0M0), who underwent a total thyroidectomy with bilateral D1 lymphadenectomy. We adopted a bilateral approach in patients who required total resection during VANS. Although a unilateral approach is technically feasible for total thyroidectomy, we believe that a bilateral approach is more desirable to manage the vessels, identify and preserve the nerves, and ensure midline region dissection. VANS was performed with continuous pulse stimulation of the vagus nerve, which confirmed that the EMG amplitude always exceeded 500 μV. In case 5, as an exception, a slight but distinct decrease in EMG amplitude was observed at the time of the thyroid prolapse and Berry's ligament dehiscence (Figure 5A), although the value returned to near baseline levels after the thyroidectomy (Figure 5B), indicating a successful recovery. No patient presented a combined EMG event or loss of signal intraoperatively,[8] either with an external neck incision approach or VANS. After extubation of the EMG endotracheal tube, we confirmed that the movements of the right and left vocal cords did not differ, using a laryngeal fiberscope.

4 | DISCUSSION

In thyroid surgery, the standard practice is to visually identify and preserve the RLNs. However, even when RLN preservation is visually confirmed, postoperative RLN palsy, including transient events, has been known to occur in approximately 3% of patients.[7,9] Considering the risk of bilateral RLN palsy in the course of total resection, we believe that the incidence of postoperative RLN palsy should be reduced to zero as much as possible. As a cause of RLN palsy, nerve transection, compression or crush injury, traction injury, electrical or thermal injury, ligature or strangulation, and ischemia have been described.[9-12] Among them, traction injuries were more common and had a shorter recovery time.[9] Furthermore, the area at the highest risk of an RLN injury was found to be near Berry's ligament. Chiang et al suggest that the lack of a standardized IONM procedure could increase the risk of stretch injury to the RLN via Berry's ligament due to excessive traction and propose a standardized IONM procedure as a four-step protocol.[1,3] The usefulness of intermittent nerve monitoring has been well documented.[13-16] CIONM overcomes the key methodological limitation inherent to intermittent nerve monitoring, which allows the nerve to be at risk in between stimulations.[8,17] In patients with CIONM, RLN stress can be identified real-time during thyroid prolapse, Berry's ligament dehiscence, or dissection of the midline region. In our study using CIONM, any stress in the RLN was immediately recognized intraoperatively. Thus, no patient developed postoperative RLN palsy, not even transiently.

For thyroid surgery, Goretzki et al described that if the first unilateral RLN does not sufficiently respond intraoperatively to IONM stimulation, the surgery should be terminated without resecting the contralateral side, and a second-phase surgery should be considered.[18] The use of CIONM allows the surgeon to detect the appearance and recovery of recurrent nerve palsy earlier. This also allows a fast and reliable decision regarding a second stage surgery. The use of CIONM also has the advantage of providing immediate feedback to surgeons on their operation techniques because they can learn real-time how manipulations such as dissection and traction affect the RLN.[6]

Schneider et al used CIONM in thyroid surgery and classified the risk of RLN injuries into six groups based on amplitude and latency changes in the EMG.[8] Even in cases with combined EMG events or loss of signal, no postoperative RLN palsy occurred in their classification if the amplitude improved intraoperatively to >50% of the baseline value. Among our study cases, we did not identify combined EMG events or loss of signal, which is consistent with the findings of Schneider et al.

Endoscopic thyroid surgery approaches, where the access incisions are made at the inferior margin of the clavicle, axillary, breast, or anterior chest, as well as oral endoscopic approaches, have been developed worldwide. The VANS technique, reported by Shimizu et al in 1998, which was the first endoscopic neck surgery approach aimed at avoiding a conspicuous scar on the anterior neck, is widely used in Japan.[7] The use of this approach with CIONM has not been described previously, whereas combinations of CIONM with transoral endoscopic thyroidectomy via the vestibular approach, as well as with endoscopic and robotic thyroidectomy, have been reported.[19,20] In endoscopic thyroid surgery, it is sometimes difficult to identify anatomical landmarks in the operating field until one becomes accustomed to this technique. We think that the case series in this study confirms the advantages of CIONM in VANS, allowing the continuous monitoring of RLNs.

For the use of VANS with CIONM in clinical practice, the cost-effectiveness of its adaptation should also be considered. To avoid the risk of airway stenosis, we suggest that CIONM be applied during VANS, at least during total resection of malignancies or Graves' disease because a total resection carries the risk of a bilateral RLN palsy. We also believe that CIONM is an option for large benign goiters, such as mediastinal goiters, to ensure that RLN function is maintained during external incision surgery.

In our experience, exposing the vagus nerve and placing the APS electrode endoscopically is technically difficult. The development of new CIONM devices adapted to endoscopic surgery constraints should be considered in the future.

Since the number of patients in this study was small, the favorable results may be related to the experience and skill of the surgeon. Therefore, we believe that further studies are needed to determine whether CIONM is truly useful for RLN injuries. In the future, prospective studies should be performed to clarify the superiority of CIONM to intermittent IONM with VANS.

Our study has several limitations: this study is (a) primarily a case series without a complex statistical analysis, (b) has a small sample cohort, (c) lacks direct comparison between the two groups, (d) has potential for selection bias because all patients were recruited from one institution, and (e) the study results cannot be generalized to other populations.

5 | CONCLUSION

For the first time, this study successfully utilized VANS with CIONM for real-time monitoring of amplitude and latency changes in the EMG. No postoperative transient or permanent RLN palsy occurred in any of the eight patients who underwent this procedure. Although the addition of CIONM to VANS prolonged the duration of the operation by approximately 30 minutes, the use of CIONM in VANS may facilitate safer neck surgery. The benefit of CIONM compared to intermittent IONM in VANS should be clarified in future clinical trials.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

BIBLIOGRAPHY

1. Chiang FY, Lu IC, Kuo WR, Lee KW, Chang NC, Wu CW. The mechanism of recurrent laryngeal nerve injury during thyroid surgery—the application of intraoperative neuromonitoring. *Surgery*. 2008;143(6): 743-749.
2. Serpell JW, Lee JC, Yeung MJ, Grodski S, Johnson W, Bailey M. Differential recurrent laryngeal nerve palsy rates after thyroidectomy. *Surgery*. 2014;156(5):1157-1166.
3. Chiang FY, Wang LF, Huang YF, Lee KW, Kuo WR. Recurrent laryngeal nerve palsy after thyroidectomy with routine identification of the recurrent laryngeal nerve. *Surgery*. 2005;137(3): 342-347.
4. Schneider R, Sekulla C, Machens A, Lorenz K, Thanh PN, Dralle H. Dynamics of loss and recovery of the nerve monitoring signal during thyroidectomy predict early postoperative vocal fold function. *Head Neck*. 2016;38(suppl 1):E1144-E1151.
5. Kurose M, Kondo A, Takano K, et al. Experience of continuous intraoperative nerve monitoring in thyroid surgery [in Japanese]. *J Jpn Soc Head Neck Surg*. 2018;28(2):233-237.
6. Schneider R, Sekulla C, Machens A, Lorenz K, Thanh PN, Dralle H. Postoperative vocal fold palsy in patients undergoing thyroid surgery with continuous or intermittent nerve monitoring. *Br J Surg*. 2015;102 (11):1380-1387.
7. Shimizu K, Akira S, Tanaka S. Video-assisted neck surgery: endoscopic resection of benign thyroid tumor aiming at scarless surgery on the neck. *J Surg Oncol*. 1998;69(3):178-180.
8. Schneider R, Randolph GW, Barczynski M, et al. Continuous intraoperative neural monitoring of the recurrent nerves in thyroid surgery: a quantum leap in technology. *Gland Surg*. 2016;5(6): 607-616.
9. Paniello RC, Park AM, Bhatt NK, Al-Lozi M. Recurrent laryngeal nerve recovery patterns assessed by serial electromyography. *Laryngoscope*. 2016;126(3):651-656.
10. Dionigi G, Wu CW, Kim HY, Rausei S, Boni L, Chiang FY. Severity of recurrent laryngeal nerve injuries in thyroid surgery. *World J Surg*. 2016;40(6):1373-1381.
11. Lee HY, Cho YG, You JY, et al. Traction injury of the recurrent laryngeal nerve: results of continuous intraoperative neuromonitoring in a swine model. *Head Neck*. 2016;38(4):582-588.
12. Randolph GW, Dralle H, International Intraoperative Monitoring Study Group, et al. Electrophysiologic recurrent laryngeal nerve monitoring during thyroid and parathyroid surgery: international standards guideline statement. *Laryngoscope*. 2011;121(suppl 1): S1-S16.
13. Wu KT, Chan YC, Chou FF, Wu YJ, Chi SY. Association between recurrent laryngeal nerve calibre and body figure: a preoperative tool to assess thin-diameter nerves in thyroidectomy. *World J Surg*. 2020;44:3036-3042. https://doi.org/10.1007/s00268-020-05549-4.
14. Li P, Liang QZ, Wang DL, et al. The transcutaneous electromyography recording method for intraoperative neuromonitoring of recurrent laryngeal nerve during minimally invasive parathyroidectomy. *Sci Rep*. 2020;10(1):7609.
15. Sinclair CF, Téllez MJ, Ulkatan S. Continuous laryngeal adductor reflex versus intermittent nerve monitoring in neck endocrine surgery. *Laryngoscope*. 2020;131:230-236. https://doi.org/10.1002/lary.28710.
16. Nisi P, Piva G, Cozzani F, et al. Intraoperative neuromonitoring in traditional and miniinvasive thyroidectomy. A single center experience in 1652 nerve at risk. *Acta Biomed*. 2020;91(1): 64-69.
17. Schneider R, Machens A, Lorenz K, Dralle H. Intraoperative nerve monitoring in thyroid surgery-shifting current paradigms. *Gland Surg*. 2020;9(suppl 2):S120-S128.

18. Goretzki PE, Schwarz K, Brinkmann J, Wirowski D, Lammers BJ. The impact of intraoperative neuromonitoring (IONM) on surgical strategy in bilateral thyroid diseases: is it worth the effort? *World J Surg*. 2010; 34(6):1274-1284.
19. Chen HK, Chen CL, Wen KS, Lin YF, Lin KY, Uen YH. Application of transoral continuous intraoperative neuromonitoring in natural orifice transluminal endoscopic surgery for thyroid disease: a preliminary study. *Surg Endosc*. 2018;32(1):517-525.
20. Dionigi G, Kim HY, Wu CW, et al. Neuromonitoring in endoscopic and robotic thyroidectomy. *Updates Surg*. 2017;69(2):171-179.

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