

Surgery of the thyroid gland

- How to minimize surgical complication

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Aim of surgical management of thyroid disease (thyroid cancer, Graves' disease, etc)

- Complete removal of tumor
- Minimizing recurrence
- Prevention of complications : lifelong disability
 - recurrent laryngeal nerve injury
 - hypoparathyroidism

- excellent survival rate of most differentiated thyroid cancer
- prevention of complication
: as important as complete removal of the tumor

Painful post-thyroidectomy complications to both surgeons and patients depending on the situation

1. Expanding hematoma by arterial bleeding

- can lead to death of the patients by airway obstruction

2. Bilateral RLN injury

- airway obstruction and dysphonia

3. Unilateral RLN injury

- inconvenient
- the most common thyroidectomy related malpractice lawsuit
- even temporary paralysis can be very painful
in professional voice user

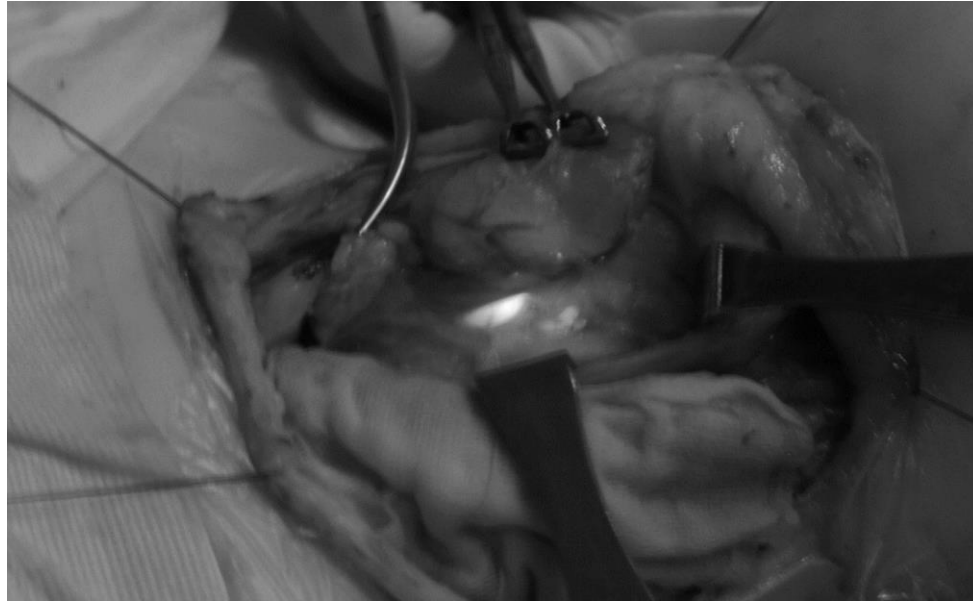
4. External branch of superior laryngeal nerver injury

- easy voice fatigue, decreased pitch, inability to project voice

Surgery of thyroid gland

- Recent advances in intraoperative parathyroid gland mapping and localization with Near-Infrared Autofluorescence (NIR AF)
- Recent advances in IONM
 - endotracheal EMG tube
 - Non-endotracheal EMG tube
 - ; needle electrode
 - ; skin adhesive electrode

Parathyroid gland mapping and localization using autofluorescence



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9th IRSS, Oct. 26-27, Seoul, Korea

Post-thyroidectomy hypoparathyroidism

- The most common complication of total thyroidectomy
 - temporary : ~ 46% / permanent : ~ 6.6%
- **Typical Sx and Sn**
 - perioral numbness, acral paresthesia (hand, foot)
 - muscle cramp
 - Trousseau sign of latent tetany (carpopedal spasm)
 - Chvostek's sign
 - laryngeal spasm
 - seizure
 - mental change - anxiety, confusion
 - QT Interval prolongation
 - cardiac arrest

Long-term effects of postoperative hypoparathyroidism in benign thyroid disease

BJS

Original article

Mortality in patients with permanent hypoparathyroidism after total thyroidectomy

M. Almquist ✉, K. Ivarsson, E. Nordenström, A. Bergenfelz

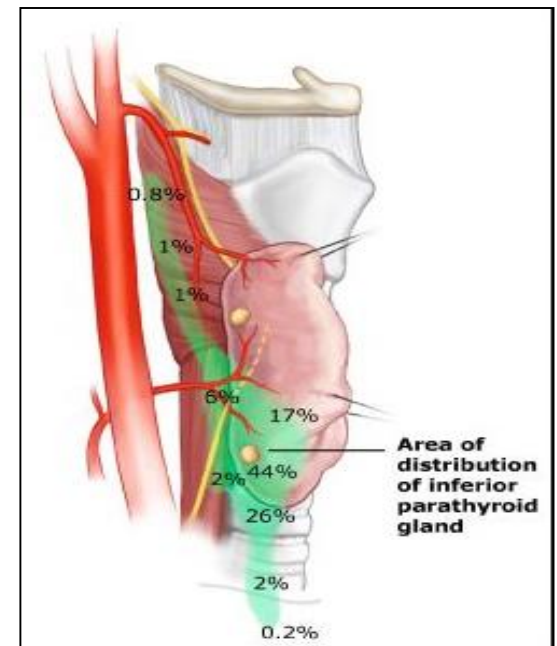
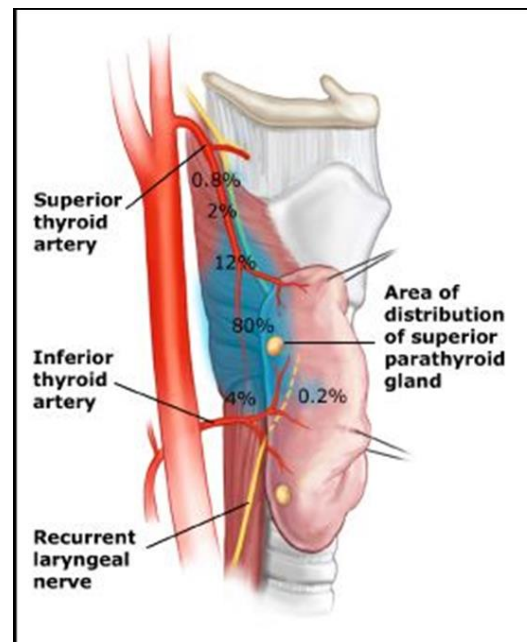
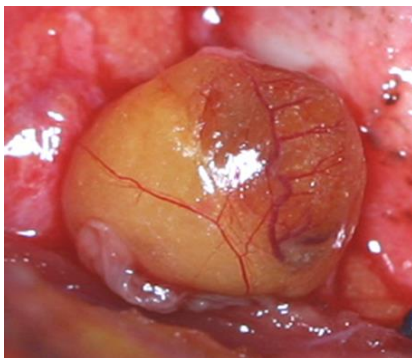
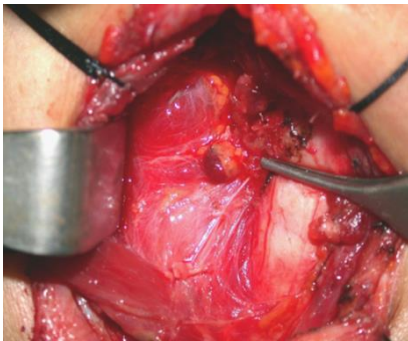
First published: 17 April 2018 | <https://doi.org/10.1002/bjs.10843> | Cited by: 6

- The risk of death in benign thyroid disease (**hazard ratio 2.09**)
 - a twofold higher among patients with permanent hypoparathyroidism after TT than patients without permanent hypoparathyroidism
- The reason : unclear
 - the use of large, supraphysiological doses of active vitamin D?
 - lower PTH levels?

Skills of intraoperative parathyroid identification

- basic requirement for surgeons to be equipped

- Less experienced surgeons in thyroidectomy
 - difficult to localize the parathyroid gland
 - : due to small size, inconspicuous coloring, variable location of PG



Intraoperative parathyroid identification and preservation

- the must procedure to learn

- Highly experienced surgeons
 - even the meticulous dissection can also result in inadvertent parathyroid excision during thyroidectomy in 9.1–15%

Lin et al, Laryngoscope, 2002

Lee et al, Laryngoscope, 1999

Sasson et al, Arch Otolaryngol HNS

No reliable intraoperative method to identify the normal parathyroid gland during thyroid surgery

- Surgeon's main tool has been an intuitive visual inspection that could be gained through extensive experiences
 - subjective, often inconclusive

Near-infrared techniques for intraoperative real-time localization of parathyroid gland using auto-fluorescence

- 2 types of commercialized equipment – approved by FDA in 2018
 - Fluobeam 800® as NIR AF **imaging system**
 - PTeye as NIR AF fiber probe-based **system (spectroscopy)**



Fluobeam



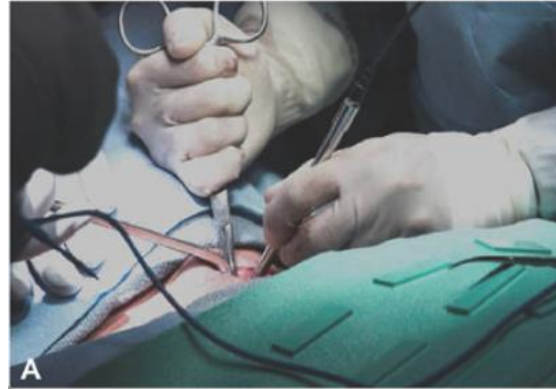
PTeye

Fluobeam - commercialized NIR AF imaging system



- Can visualize parathyroid gland and surrounding tissues
- Needs both operating light and fluorescent room light turned off to get images
 - as the intensity of the AF from parathyroid gland is considerably weak
- To use the Fluobeam, it is necessary to maintain the operation room dark
 - can interrupt the work flow
 - a drawback

PTeye - commercialized NIR AF fiber probe based system

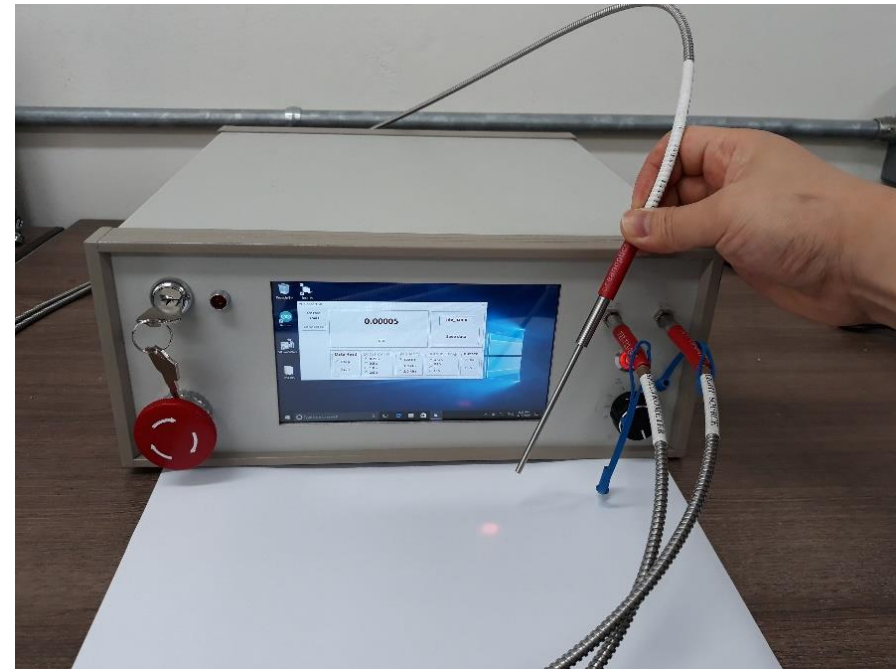


(Thomas G.
Surgery, 2019)

- Pteye probe
 - needs tissue contact and conducts point-by-point measurements
 - provides real-time quantitative information
 - works even in the presence of operating light, room light and head light
- Drawbacks
 - does not provide spatial information on the operation site
 - identifies only exposed parathyroid gland
 - : can not identify non-exposed parathyroid gland

Development of Lab-built NIR AF imaging system and probe system by Kosin Head and Neck Team

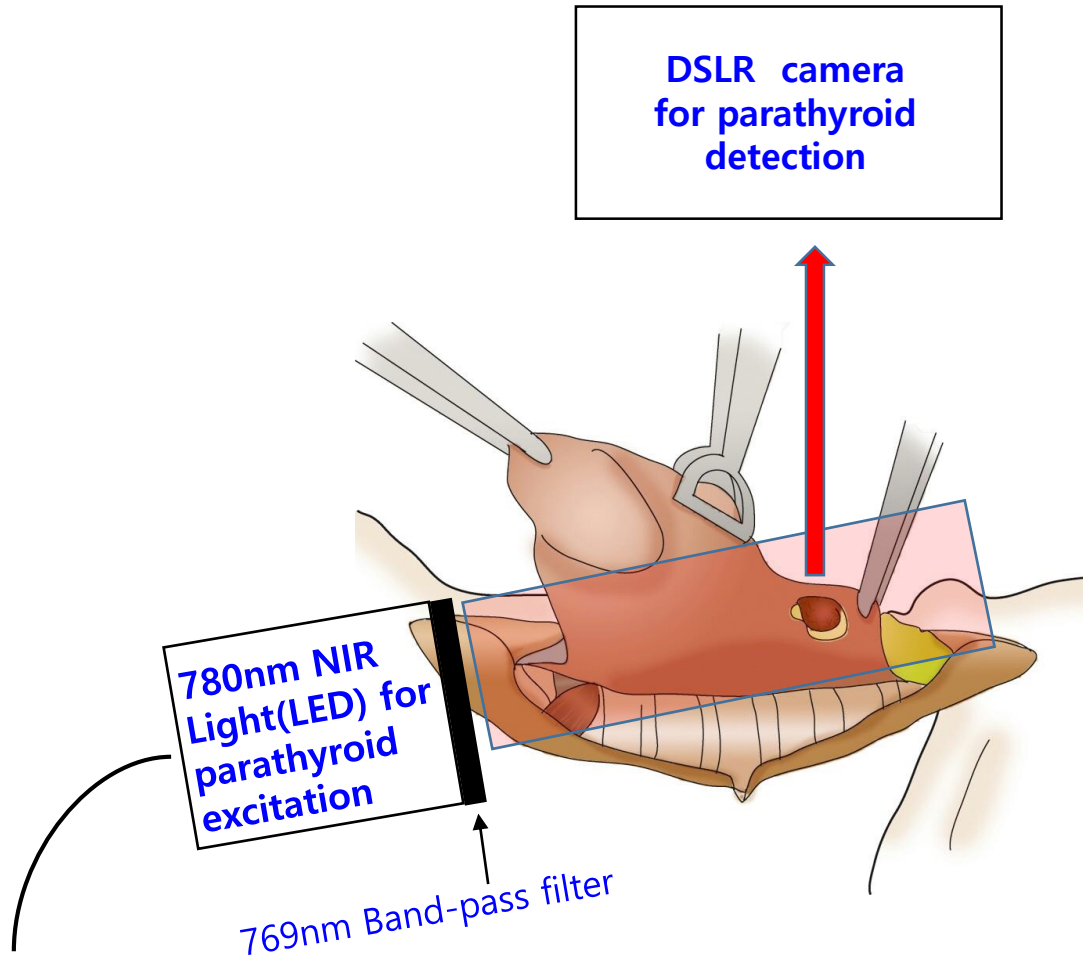
- usefulness of our imaging and probe techniques in **parathyroid gland mapping and localization**



- Near Infrared Autofluorescence (NIR AF) Imaging system using DSLR camera

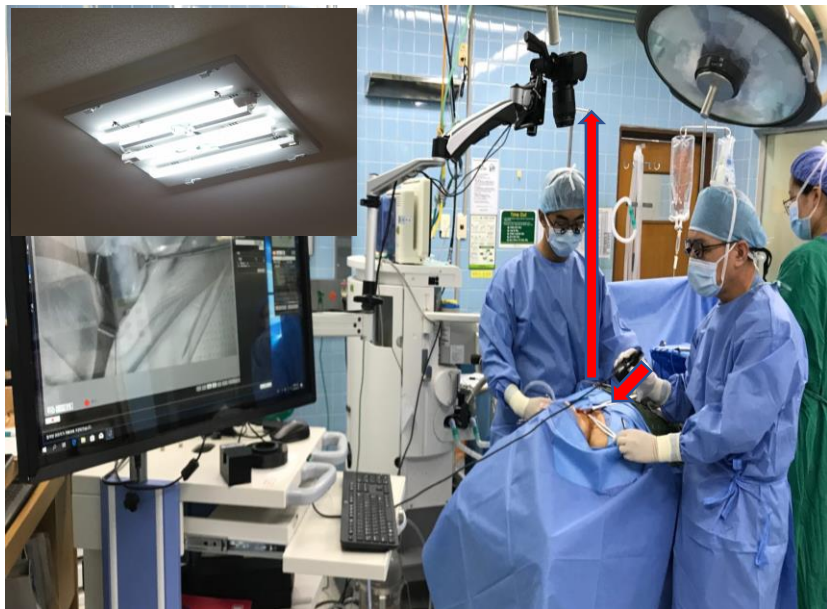
NIR AF probe

Schema of NIR AF imaging system using DSLR camera



Our NIR AF imaging system

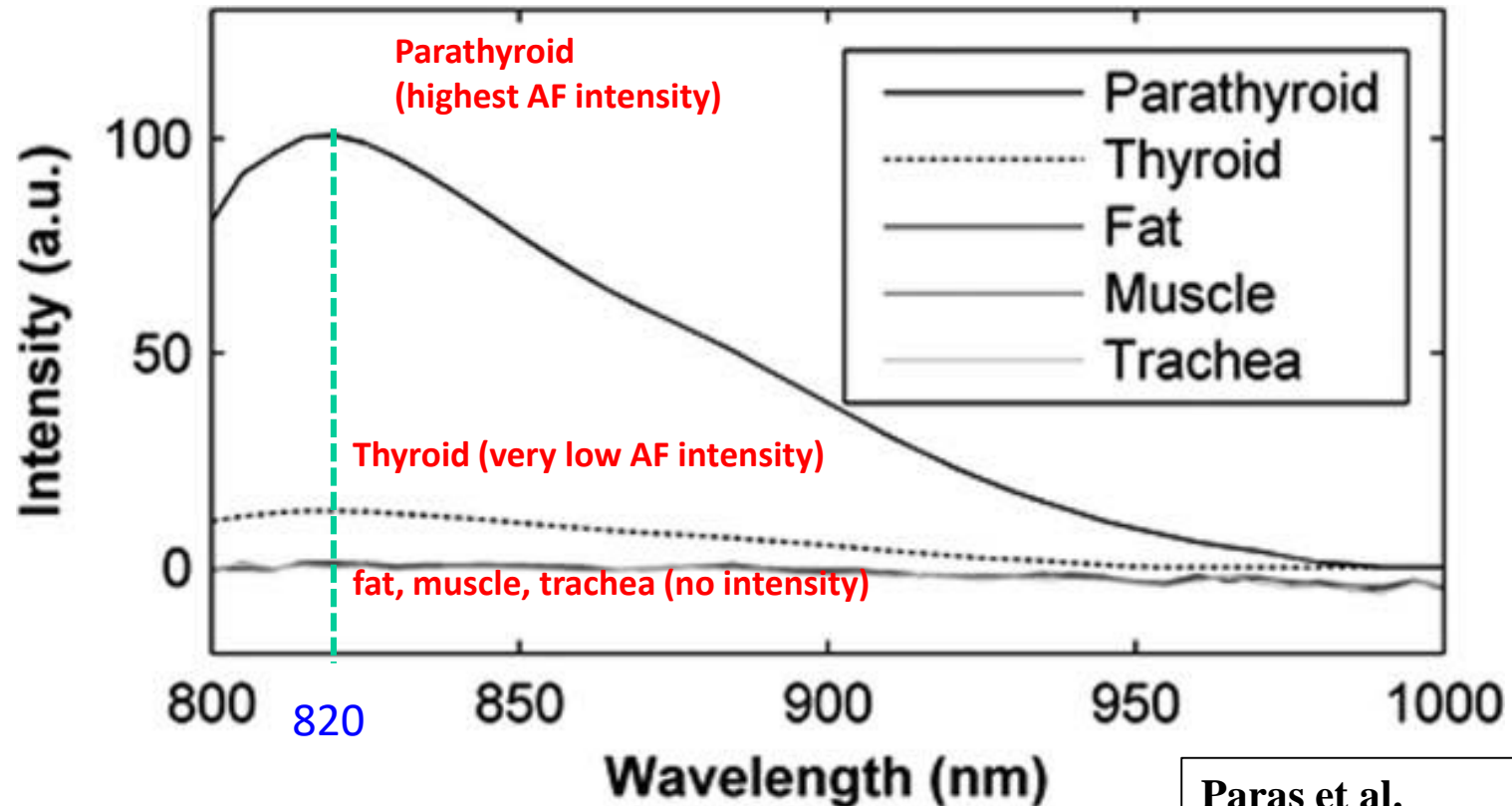
- uses AF : no need to use any exogenous contrast dye
- works in the presence of fluorescence light turned on (operating light turned off)
 - : enables us to maintain the work flow



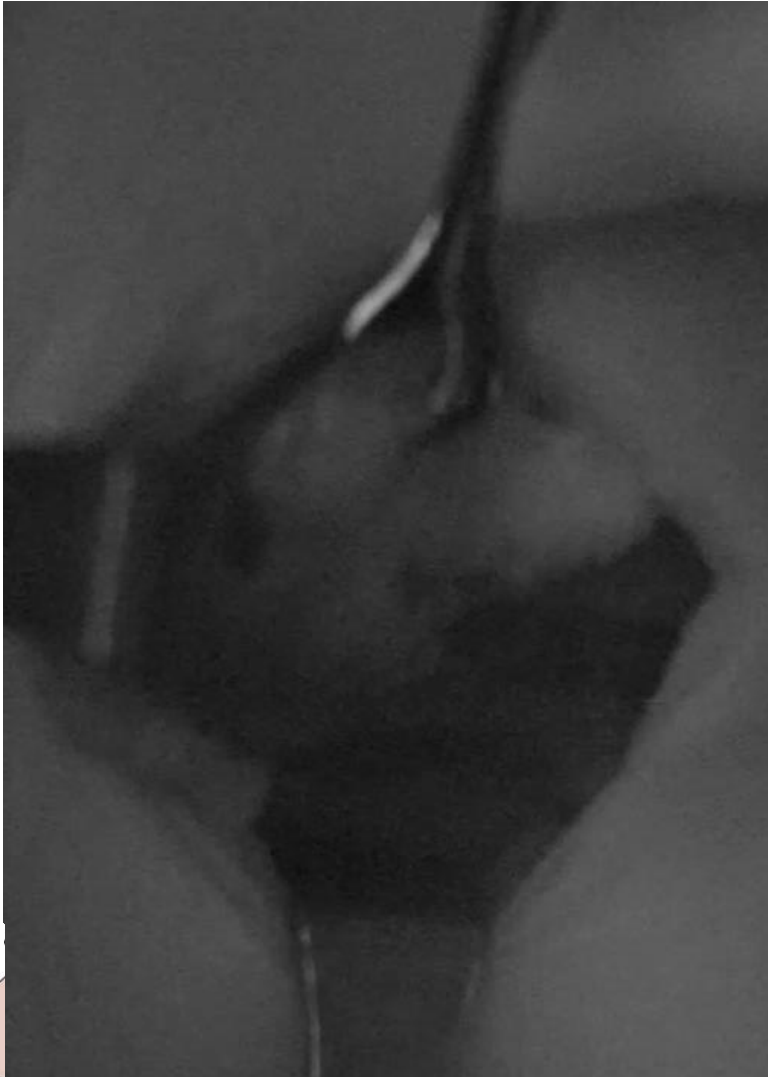
- Commercialized Fluobeam
 - needs both operating light and fluorescent light turned off

Comparison of NIR auto-fluorescence intensity in neck organs (Paras et al, 2011 of Vanderbilt group)

- **NIR AF** can discriminate parathyroid gland from surrounding tissues

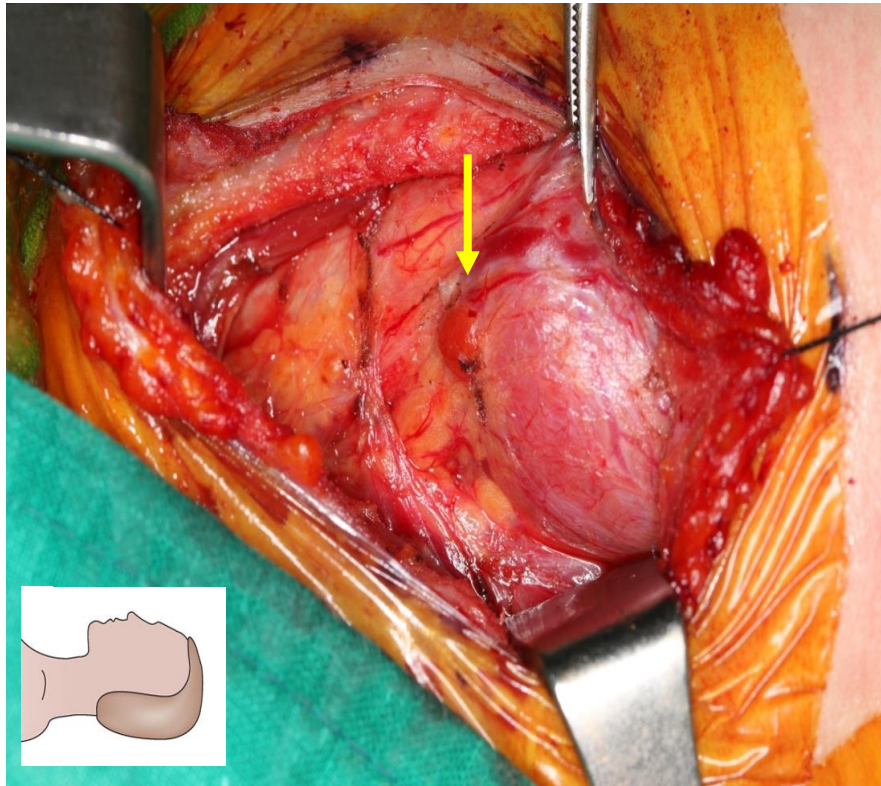


Ideal NIR AF image for parathyroid gland mapping

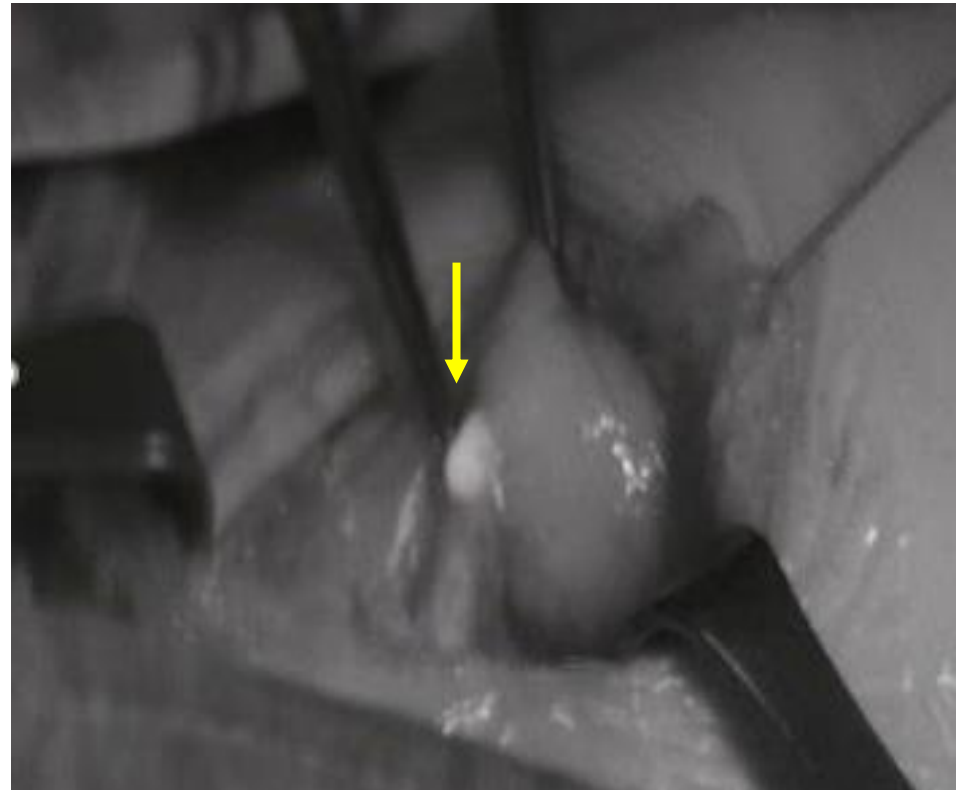
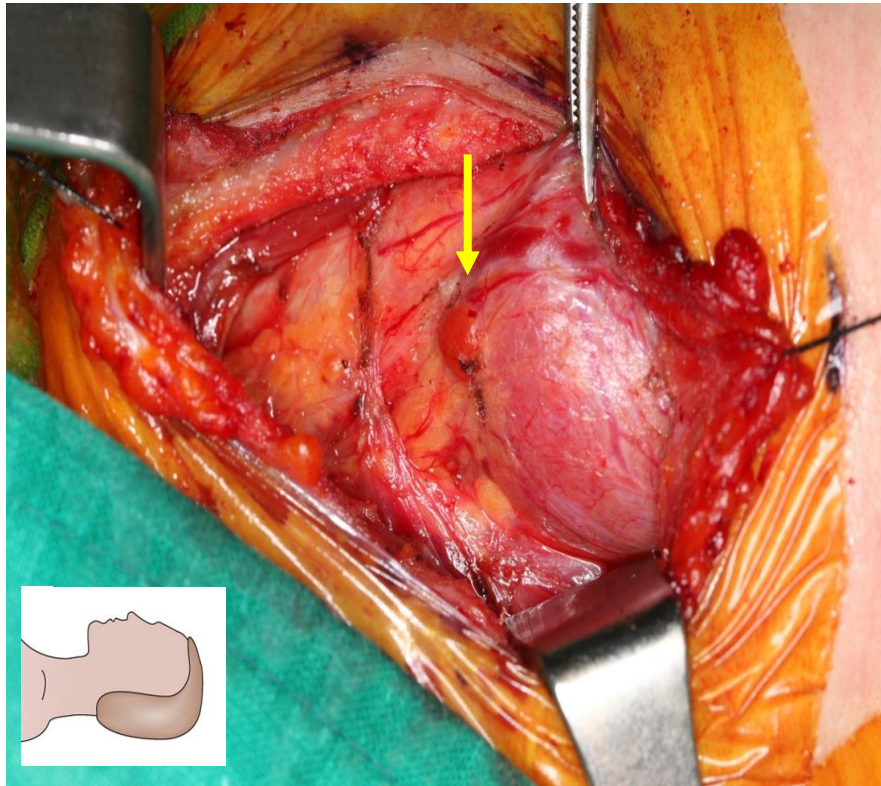


- parathyroid gland
: the strongest fluorescence
: secretory granule
- thyroid gland
: weak fluorescence
- surrounding fat, LN, and muscle
: no fluorescence

- No confidence for parathyroid gland?
- get confidence with the use of NIR AF imaging

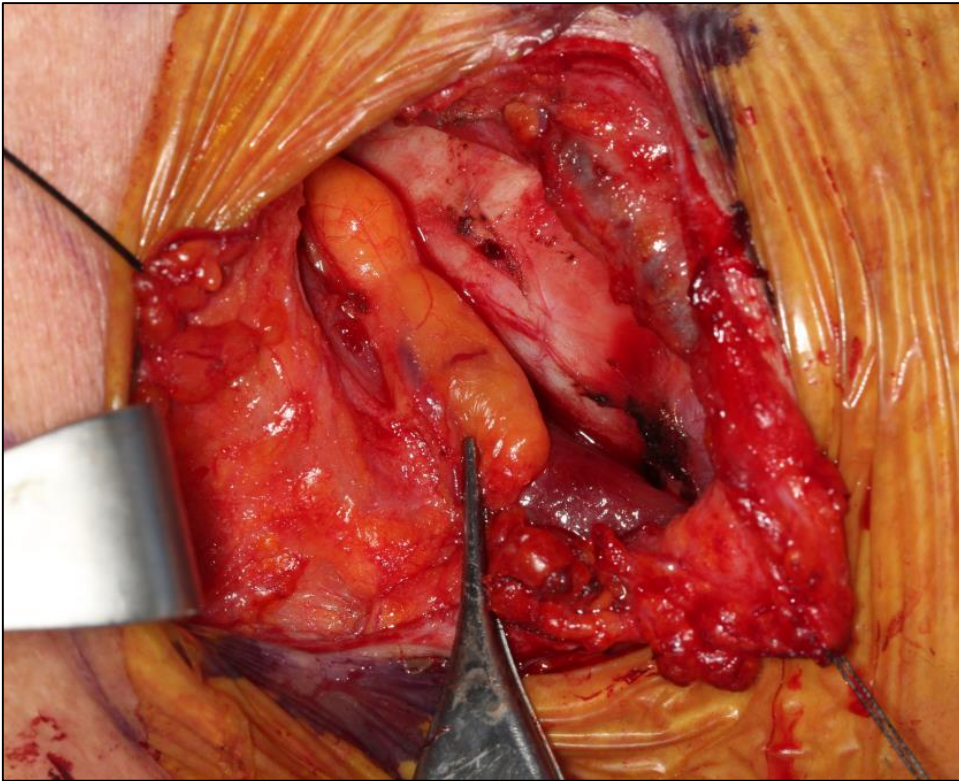


- No confidence for parathyroid gland?
- get confidence with the use of NIR AF imaging



Is this a parathyroid gland?

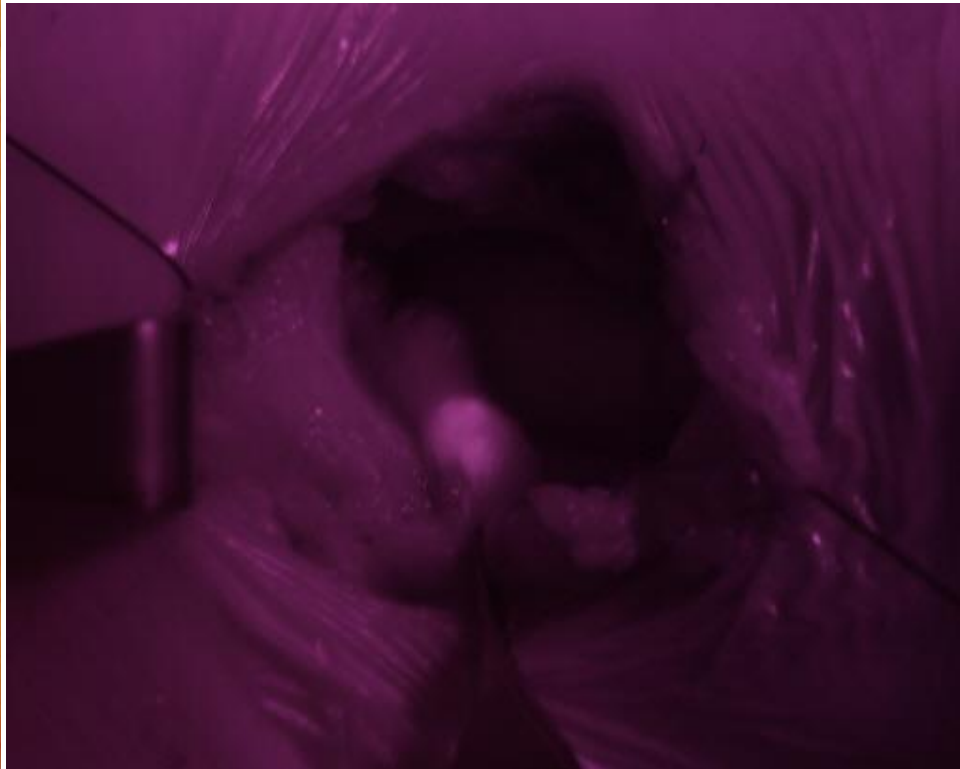
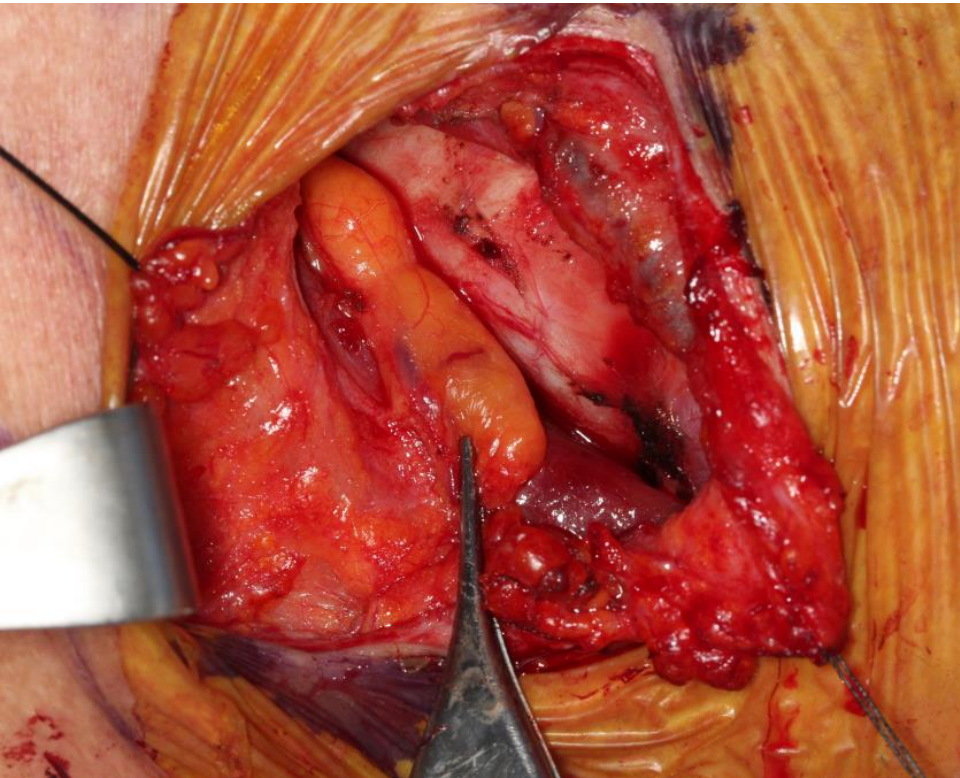
- equivocal by your naked eye



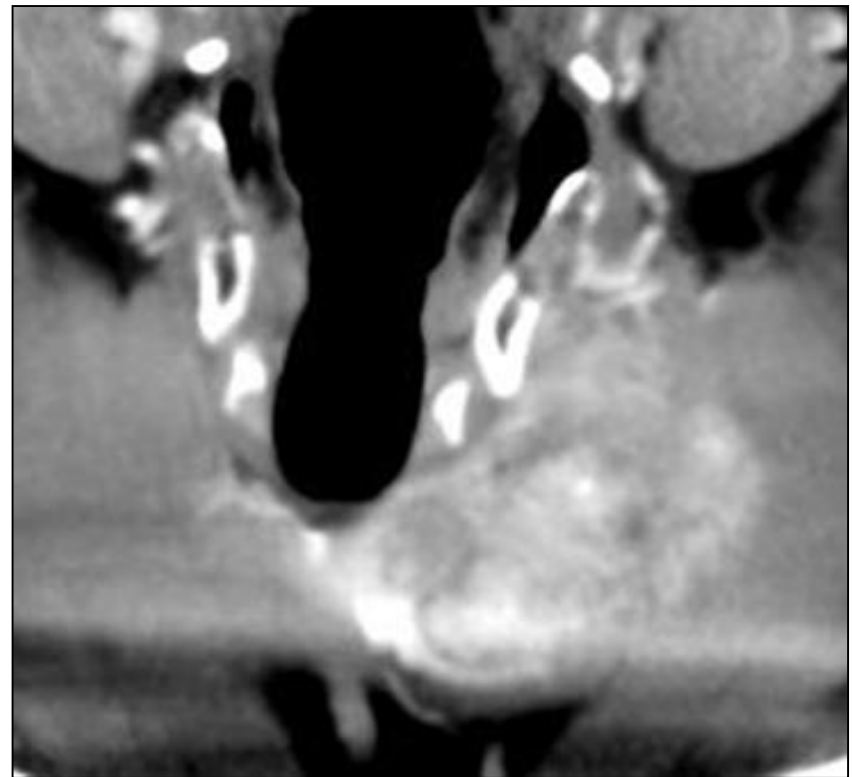
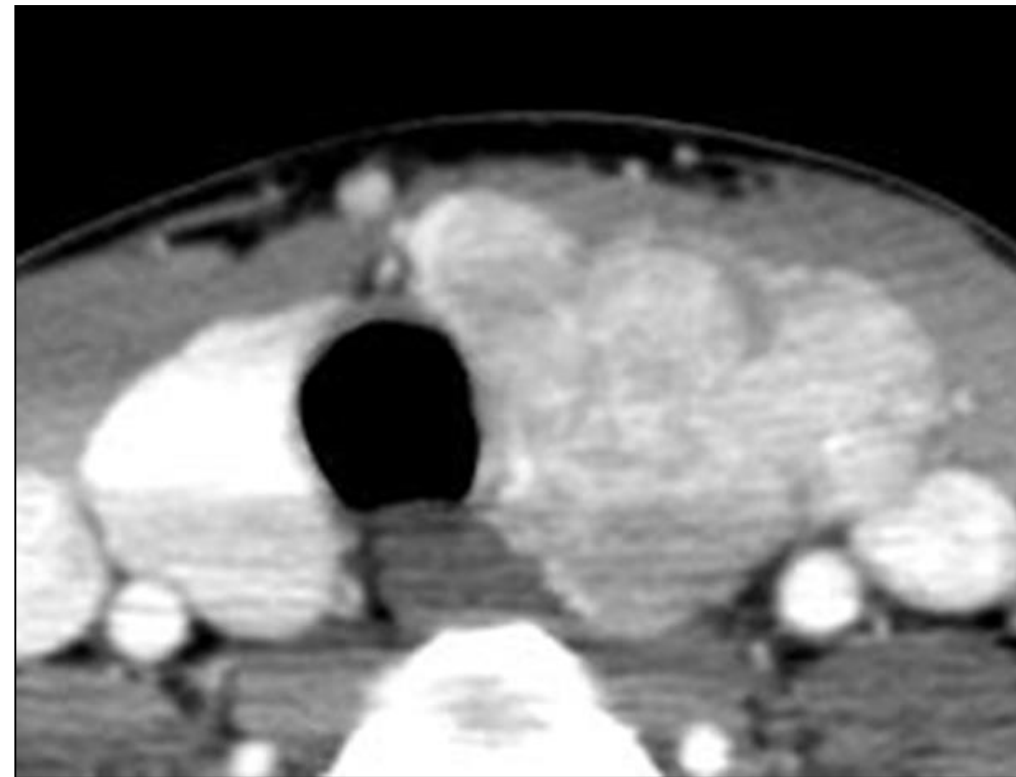
Is it a parathyroid gland?

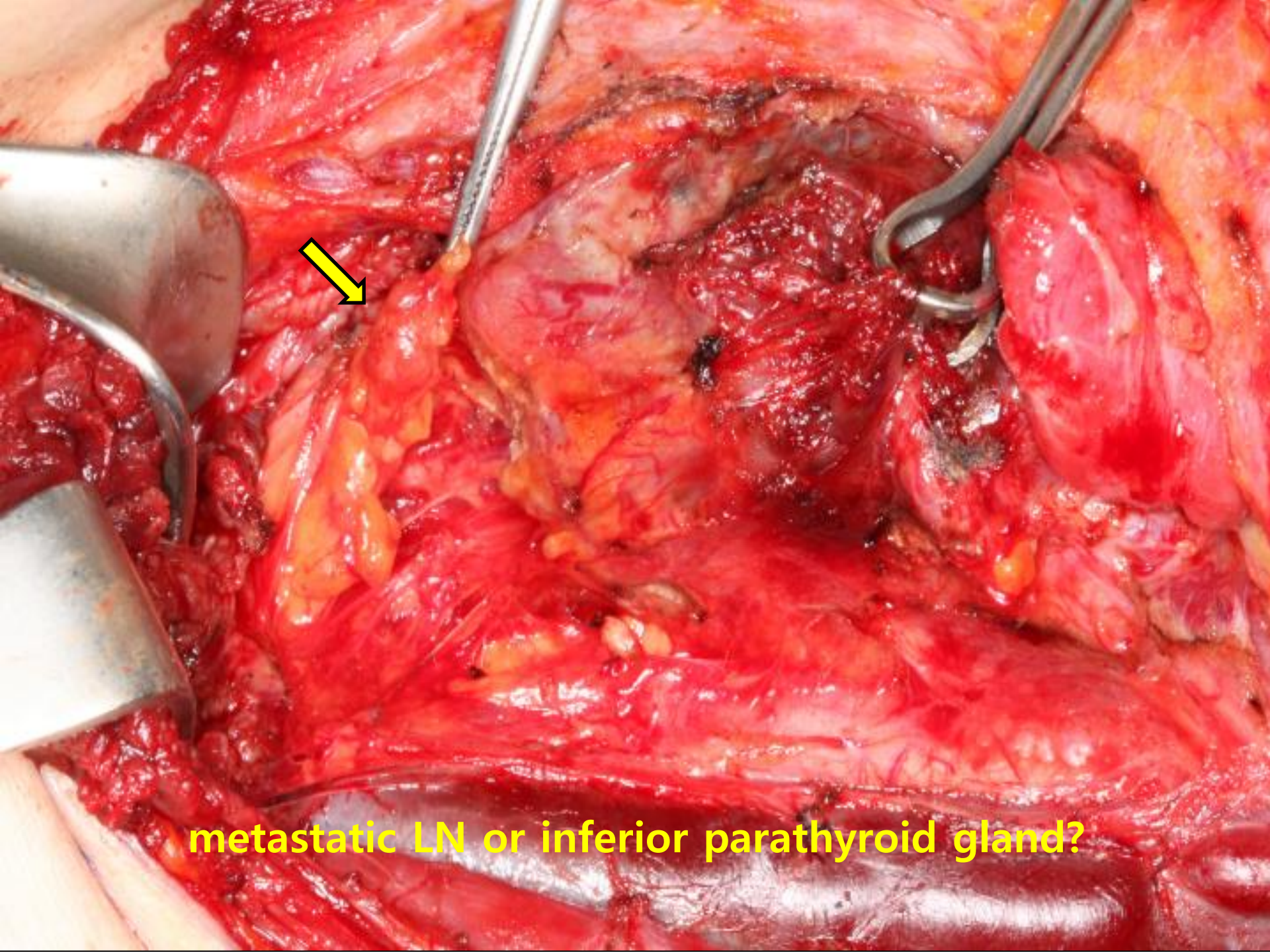
- equivocal by naked eye

- unequivocal by NIR AF imaging



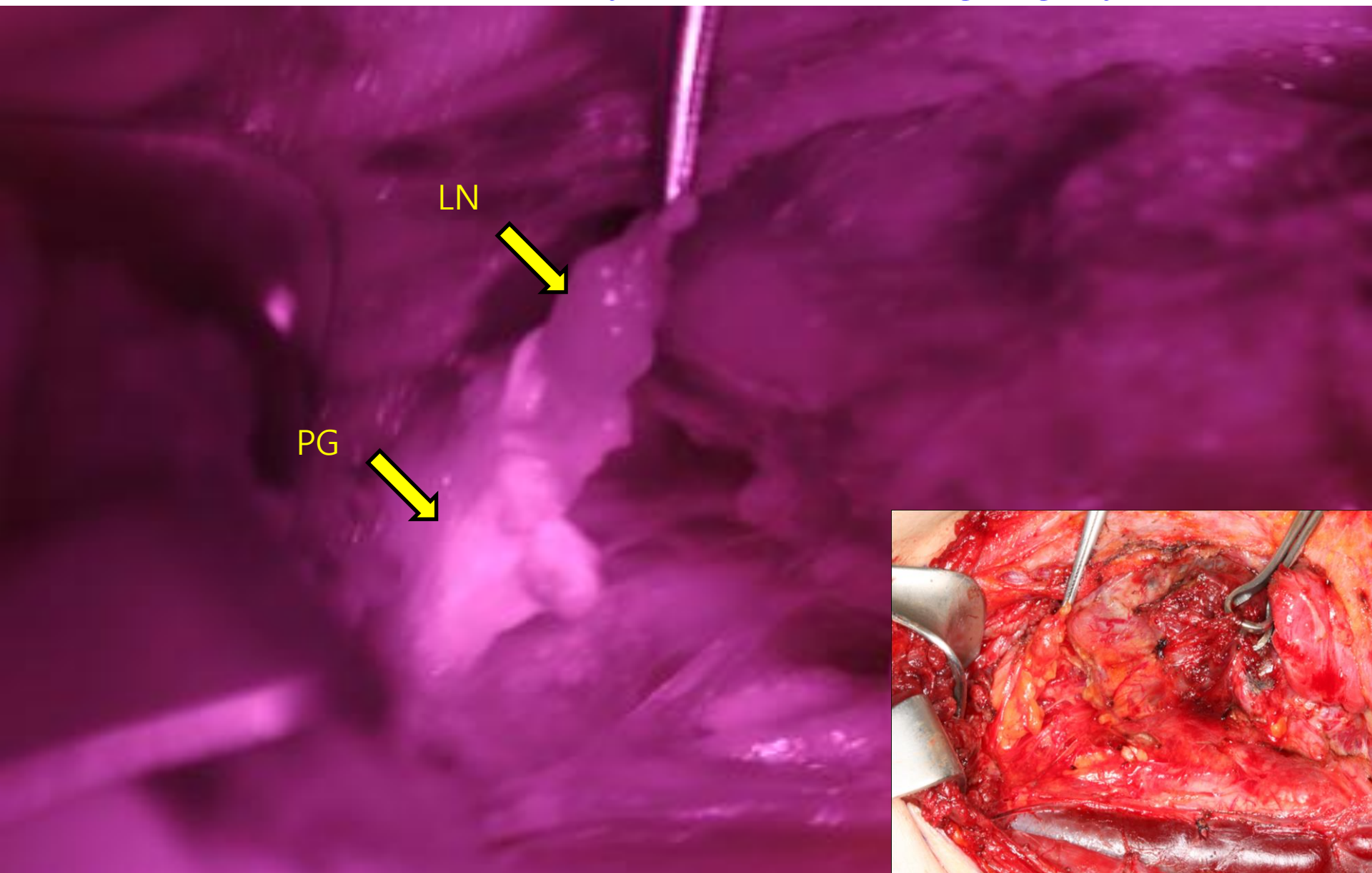
Left advanced PTC (4.5 cm) with left neck metastasis
(cT3N1b), 오0우 (M/33)





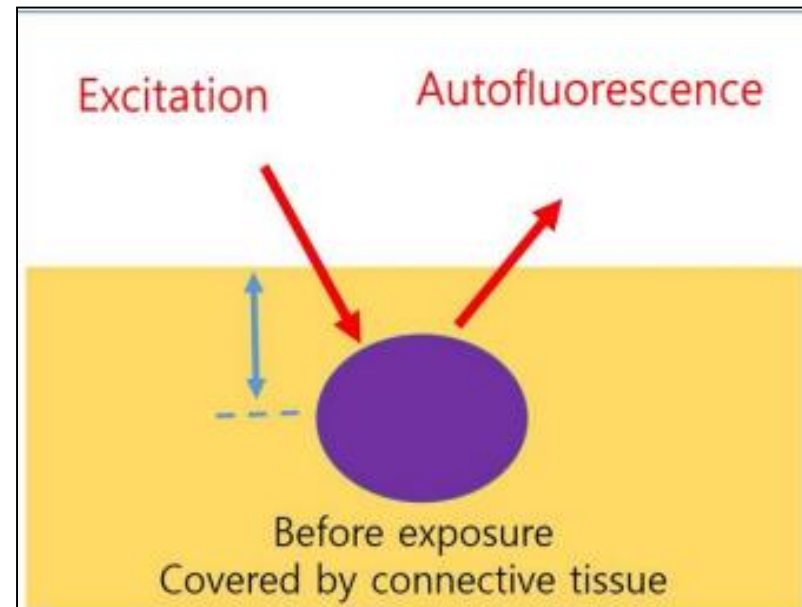
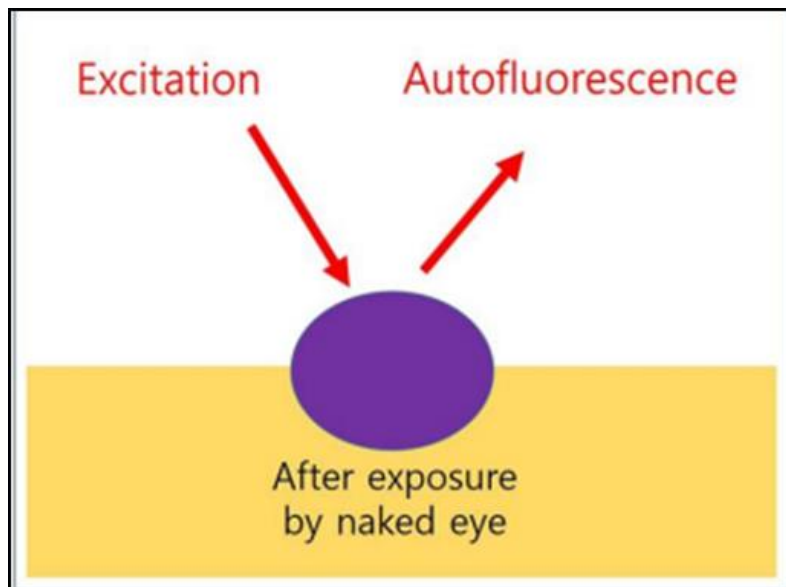
metastatic LN or inferior parathyroid gland?

Discrimination of the parathyroid from the metastatic LN by NIR AF imaging system



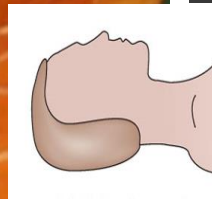
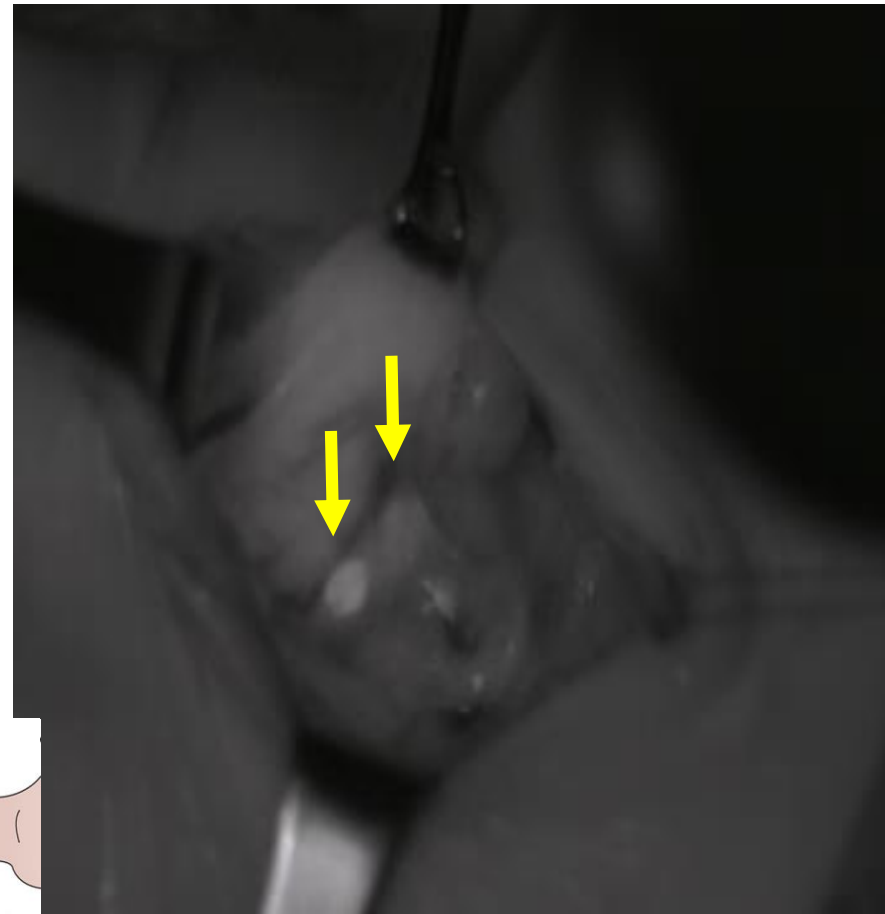
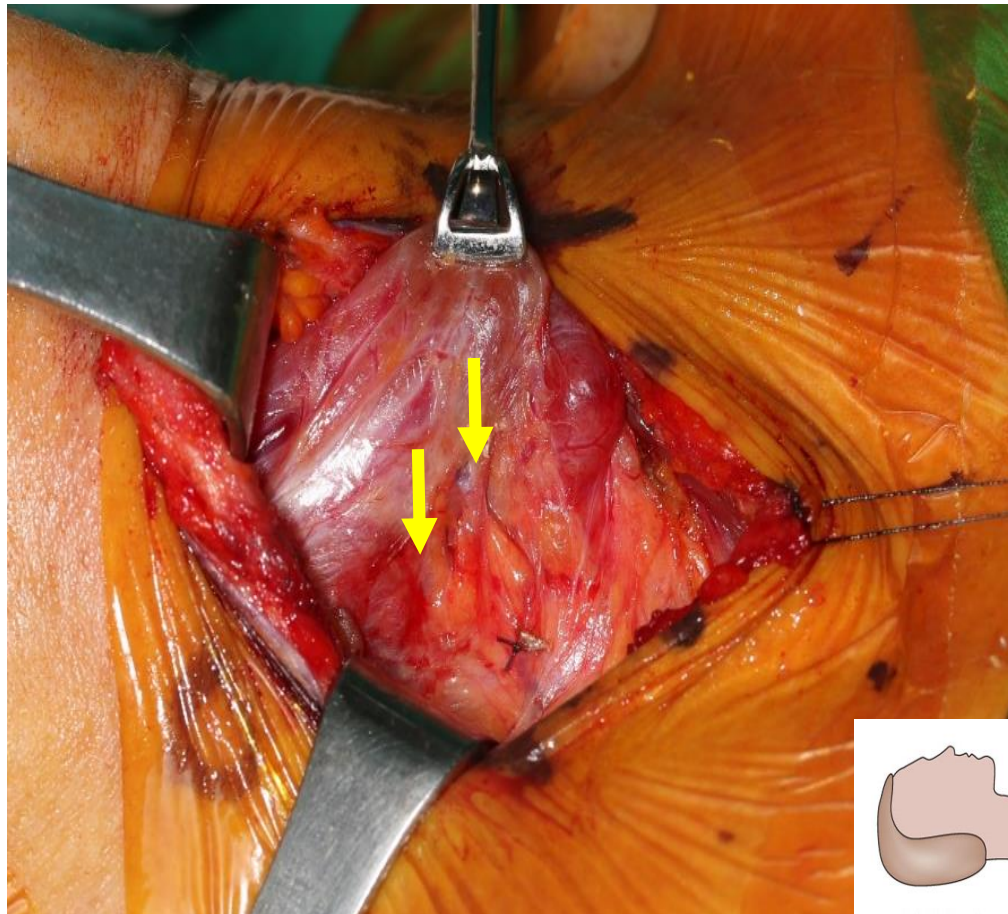
Endpoint of intraoperative parathyroid gland imaging

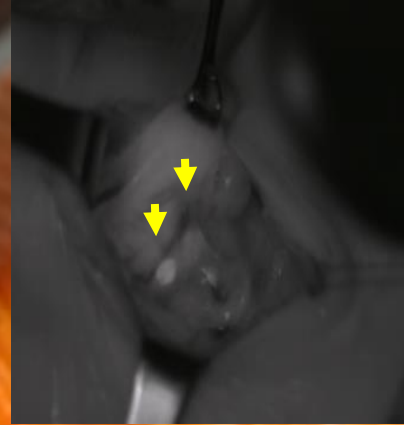
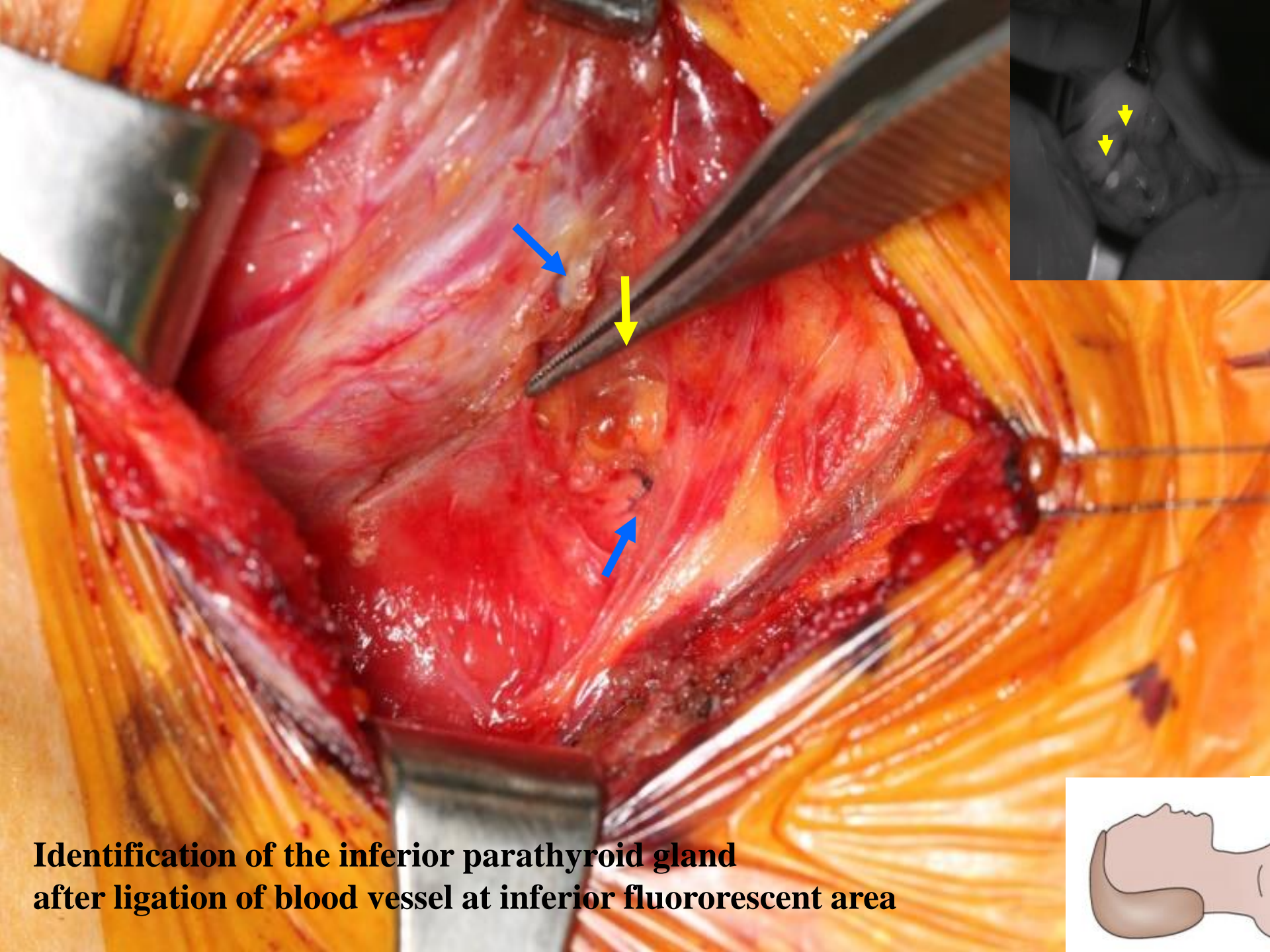
- not only to detect the exposed gland but also to preserve its function
- Just identifying the exposed parathyroid gland with NIR AF ; can be meaningful in most surgical situation
- **Early localization of the parathyroid gland buried by fat tissues**
 - more important for surgeons
 - for preservation of the parathyroid gland function



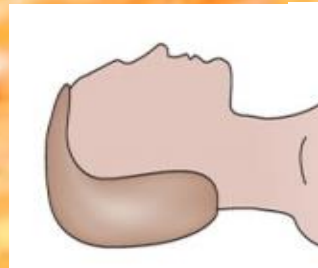
Case. Can we detect a parathyroid gland when it is covered by connective tissues or vessels?

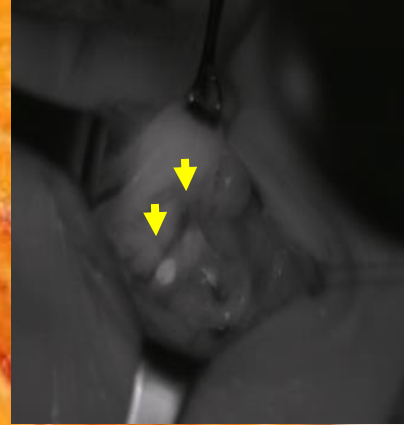
- autofluorescence image : 2 fluorescent areas with different intensity
- superior fluorescent area : covered by connective tissues
- inferior fluorescent area : covered by blood vessels



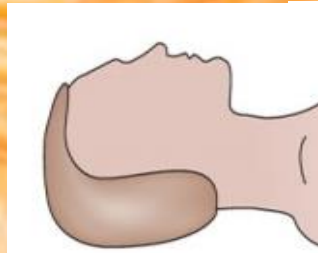


**Identification of the inferior parathyroid gland
after ligation of blood vessel at inferior fluorescent area**

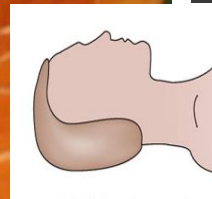
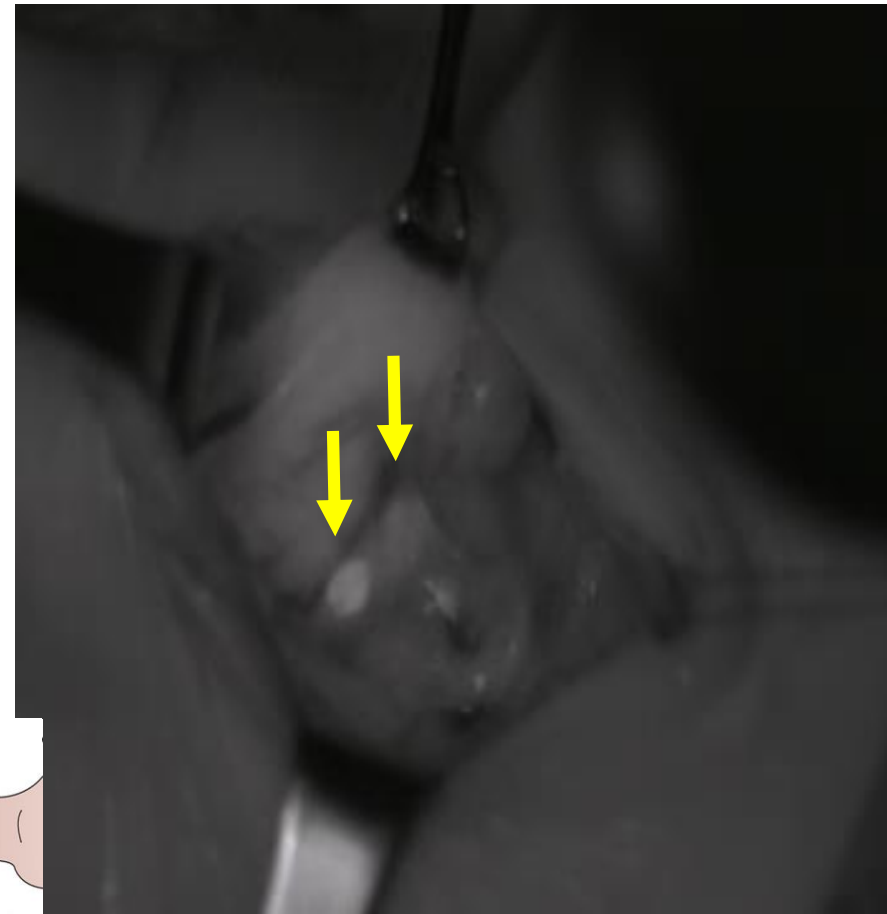
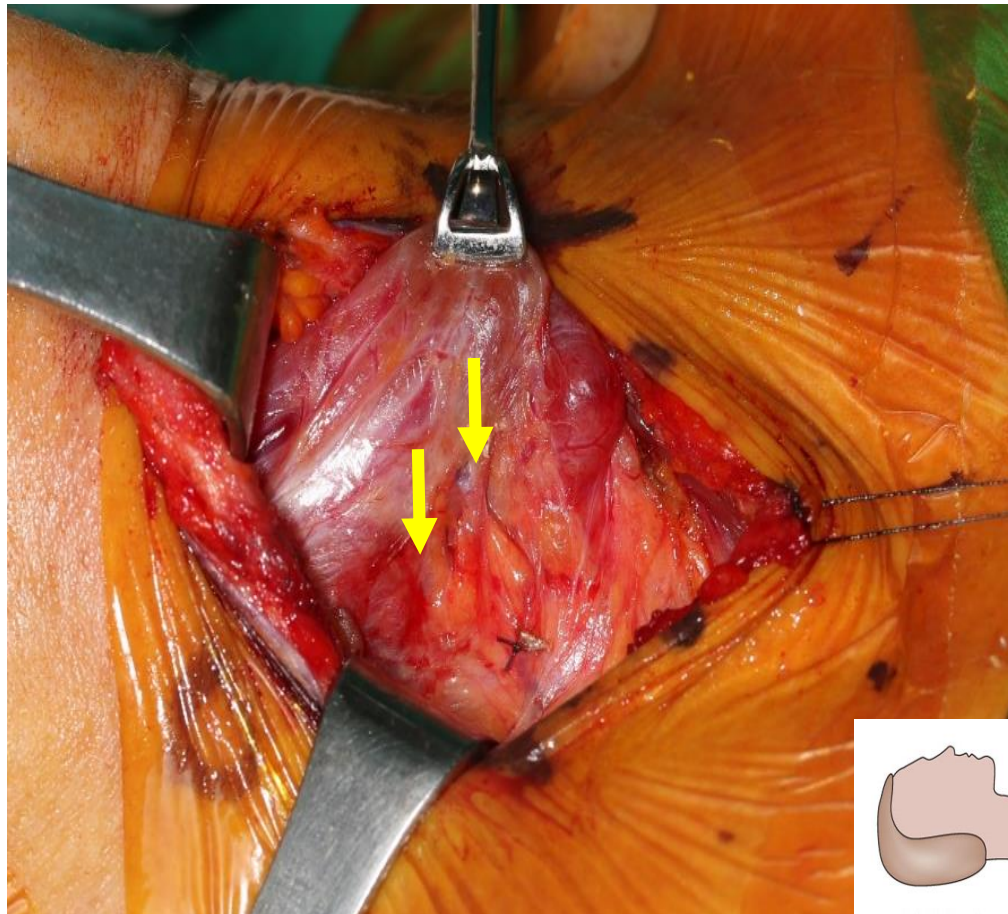




- **Identification of superior parathyroid gland after dissection of connective tissue at superior fluorescent area**



- Even the parathyroid glands covered by connective tissues or blood vessels can be detected with our imaging technique



Conceptualization of the parathyroid gland mapping

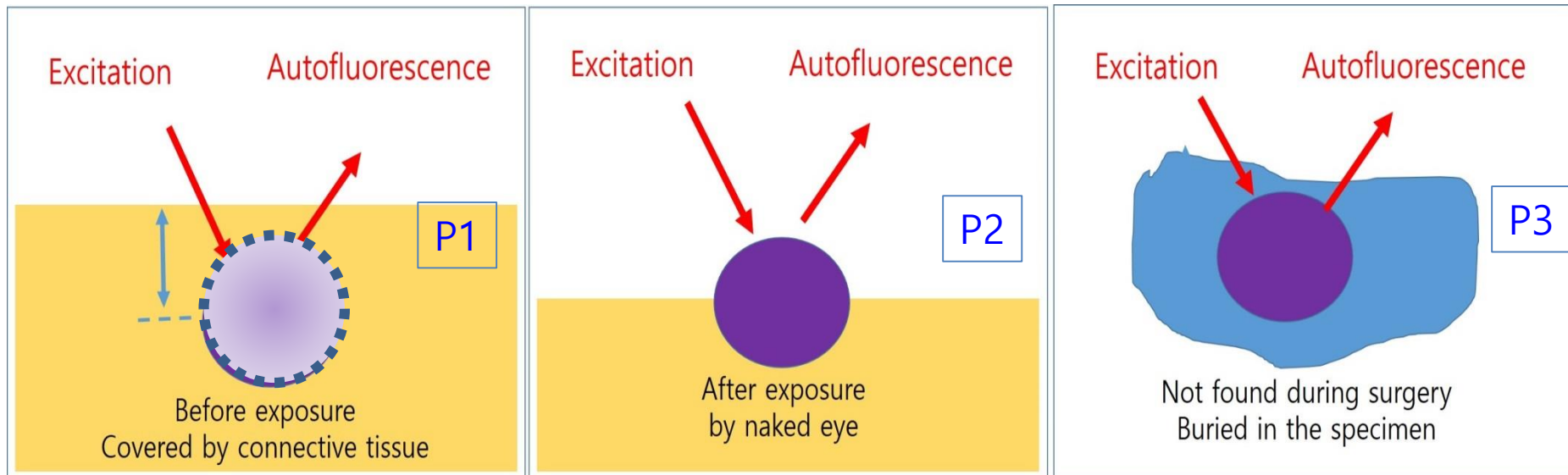
- definitive identification of parathyroid gland through localization process for parathyroid gland which was initially not visualized by naked eye

- Parathyroid gland mapping

Stage P1 - taking images before visual identification by surgeons

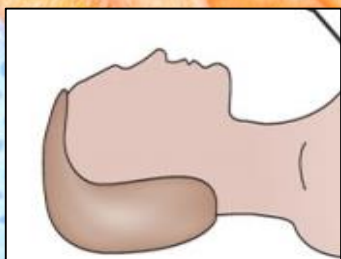
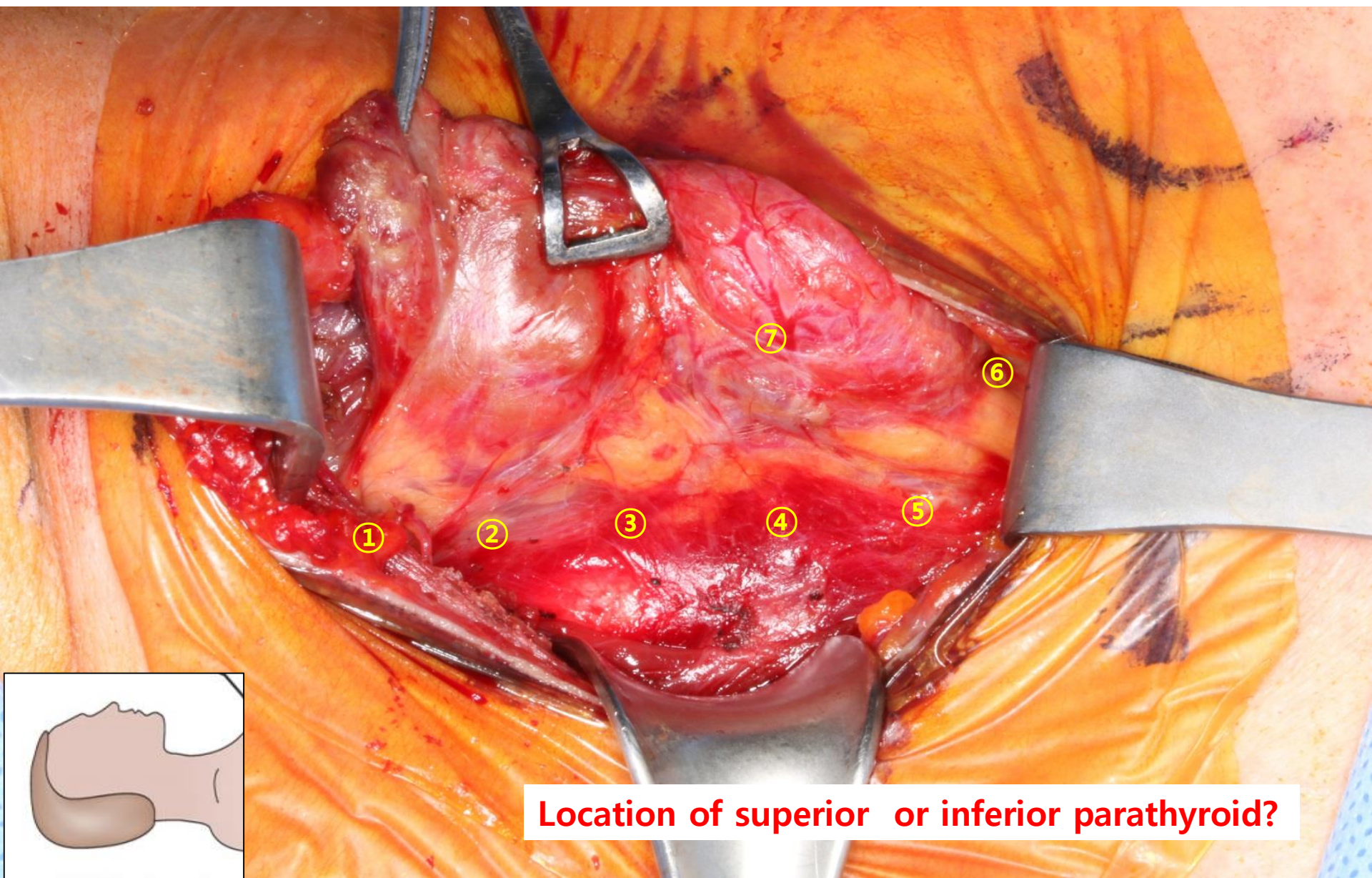
Stage P2 - taking images after visual identification by surgeons

Stage P3 - taking images in the removed specimen



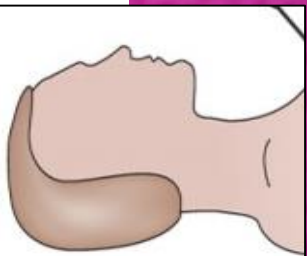
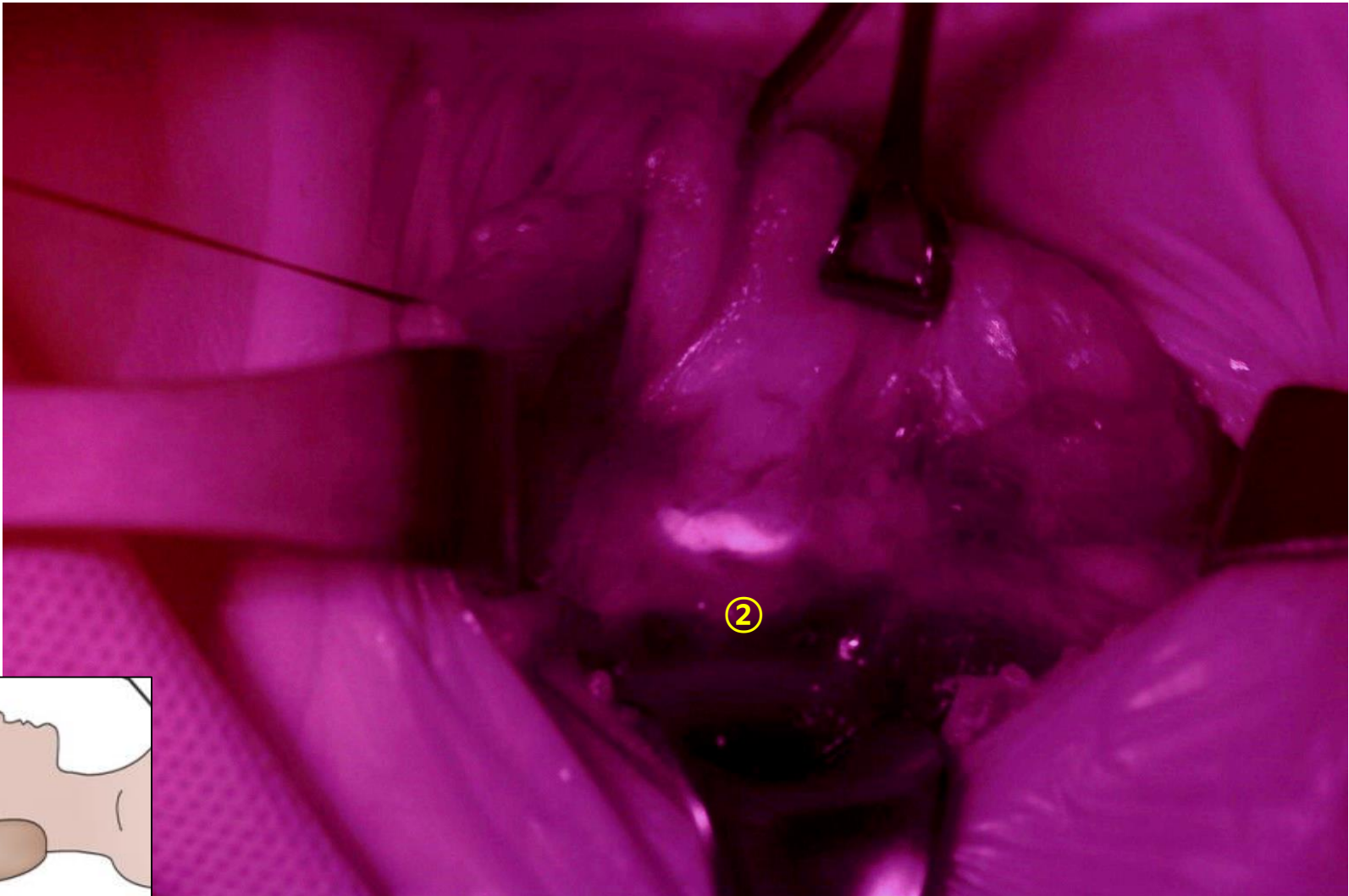
Cases of parathyroid gland mapping

Case. Before visual identification of parathyroid gland by surgeons

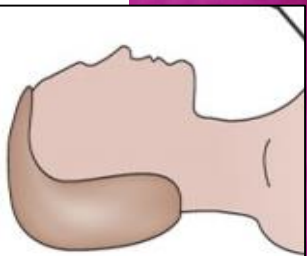


Location of superior or inferior parathyroid?

Localization of right superior parathyroid gland
(still covered by fatty connective tissues)
with NIR images

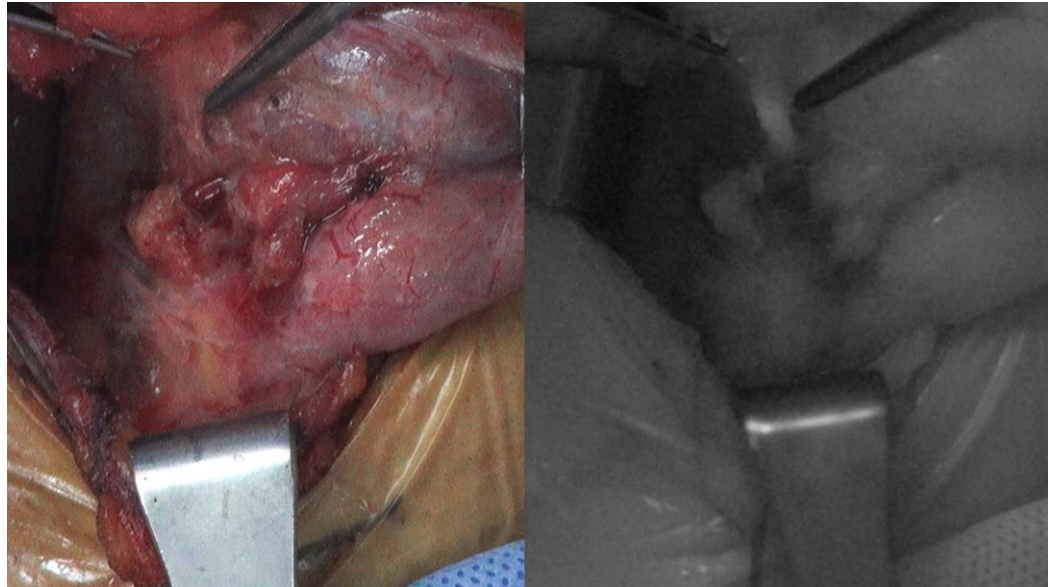


Localization of right inferior parathyroid gland
(still covered by adipose tissues)
with NIR imaging



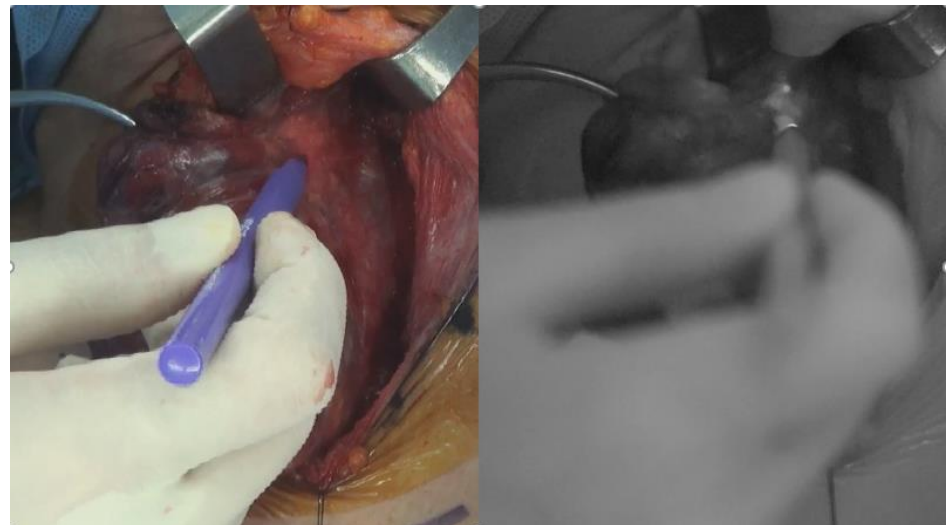
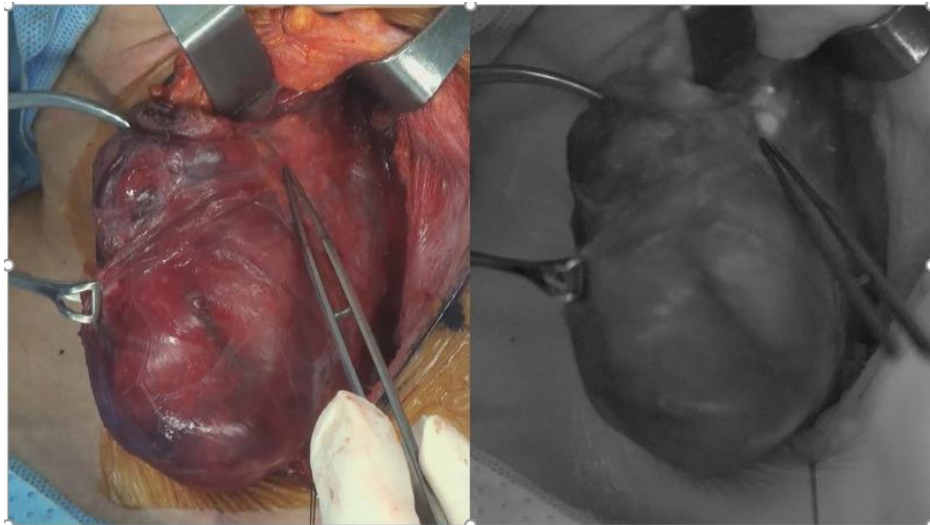
Upgraded the prototype to improve spatial information

- Added a video camera to facilitate anatomical guidance
 - can display both white light and NIR light images together



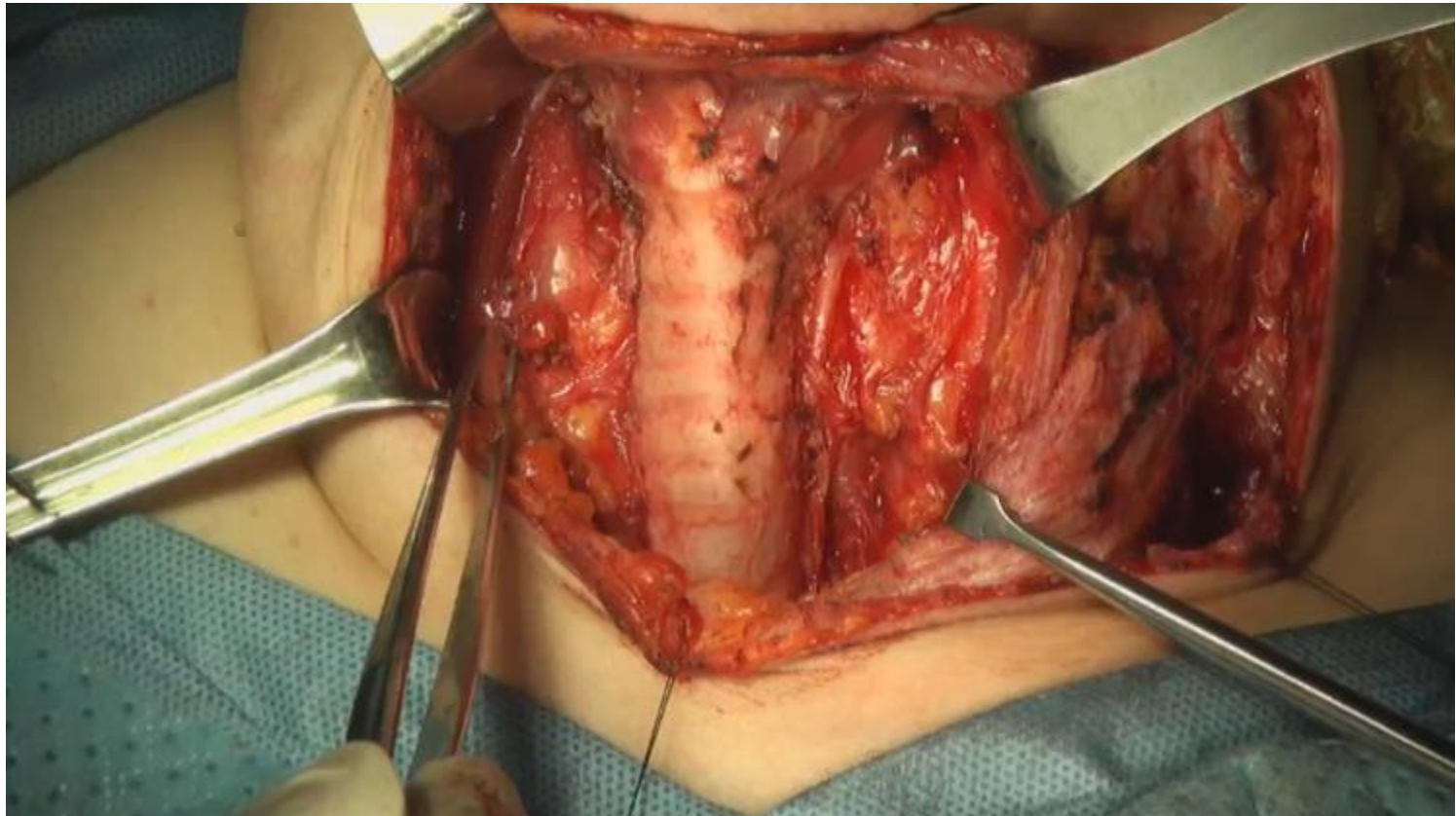
- AF image of sup. parathyroid gland hidden by connective tissue

Mapping by marking the potential location of non-exposed parathyroid gland based on NIR system



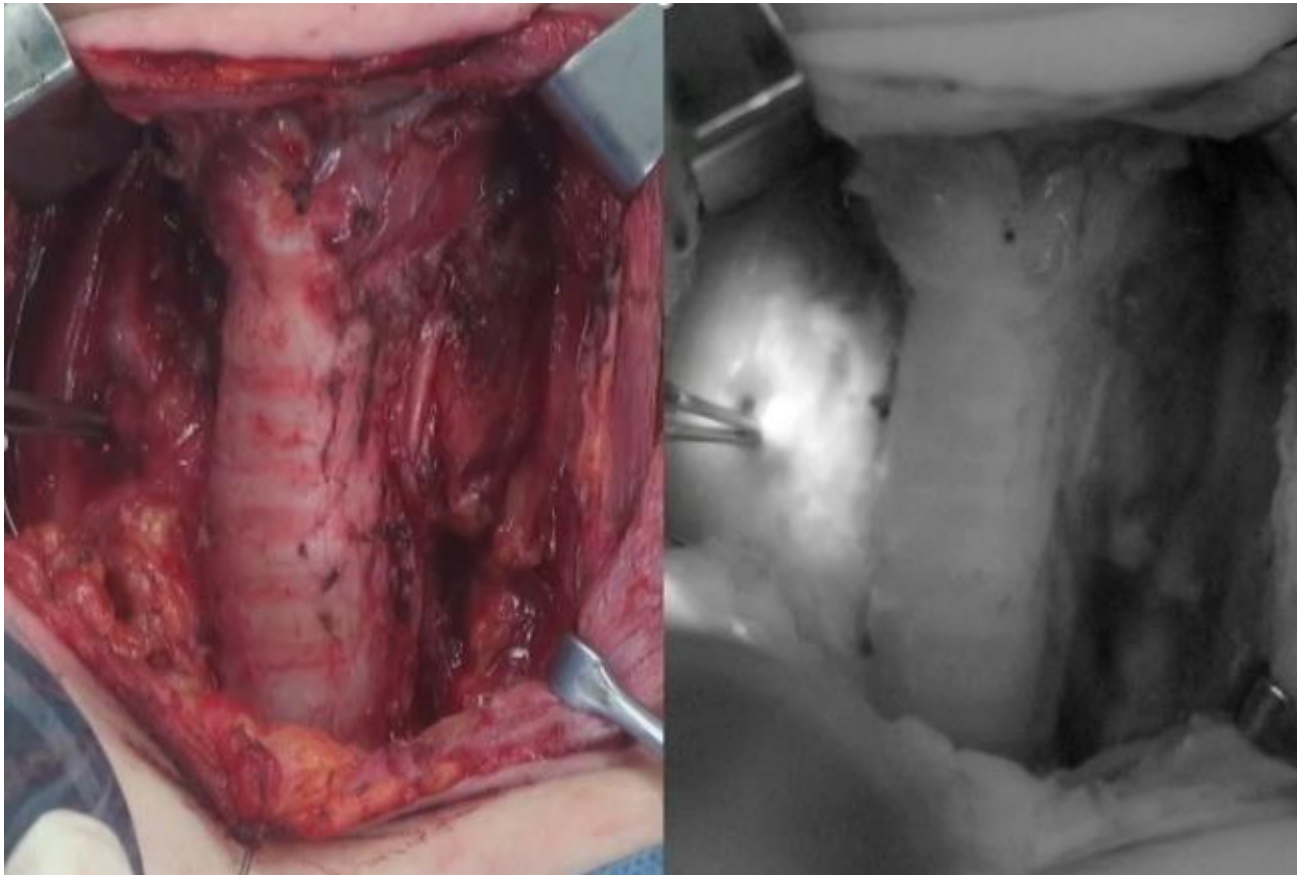
ICG angiography coupled with NIR AF imaging system - to assess the perfusion of parathyroid gland

- preservation of parathyroid glands
 - not necessarily mean the preservation of the function



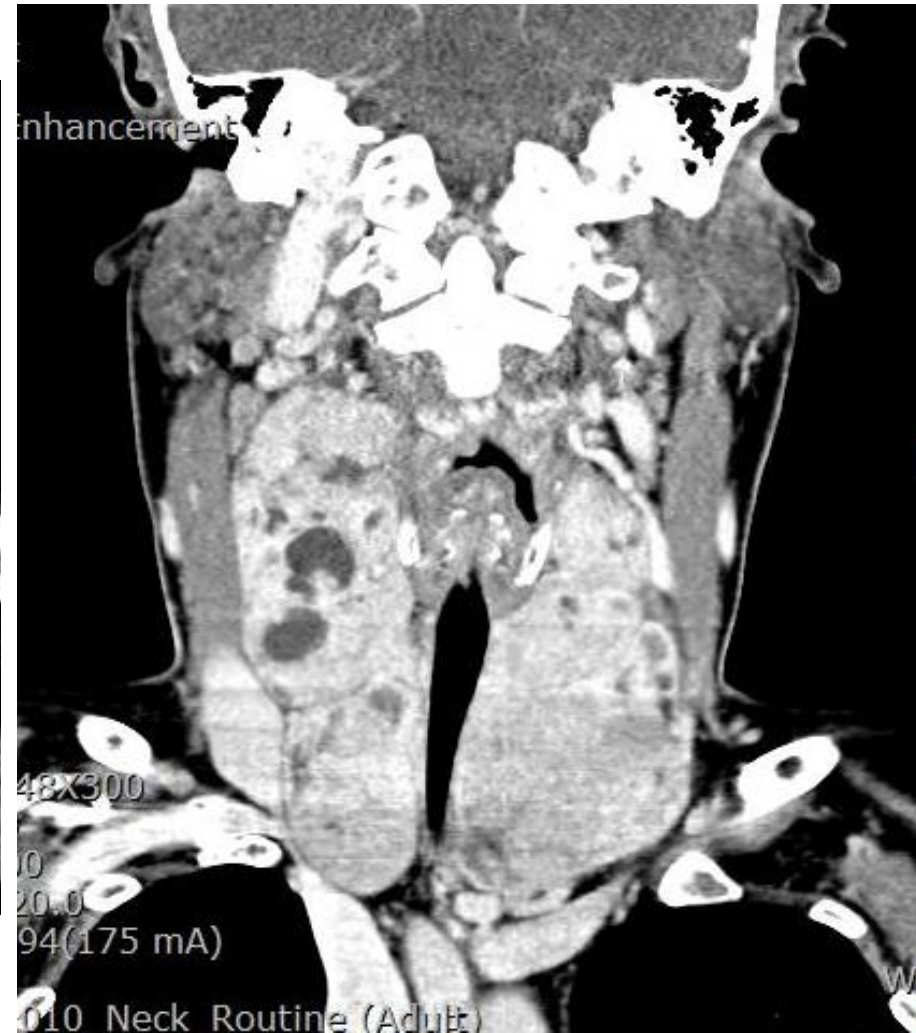
ICG angiography with NIR AF imaging system

- Right inferior PG : good blood flow and good perfusion
- Left superior PG : good perfusion even in the presence of congested color

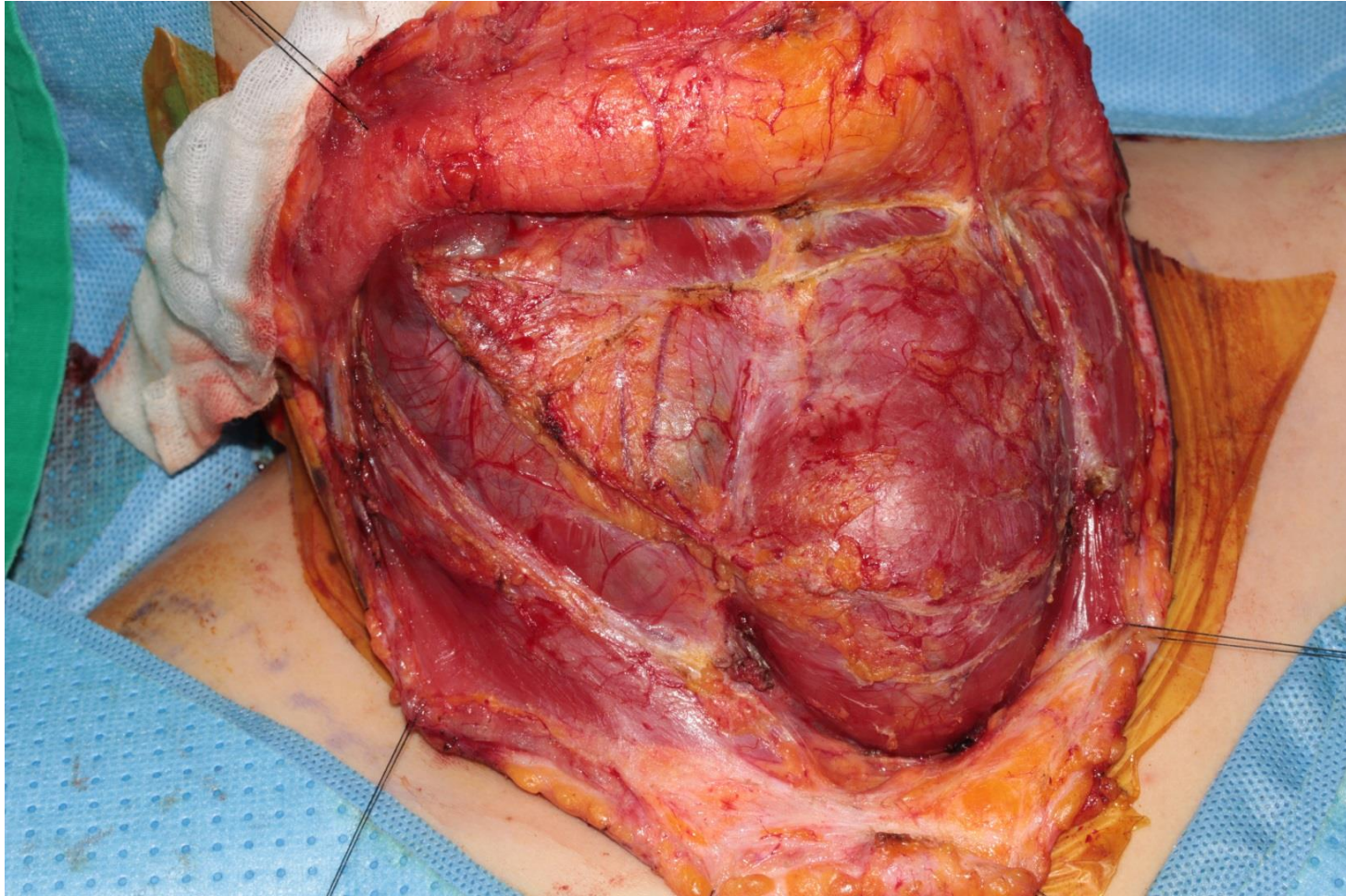


A case of huge multinodular goiter

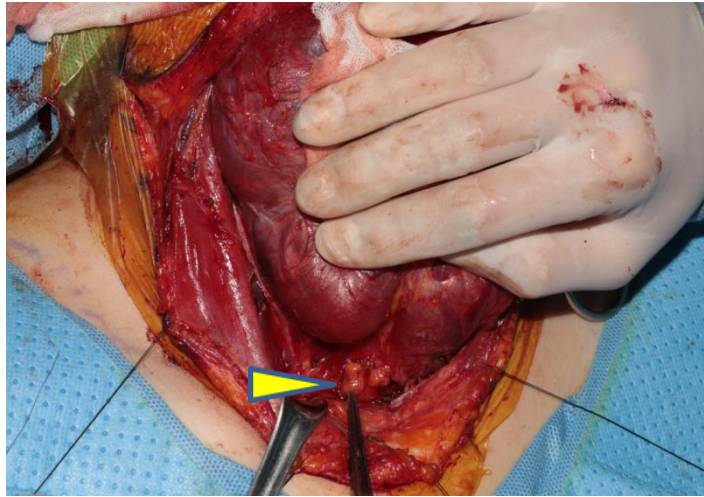
- 이 0 연 (F/30)



Total thyroidectomy



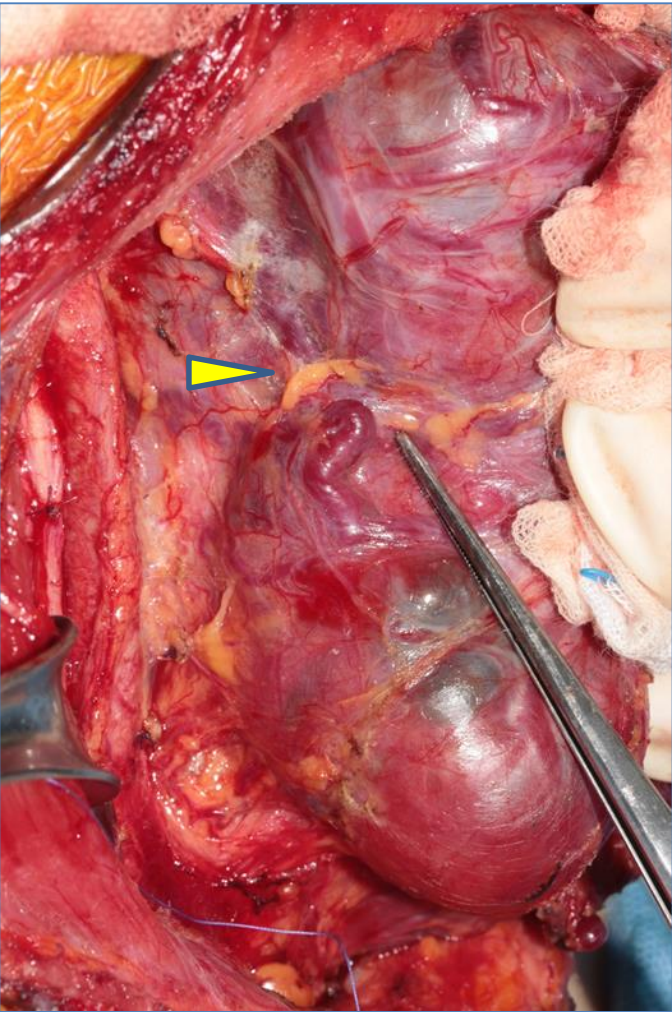
Right inferior parathyroid gland mapping with NIR AF guidance



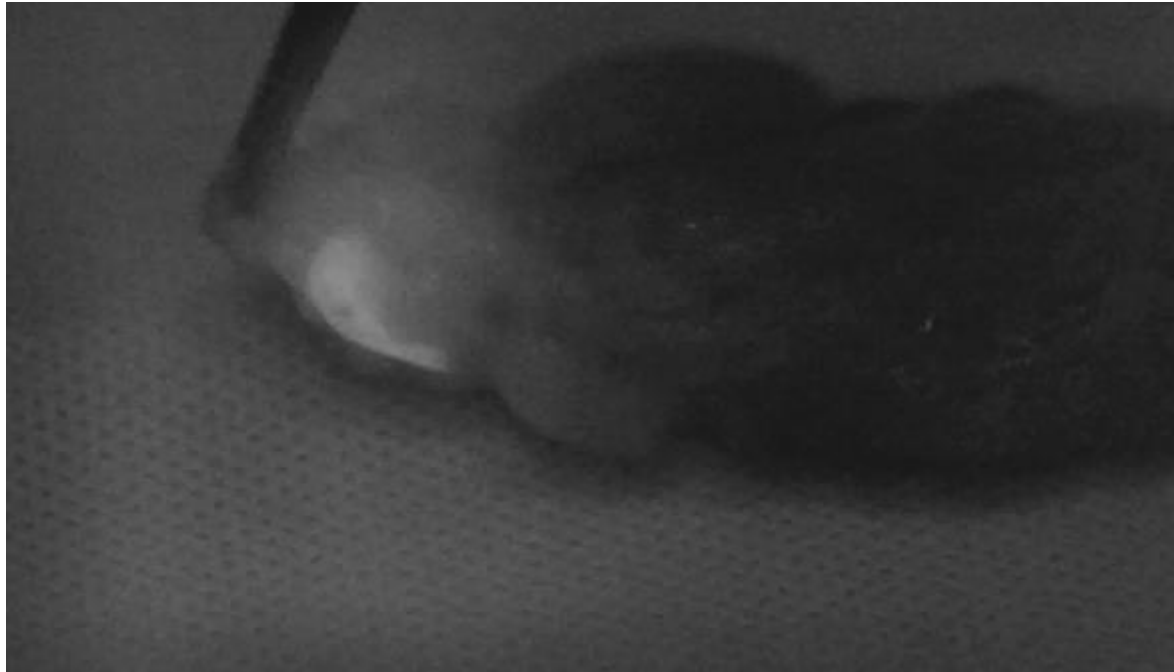
- Preserved inferior parathyroid gland



A small right superior parathyroid
- mapped very easily from the huge thyroid goiter

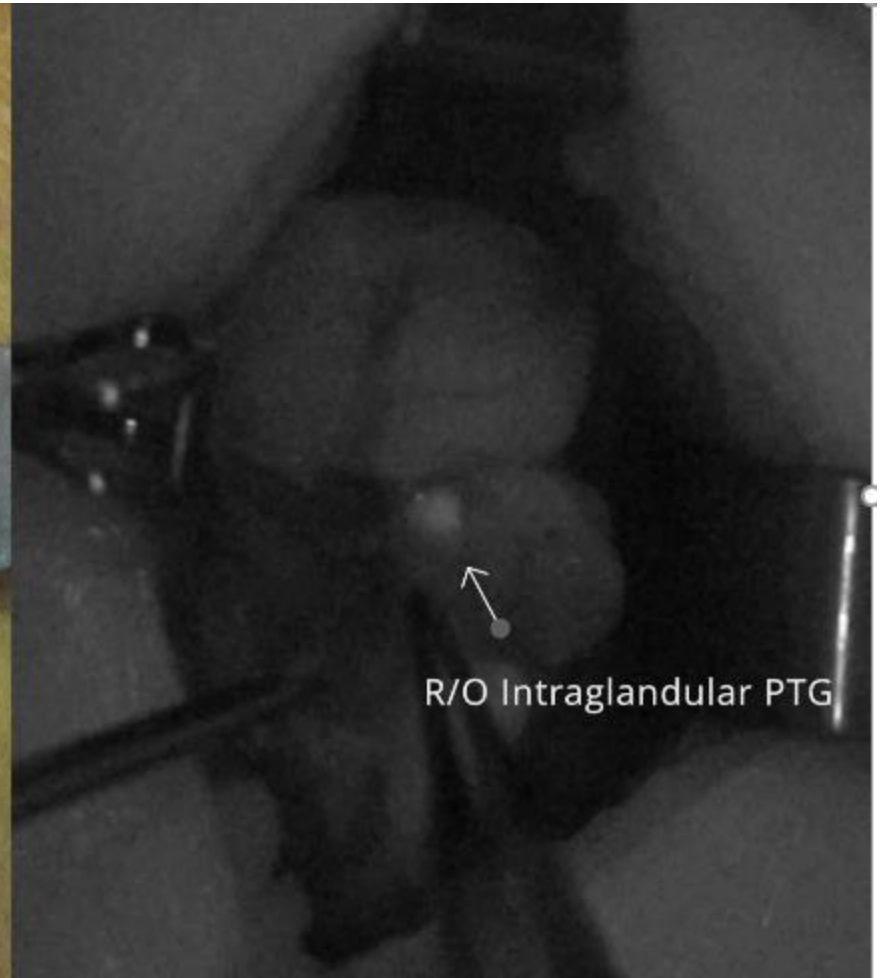


Case. Identification of inadvertently removed parathyroid gland from central neck dissection specimen



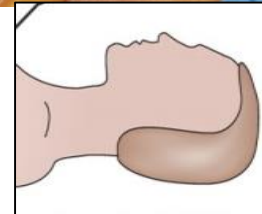
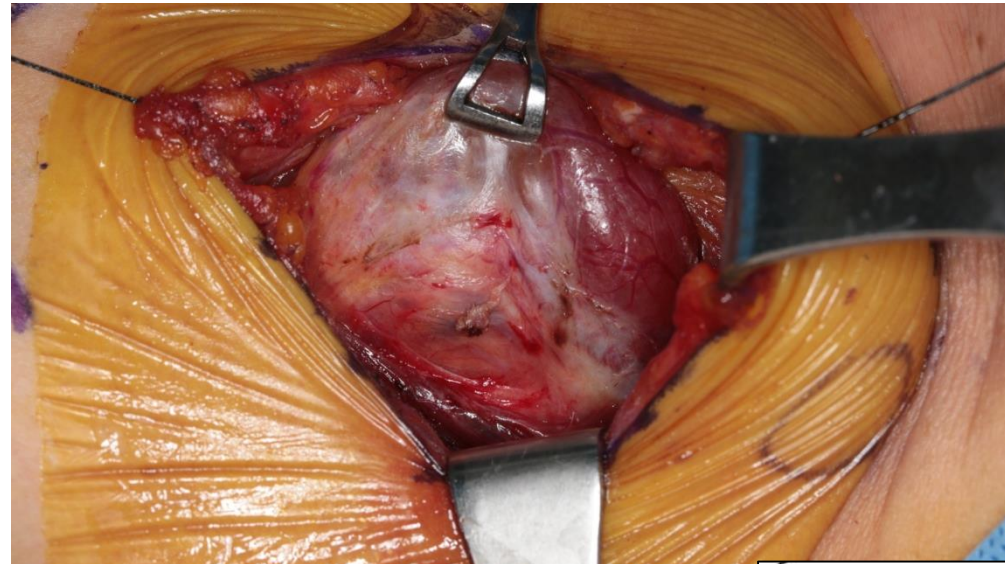
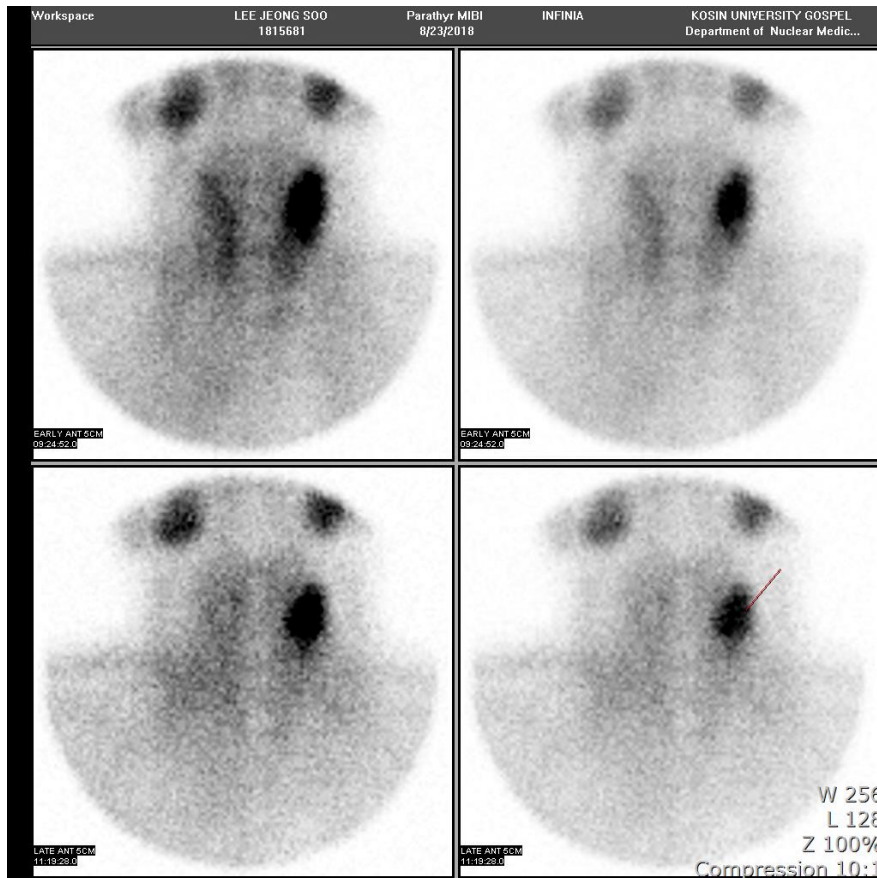
- The parathyroid gland
 - : identified from the CND specimen with NIR AF imaging
 - : auto-transplanted

Case. Intrathyroidal parathyroid gland



Parathyroid adenoma mapping
with NIR AF imaging

Case. Adhesive superior parathyroid adenoma

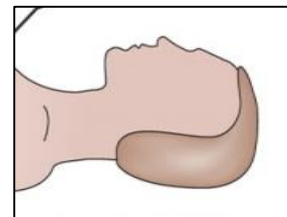


- iPTH level : 141
- Serum calcium : 11.7

- mobilized left thyroid lobe
- no parathyroid adenoma : identified yet

Localizing parathyroid adenoma with NIR light

- discernible, shining adenoma when it is stimulated by NIR light



Removal of the parathyroid adenoma



Early localization of parathyroid gland with NIR AF before visual identification by surgeon (PG mapping) : possible in 92% by imaging in our series

Table 1. Accuracy of Parathyroid Gland Mapping

Characteristic	Stage P1		Stages P1, P2		Stages P1, P2, P3	
	n/total	%	n/total	%	n/total	%
Sensitivity	64/69	92.75	68/69	98.55	69/69	100
Specificity	1/1	100	1/1	100	1/1	100
Positive predictive value	64/64	100	68/68	100	69/69	100
Negative predictive value	1/6	16.66	1/2	50	1/1	100
Accuracy	65/70	92.85	69/70	98.57	70/70	100

Stage P1, imaging before identification of the gland by direct visualization; stage P2, imaging after identification; stage P3, imaging in the removed specimen.

- Excluded naturally exposed parathyroid gland during initial dissection

Efficacy of NIR AF imaging for preserving parathyroid function

- Benmiloud et al, Surgery (2018)
 - NIR AF use during total thyroidectomy significantly
 - : reduced postoperative hypocalcemia (from 20.9% to 5.2%)
 - : improved inadvertent resection of parathyroid (from 7.2% to 1.1%)
 - : reduced autotransplantation rate (from 15% to 2.1%)
- Dip et, JACS (2019)
 - randomized controlled trial comparing white light with NIR AF for parathyroid gland identification during total thyroidectomy
 - : temporary hypocalcemia (from 16.5% to 8.2%) ($p < 0.103$)
 - : reduced severe hypocalcemia (11.8% to 1.2%) ($p = 0.005$)

Limitations of the NIR AF technique

- False positive from brown fat or colloid nodule
- False negative from limited penetration
due to fatty tissues, blood vessels or intrathyroidal parathyroid gland
- There is a learning curve for the correct interpretation of the images



Parathyroid identification with Lab-built NIR AF probe



NIR AF probe

- can be used in the presence of fluorescence light, operating light, and even head light
- can provide an audio and visual display to indicate parathyroid gland

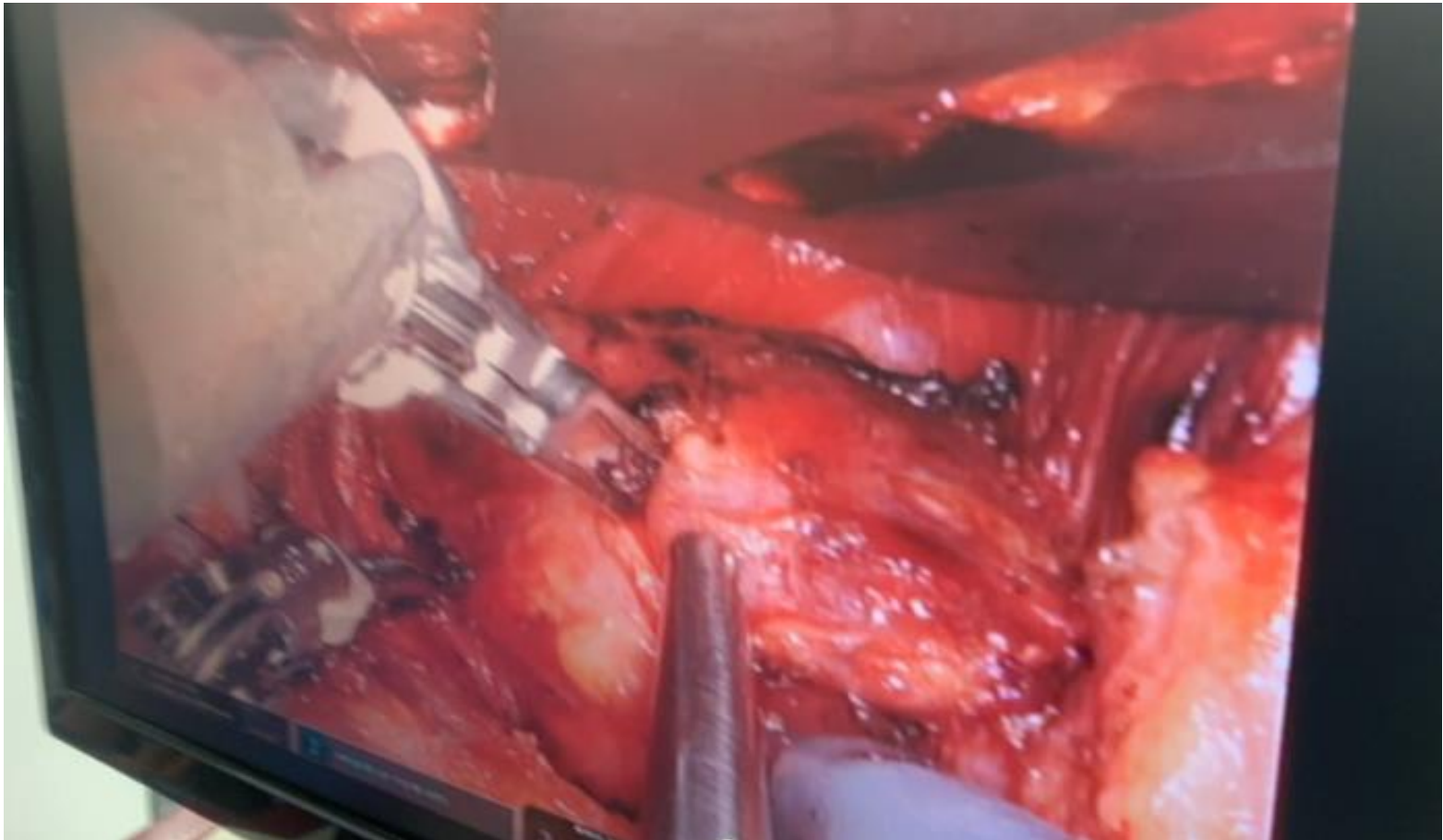


- **AF intensity**

- **thyroid**
: 0.3
- **fat**
: 0.2
- **trachea**
: 0.01
- **muscle**
: 0.05
- **Parathyroid**
: 1.7

- parathyroid showed 6-fold higher intensity than the thyroid
 - made it possible to differentiate parathyroid gland from other tissues

Application of NIR AF probe to robotic thyroidectomy



Summary

- NIR AF imaging with DSLR camera is a very useful tool for the early localization of the parathyroid gland before visual identification by surgeons
- Parathyroid gland mapping and localization is possible with high accuracy rate using NIR AF imaging
- Parathyroid AF will be increasingly used in thyroid and parathyroid surgery in the near future

Intraoperative Neuromonitoring (IONM)

Monitoring systems

1. The **recording side**

- involves the endotracheal tube recording electrodes, its recording electrode ground, and associated connections at the interface-connector box and monitor.

2. The **stimulation side**

- includes the stimulation neural probe, its grounding electrode, and associated connections to the interface box-connector and stimulation current pulse generator within the monitor.

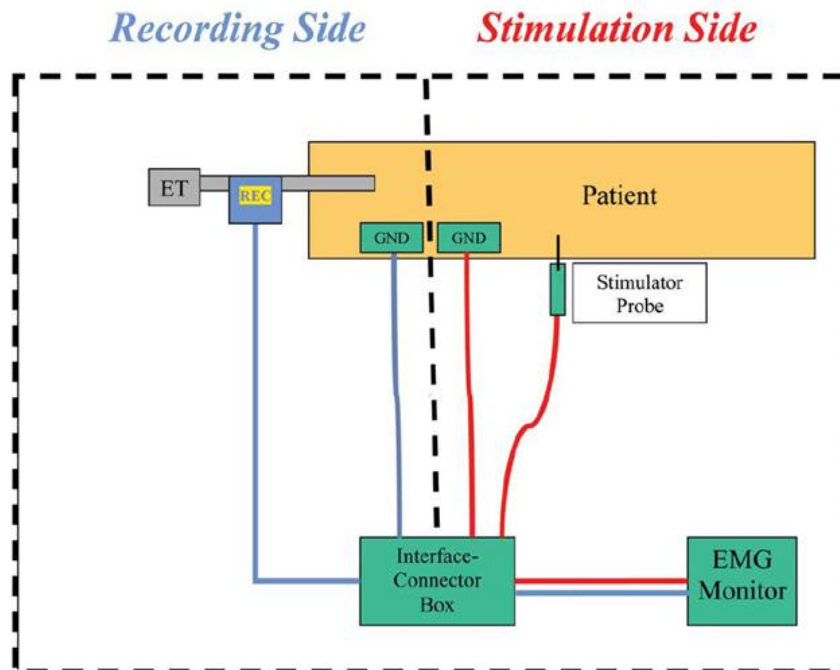
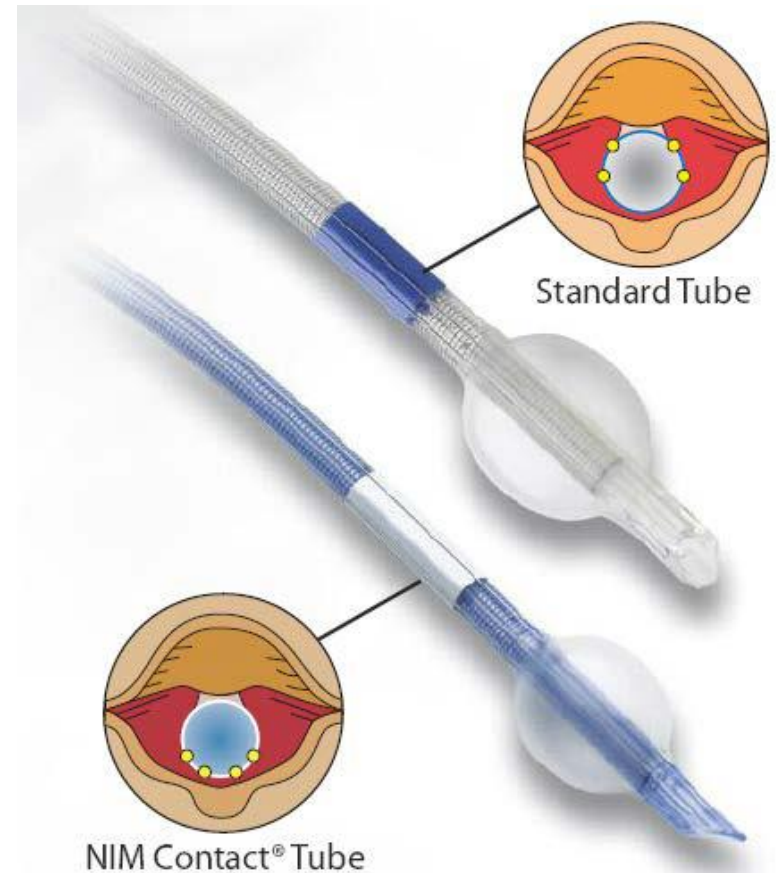
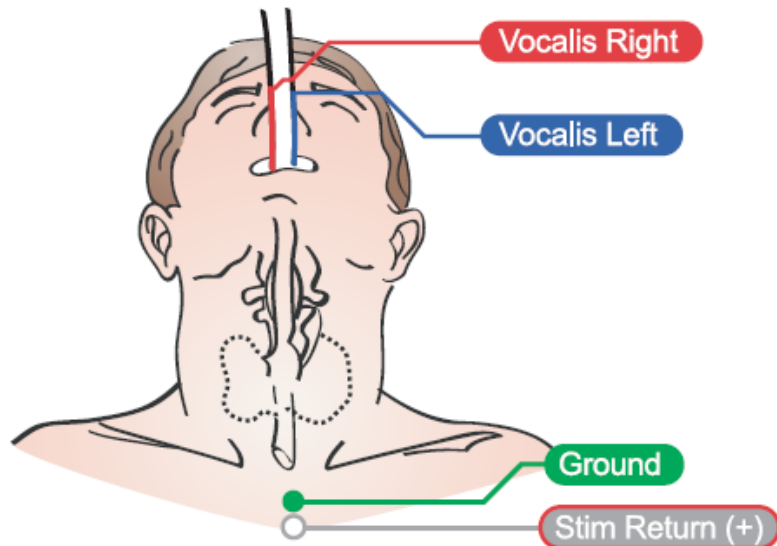


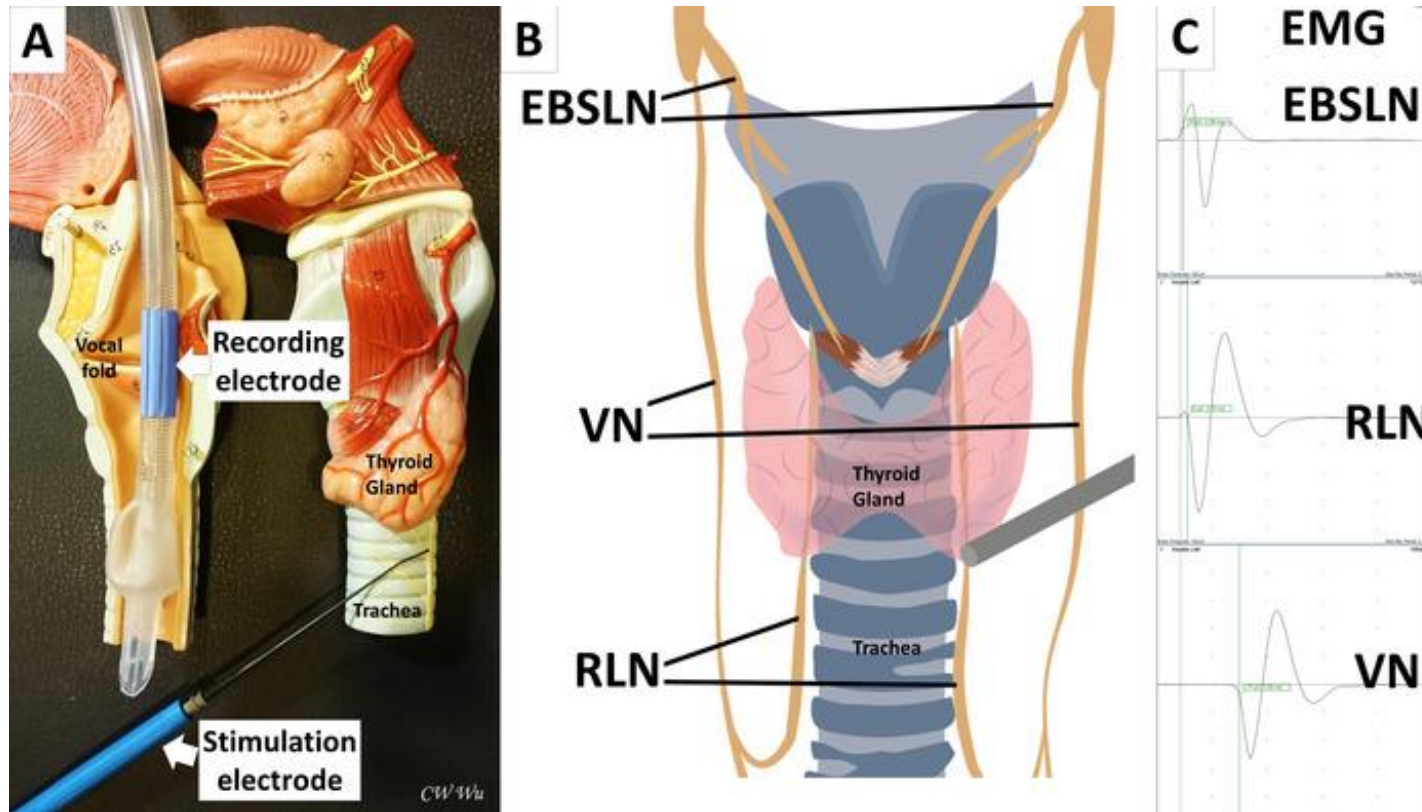
Fig. 2. Basic monitoring equipment setup. ET = endotracheal tube; REC = recording electrodes; GND = ground electrodes; EMG = electromyography.

Standards of equipment

EMG Endotracheal Tube



EMG endotracheal tube placement



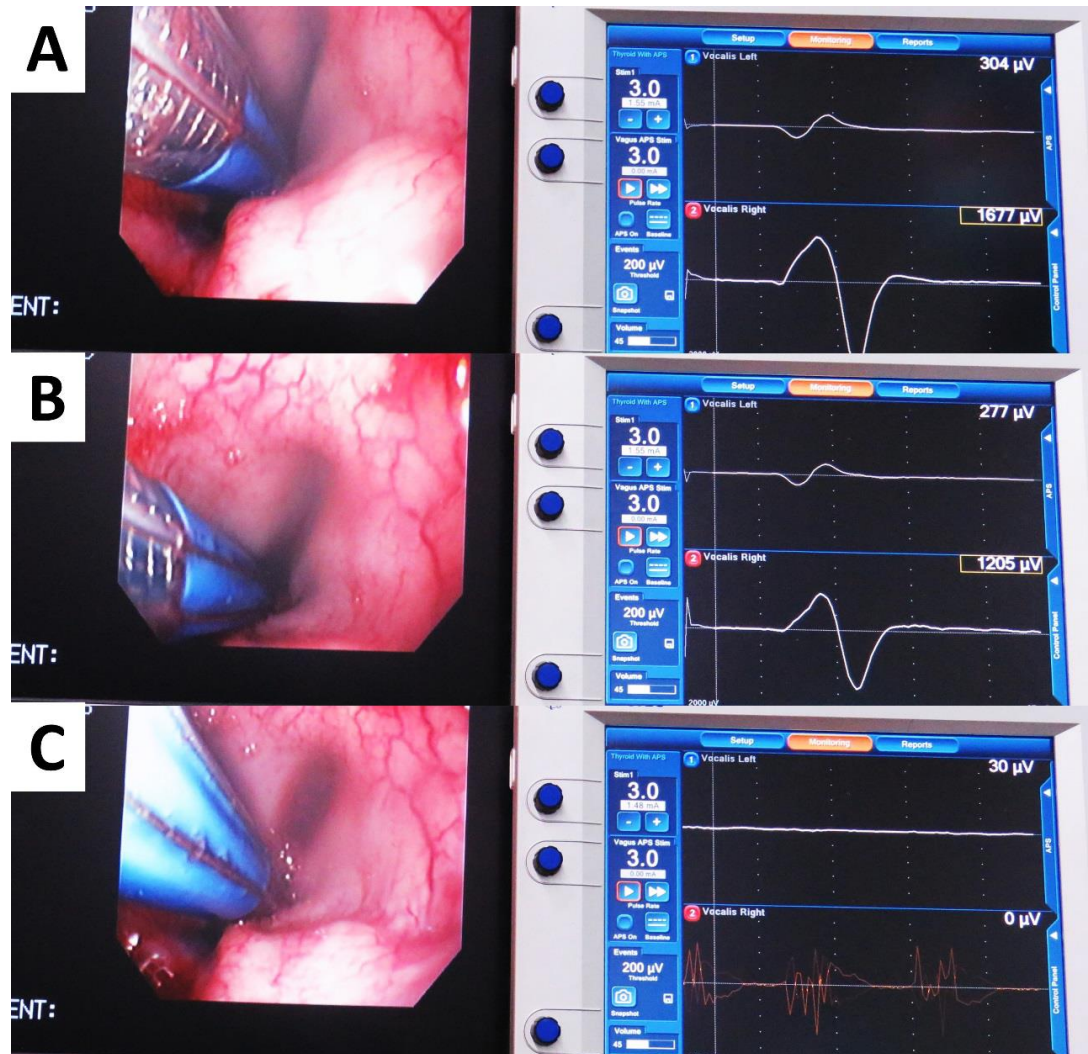
Check proper position of electrode

The screenshot displays a software interface for electrode placement. The main window is titled "2. Place Electrodes" and shows a diagram of a patient's head and neck. The diagram is divided into "Right" and "Left" sections. On the right side, "Vocalis 2" is labeled in a red box. On the left side, "Vocalis 1" is labeled in a blue box. Below the main diagram are three circular insets showing different tube types: "Standard Tube", "Contact Tube", and "TriVantage Tube". A "Ground" electrode is shown on the patient's chest, and a "Stim Return (+)" electrode is shown on the patient's neck. A photograph of the electrode placement device is shown at the bottom left. The interface includes a "Setup" tab, a "Monitoring" tab, and a "Reports" tab. A yellow warning box at the top right states "Warning: EMG Monitoring Is Disabled". A list of electrode checks is shown on the right side, with green checkmarks indicating successful placement:

- 1 - Vocalis 1 ✓
- 2 - Vocalis 2 ✓
- Stim 1 Return ✓
- Ground ✓

The interface also includes a "Show Details" button and a "Save" button. The bottom of the interface shows the date and time "11/21/2018 08:18 AM" and the version numbers "GUI v2014.11.11.921" and "DSP v2014.2.12.833".

EMG Endotracheal Tube Placement



Wu, et al.
J Vis Exp 2019

EMG monitor : Monitor Assessment

Check proper position of electrode

The screenshot displays the 'Setup' tab of an EMG monitor interface. The main area shows a diagram of a patient's head and neck with an endotracheal tube. Three tube types are illustrated: 'Standard Tube', 'Contact Tube', and 'TriVantage Tube'. Electrode positions are marked: 'Vocalis 2' (red) on the right side of the tongue and 'Vocalis 1' (blue) on the left side. A 'Ground' electrode (green) is attached to the patient's chest, and a 'Stim Return (+)' electrode (red) is attached to the patient's arm. Below the diagram is a photograph of the monitor's electrode connector strip with colored leads plugged in.

On the right side of the interface, the 'Electrode Check' panel displays a yellow warning: 'Warning: EMG Monitoring Is Disabled'. Below this, the check status is as follows:

Item	Status
1 - Vocalis 1	✓
2 - Vocalis 2	✓
Stim 1 Return	✓
Ground	✓

At the bottom of the interface, the date and time are '11/21/2018 08:18 AM', and the version information is 'GUI v2014.11.11.921 DSP v2014.2.12.833'.

EMG monitor : Monitor Assessment

- Impedance ($<5.0 \text{ k}\Omega$),
- impedance imbalance ($<1.0 \text{ k}\Omega$)

The screenshot displays the 'Setup' tab of an EMG monitor. The main window shows a diagram of a patient's head and neck with three endotracheal tube options: Standard Tube, Contact Tube, and TriVantage Tube. The Contact Tube is selected, with 'Vocalis 1' and 'Vocalis 2' electrodes placed on either side of the tube. A 'Ground' electrode is attached to the patient's chest, and a 'Stim Return (+)' electrode is attached to the monitor. Below the diagram is a photograph of the monitor's electrode input panel with colored leads plugged in.

The 'Electrode Check' panel on the right shows the following data:

Electrode	(+) Impedance	(-) Impedance	Difference (Δ)	Status
1 - Vocalis 1 Endotracheal Tube	(+)0.3k Ω	(-)0.3k Ω	$\Delta <0.1\text{k}\Omega$	✓
2 - Vocalis 2 Endotracheal Tube	(+)0.3k Ω	(-)0.2k Ω	$\Delta 0.1\text{k}\Omega$	✓

Below this is a table of 'Normal Electrode Impedances':

Electrode	Electrode Impedance	Difference (Δ)
Subdermal	$<10\text{k}\Omega$	$<2\text{k}\Omega$
Endotracheal Tube	$<7.5\text{k}\Omega$	$<1.5\text{k}\Omega$
Hookwire	$<150\text{k}\Omega$	$<100\text{k}\Omega$
Prass Paired	$<25\text{k}\Omega$	$<5\text{k}\Omega$
Surface	$<40\text{k}\Omega$	$<8\text{k}\Omega$

Additional checks shown:

Stim 1 Return	1.2k Ω	✓
Ground	0.7k Ω	✓

The interface includes navigation buttons for 'Previous', 'Monitor', and 'Information', and a 'Save' button at the bottom right. The status bar at the bottom shows the date and time '11/21/2018 08:19 AM' and version information 'GUI v2014.11.11.921 DSP v2014.2.12.833'.

EMG monitor : Monitor Assessment

The screenshot displays the 'Audio Settings' dialog box within the EMG monitor software. The dialog is titled 'Audio Settings' and is divided into three main sections: 'Stimulus Delivery Audio', 'Monitoring Audio', and 'Volume Balance'. The 'Stimulus Delivery Audio' section contains five radio button options: 'Off', 'Brief Tone' (selected), 'Continuous Tone', 'Voice - Stimulus', and 'Voice - Settings'. The 'Monitoring Audio' section contains three checked checkboxes: 'EMG Audio', 'Event Tones', and 'Voice - Stimulated EMG Values', along with an unchecked checkbox for 'Show Channel Mute Buttons'. The 'Volume Balance' section features three volume sliders: 'EMG Audio' (set to 3), 'Event Tones' (set to 2), and 'Voices' (set to 3). The background software interface includes tabs for 'Audio', 'Monitoring', 'Stimulation', and 'Microscope'. On the right side, there are buttons for 'Electrode Check', 'Freeze', 'Display', and 'Measure'. Below these is an 'Events' section with 'Event Capture' checked and an 'Event Threshold' of 100 μV . Further down are 'Snapshot Action' buttons for 'Comment', 'Print', and 'Save' (checked). At the bottom right, there are 'OK' and 'Help' buttons. The status bar at the bottom shows the date and time '11/21/2018 08:21 AM' and the version information 'GUI v2014.11.11.921 DSP v2014.2.12.833'.

EMG monitor : Monitor Assessment

The screenshot displays the 'Monitoring Settings' window of an EMG monitoring software. The interface is organized into several functional areas:

- View Scale:** A vertical column of radio buttons allows selection of voltage scales from 20 μV to 100,000 μV . The 1000 μV scale is currently selected.
- Waveform Display:** Two waveforms are shown. The top waveform, labeled '1 Orbicularis Oculi', has a peak amplitude of 386 μV . The bottom waveform, labeled '2 Orbicularis Oris', has a peak amplitude of 371 μV . A horizontal scale bar at the bottom indicates 25 ms.
- Measurement Cursor Position:** Radio buttons for 'Peak Amplitude' (selected) and 'Latency' are present.
- Waveform Filters:** Checkboxes for 'Artifact Filter' and 'Low Frequency Filter' are both checked.
- Event Capture:** Includes a checked 'Display Transient Event' option, an unchecked 'Auto Threshold' option, and a 'Sequence Display' section with 'Largest Overall' selected.
- Latency:** Radio buttons for 'Onset' (selected) and 'Peak' are shown.
- Snapshot:** A 'Default Snapshot Action' section with checkboxes for 'Comment', 'Print' (checked), and 'Save' (checked). A 'Probe Saves Snapshot' checkbox is also present.
- Right Panel:** Contains utility buttons for 'Electrode Check', 'Freeze', 'Display', and 'Measure'. An 'Events' section shows 'Event Capture' checked and an 'Event Threshold' set to 100 μV . A 'Snapshot Action' section includes 'Comment', 'Print', and 'Save' (checked) buttons.
- Bottom Bar:** Features an 'OK' button, an 'Advanced Settings' button, a 'Help' button, and a system message: 'You may now remove the USB drive.' The version number '1.11.921 DSP v2014.2.12.833' is displayed in the bottom right corner.

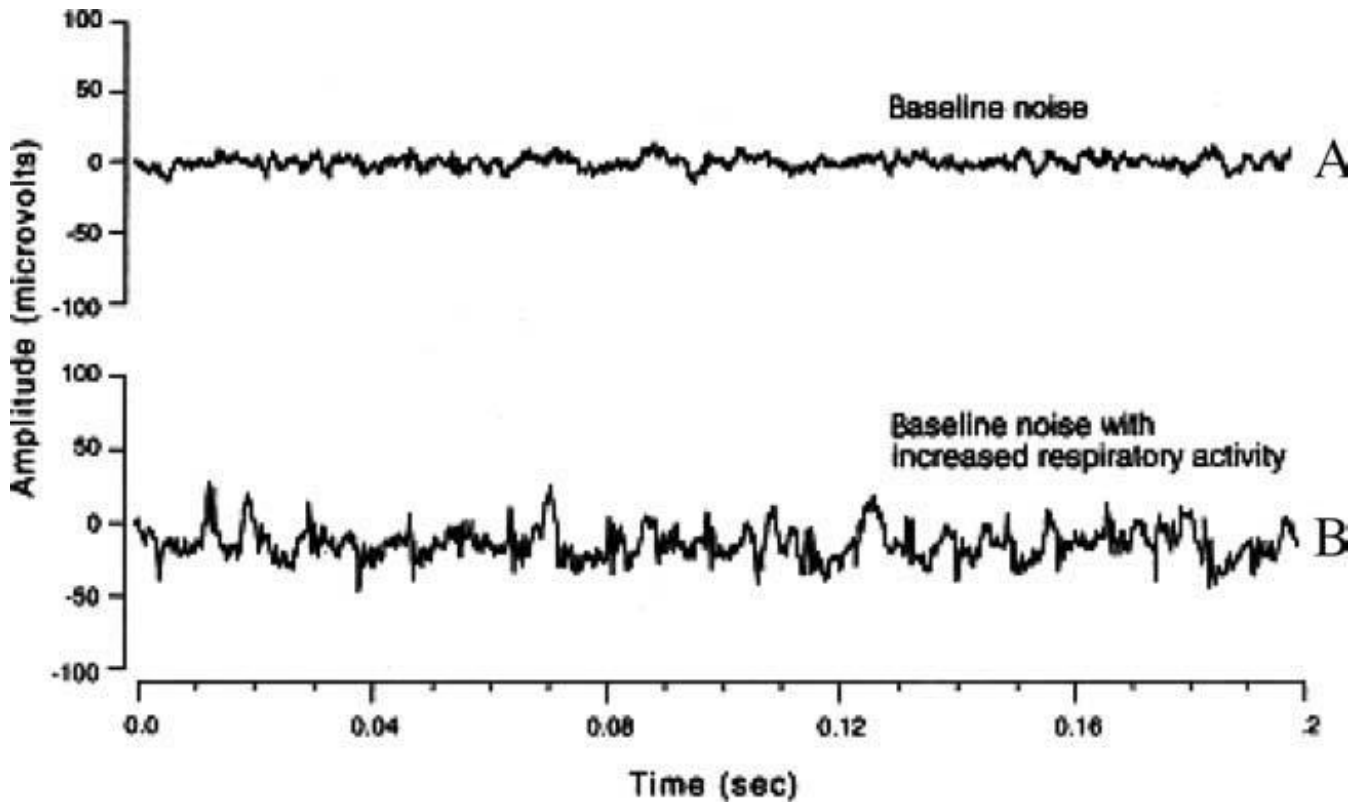
EMG monitor : Monitor Assessment

The screenshot displays the 'Stimulation' tab of an EMG monitor software interface. The main window is titled 'Stimulator Settings' and is divided into two columns for 'Stimulator 1' and 'Stimulator 2'. Each stimulator has a 'Name' field (Stim1 and Stim2), a 'Type' section with radio buttons for 'Monopolar' (selected) and 'Bipolar', and a 'Rate' section with radio buttons for 1/sec, 4/sec (selected), 7/sec, and 10/sec. The 'Pulse Width' section for each stimulator has radio buttons for 50 μs, 100 μs (selected), 150 μs, 200 μs, and 250 μs. Below these settings, a 'Current Warning Level' is set to 3.0 mA. At the bottom of the stimulator settings, a 'Rejection Period' is set to 1.2 ms, and a checkbox 'Reject Stim Pulse Artifacts' is checked.

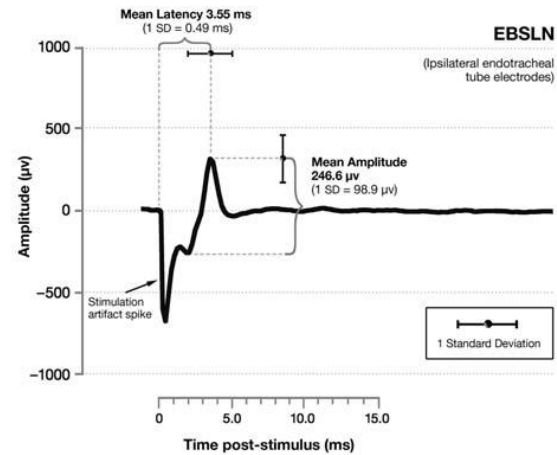
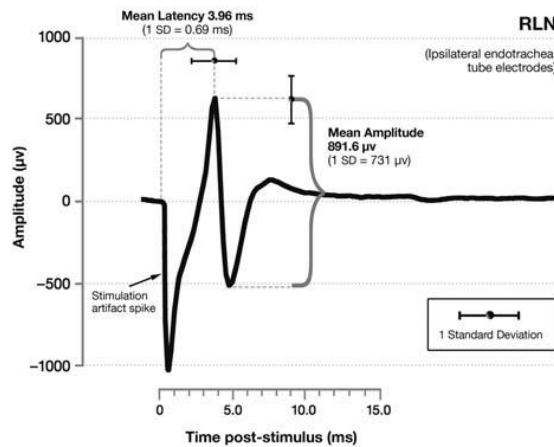
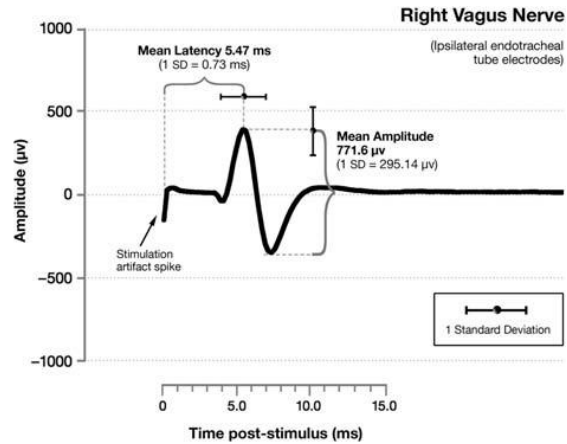
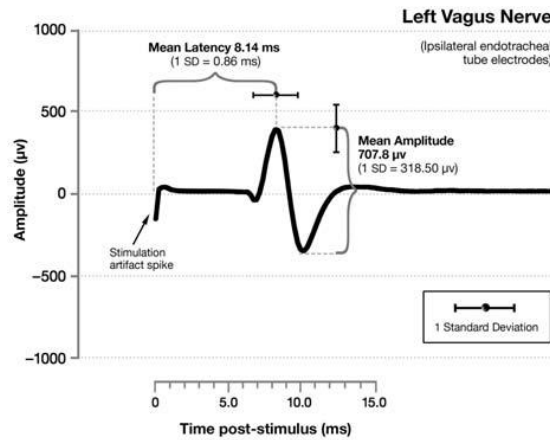
On the right side of the interface, there is a vertical toolbar with several icons: 'Electrode Check', 'Freeze', 'Display', and 'Measure'. Below this is an 'Events' section with a checked 'Event Capture' checkbox, a threshold set to 100 μV, and a 'Snapshot Action' section with 'Comment', 'Print', and 'Save' buttons. At the bottom right, there are 'OK' and 'Help' buttons, and a link to 'Advanced Settings'.

The status bar at the bottom of the window shows the date and time '11/21/2018 08:21 AM' and the version information 'GUI v2014.11.11.921 DSP v2014.2.12.833'.

EMG monitor : Monitor Assessment



EMG monitor : Monitor Assessment

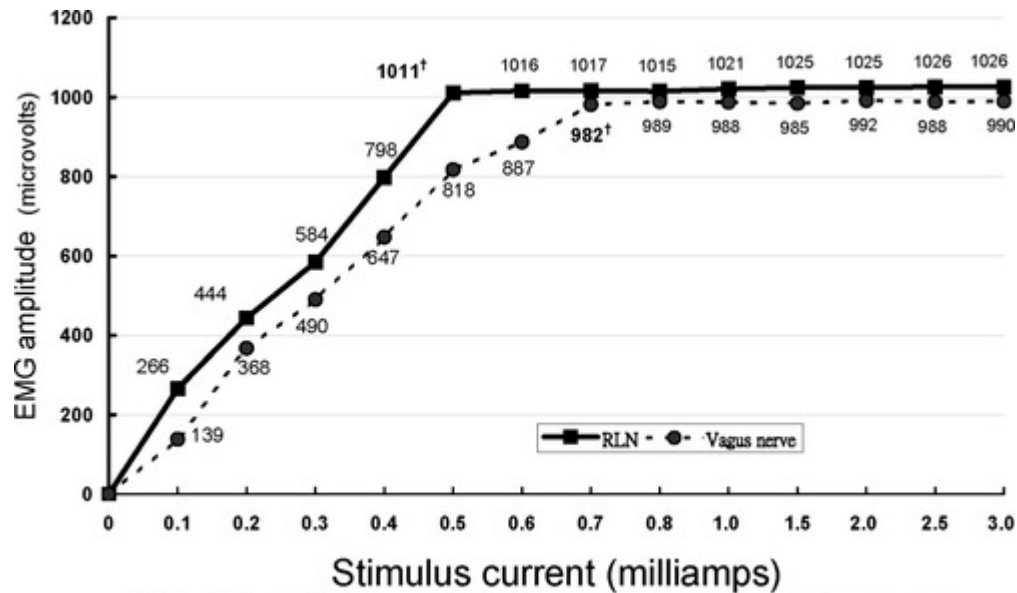


Optimal Intensity of Stimulation

- Idea is to use minimum current intensity (mA) to induce maximal response (μA)
- If stimulus current is too high, it may cause false-positive signal by shunt effect

Equipment Set Up

Correlation of Stimulus Current Intensity and EMG Response

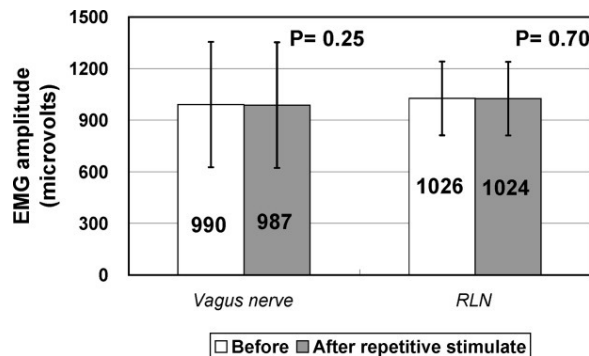


*data of 0.1 and 0.2 mA was obtained from selected nerves which have response.

†approximately maximal response occur.

Nerve Stimulation : Background

- Supra-maximal stimulation
: to get constant EMG amplitude
- 3mA, 100µs pulse, 4Hz frequency, for 10 minutes
: no electrophysiological or cardiopulmonary effects



Wu, et al. Head & Neck 2010

- No vagal side effects during or after continuous VN stimulation

Schneider, et al. Am J Surg. 2010

Suggested Optimal Stimulus Current

- Vagus Nerve
 - with nerve exposure : 2-3 mA
 - without nerve exposure : 3 mA
- Recurrent Laryngeal Nerve
 - with nerve exposure : 1-2mA
 - without nerve exposure : 2-3 mA
- EBSLN : 0.5 –1 mA

Standardized Nerve Stimulation Procedures

- L1 : Preoperative laryngoscopy
- V1: Test of VN before identification of the RLN
- R1: Test of RLN when it was first identified
- R2: Test of RLN after complete dissection
- V2: Test of VN after complete hemostasis
- L2 : Postoperative laryngoscopy

Equipment/Endotracheal Setup Standard

A. Endotracheal tube

- Intubation – short-acting NMB, drying agent
- Electrodes at cords – note depth, no rotation, no salivary pooling
- Position patient – Then verify position via –Glottic Exam or
– Respiratory Variation
–Then fix tube position

B. Equipment

- Ground electrodes - shoulder
- Monitor: -100 μ V event threshold
 -stimulation current 1-2 mA
 -impedance (<5 kilo ohms per electrode)
- Separate monitor and electrocautery units

C. Initial surgical field testing

- Stimulate ipsilateral Vagus

Nonendotracheal tube based IONM
with needle or skin adhesive electrode

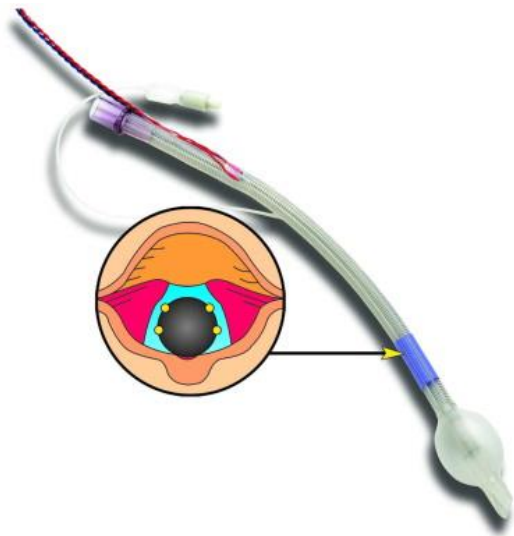
Kang-Dae Lee, M.D.

**Department of Otolaryngology – H&N Surgery,
College of Medicine, Kosin University, Busan, South Korea**

VI Eurasian H&N cancer Forum, July 11-14, 2019, Moscow, Russia

EMG endotracheal tube based IONM for thyroid or parathyroid surgery

- standard in IONM of RLN and EBSLN
- a useful adjunct for intraoperative laryngeal nerve function assessment
- typically, monitoring is performed by measurement of EMG responses recorded by endotracheal tube (ETT) surface electrodes

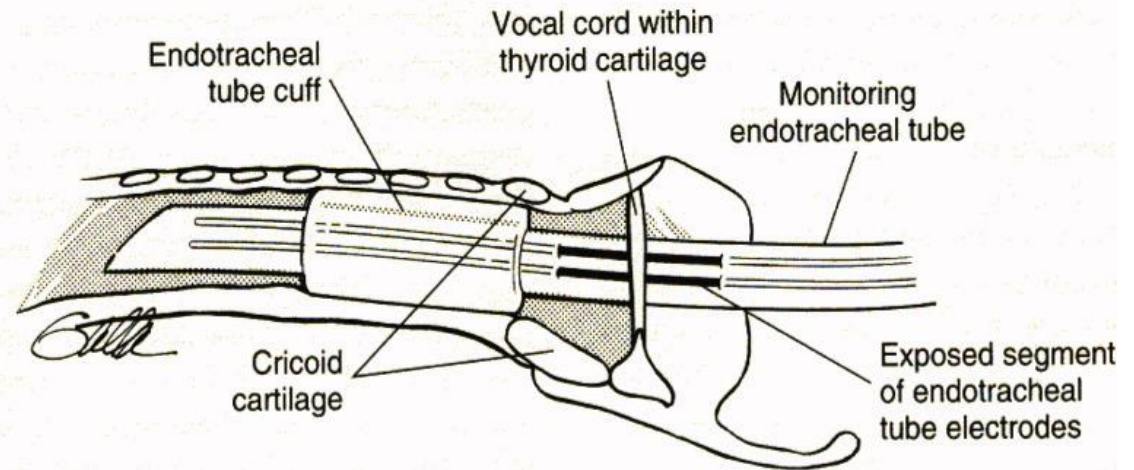
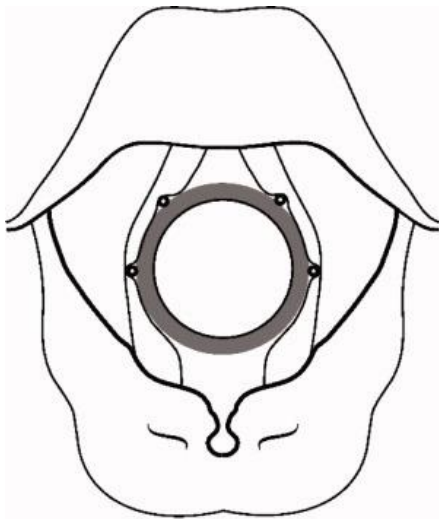


Medtronic EMG tube



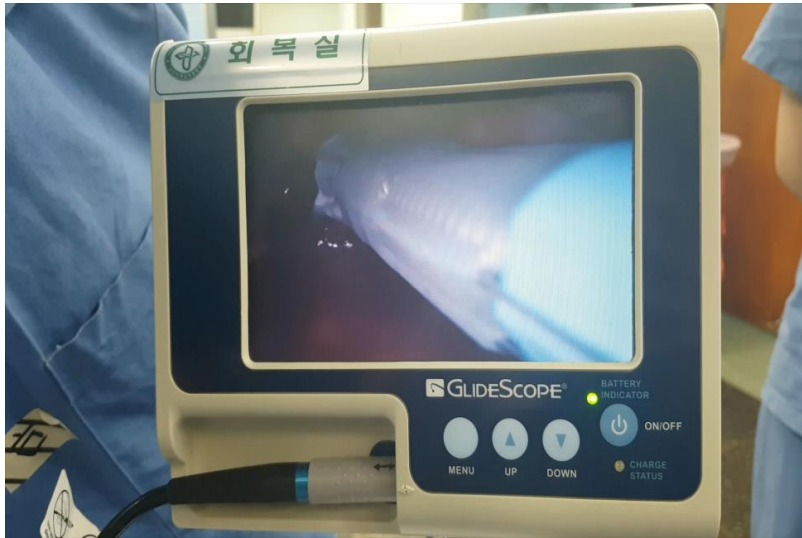
Inomed laryngeal electrode

Monitoring Tubes



- significant equipment problems
 - : mostly relating to the endotracheal tube
 - : 3.8% ~ 23%

Major problems of endotracheal surface electrode



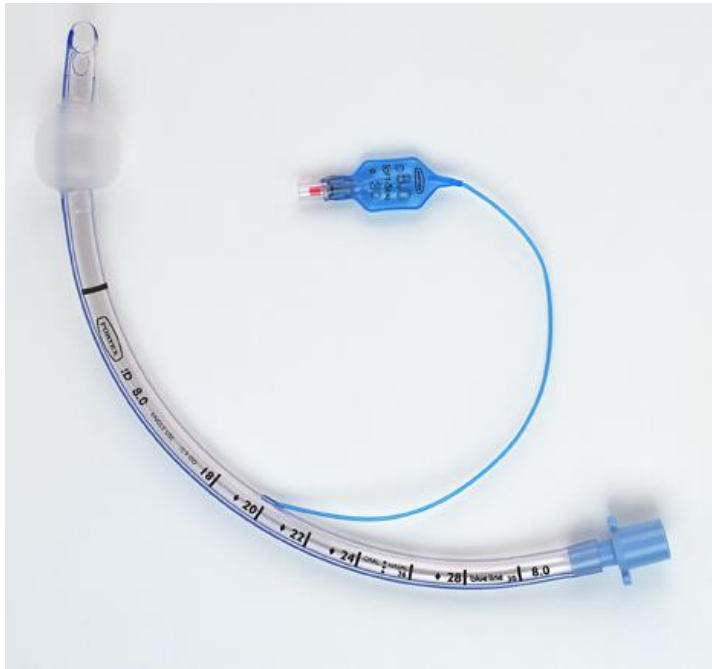
- To overcome the limitation of EMG endotracheal tube
 - nonendotracheal tube based IONM have been studied

- False LOS (Loss of signal) of EMG tube

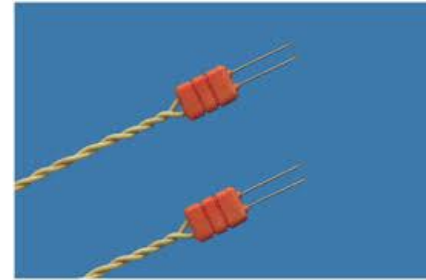
- EMG tube malposition
 - rotation
 - extrusion; time-consuming readjustment
- Saliva pooling
- Monitoring equipment dysfunction
- Misuse (repeated use) of neuromuscular blocking agent

Representative studies on alternative methods of IONM (Prof. Chiang & Prof. Wu, Kaohsiung, Taiwan)

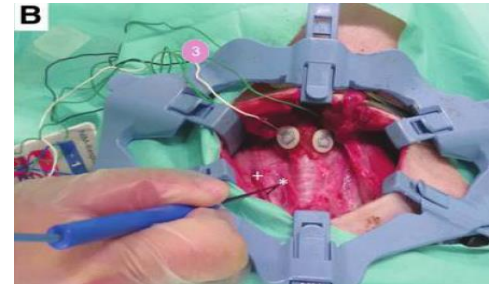
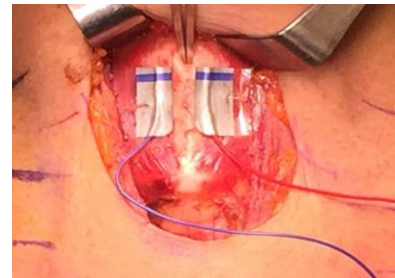
- Intubation with ordinary endotracheal tube instead of EMG tube



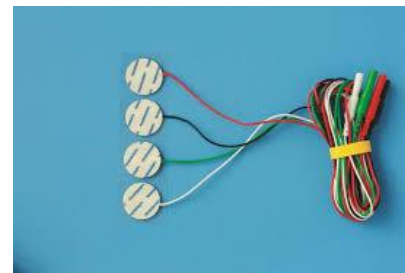
- needle electrode (human study)



- anterior laryngeal electrode (animal study)

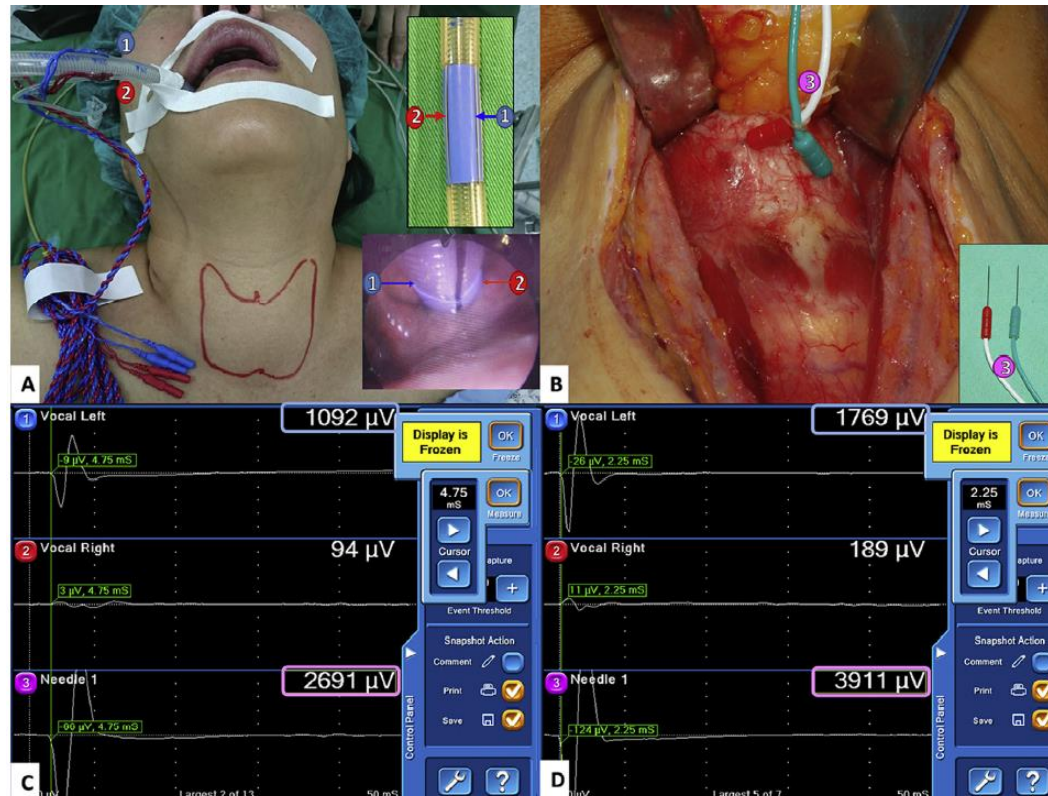


- skin adhesive electrode to monitor the nerve (animal study)



Comparison of EMG signals recorded by surface electrodes on **endotracheal tube** and **thyroid cartilage** during monitored thyroidectomy.

Chiang FY¹, Lu IC², Chang PY³, Dionigi G⁴, Randolph GW⁵, Sun H⁶, Lee KD⁷, Tae K⁸, Ji YB⁸, Kim SW⁷, Lee HS⁷, Wu CW⁹.

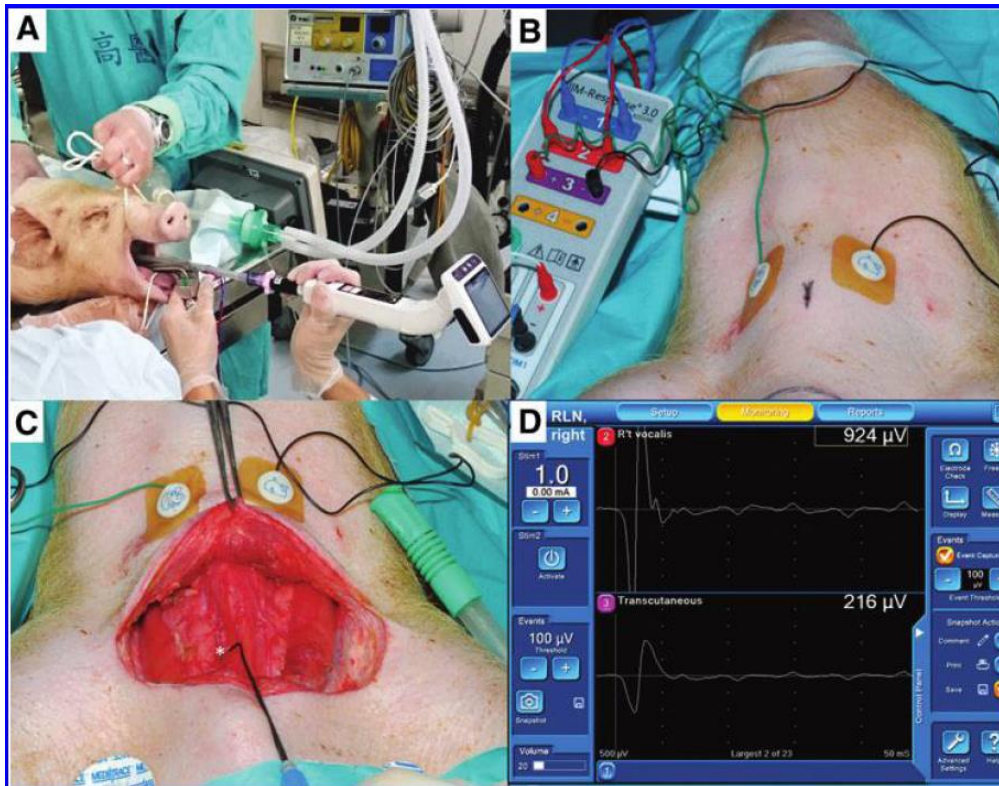


- surface electrode of EMG endotracheal tube

- transcartilagenous needle electrodes in human thyroidectomy

Transcutaneous Recording During Intraoperative Neuromonitoring in Thyroid Surgery.

Wu CW^{1,2}, Chiang FY^{1,2}, Randolph GW^{3,4,5}, Dionigi G⁶, Kim HY⁷, Lin YC¹, Huang TY¹, Lin CI¹, Hun PC⁸, Kamani D³, Chang PY⁹, Lu IC^{2,9}.



→ •EMG ET

→ •Skin electrode

- compared surface electrode of EMG tube and adhesive skin electrodes
- demonstrated the feasibility of skin electrode for IONM in a porcine model

Evaluation of feasibility of IONM

- without EMG endotracheal tube
- with ordinary endotracheal tube in human

1. Transcartilagenous needle electrode
2. Transcutaneous skin adhesive electrode

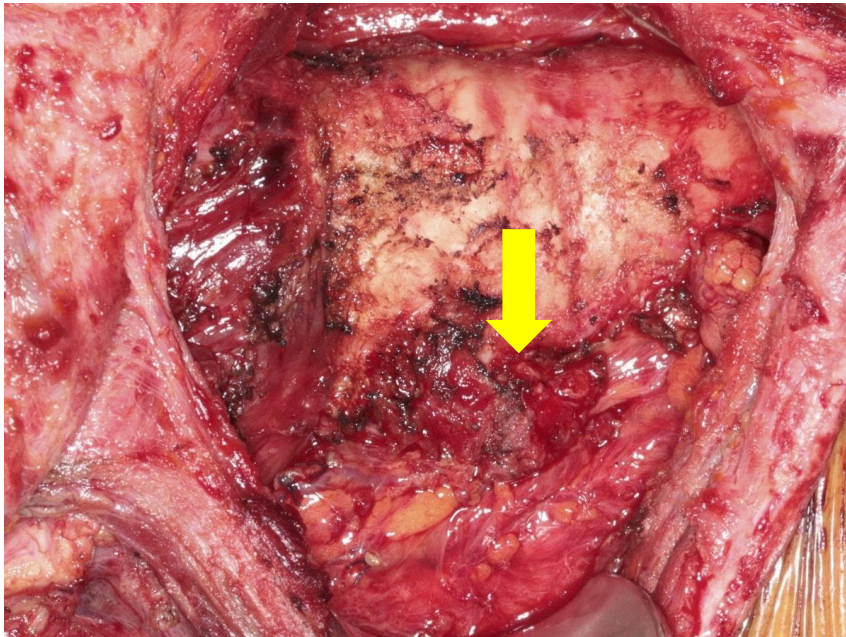


IONM with transcartilagenous needle electrode in Kosin University Gospel Hospital

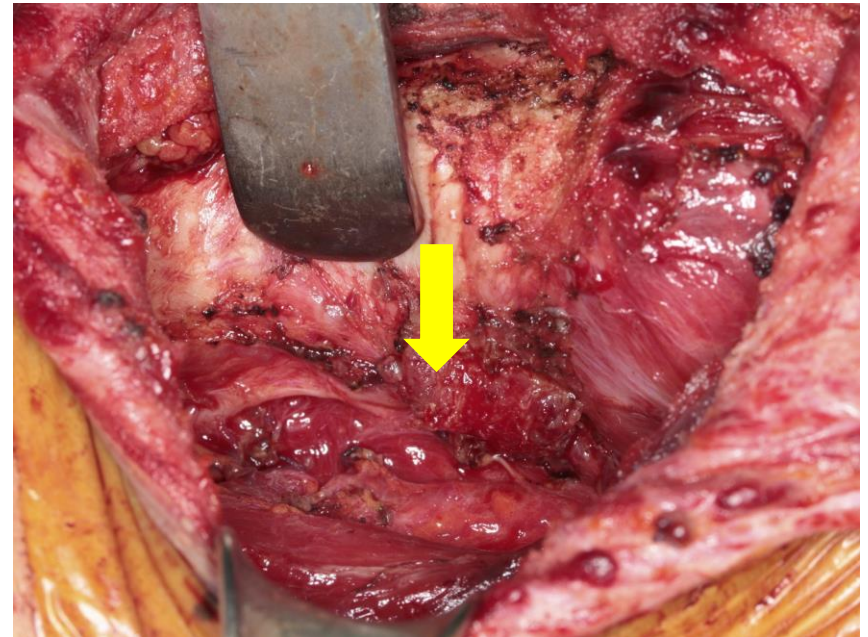


A Case - bilateral RLN invasion

- Total thyroidectomy with CND with right selective neck dissection (II-V)



Right RLN invasion



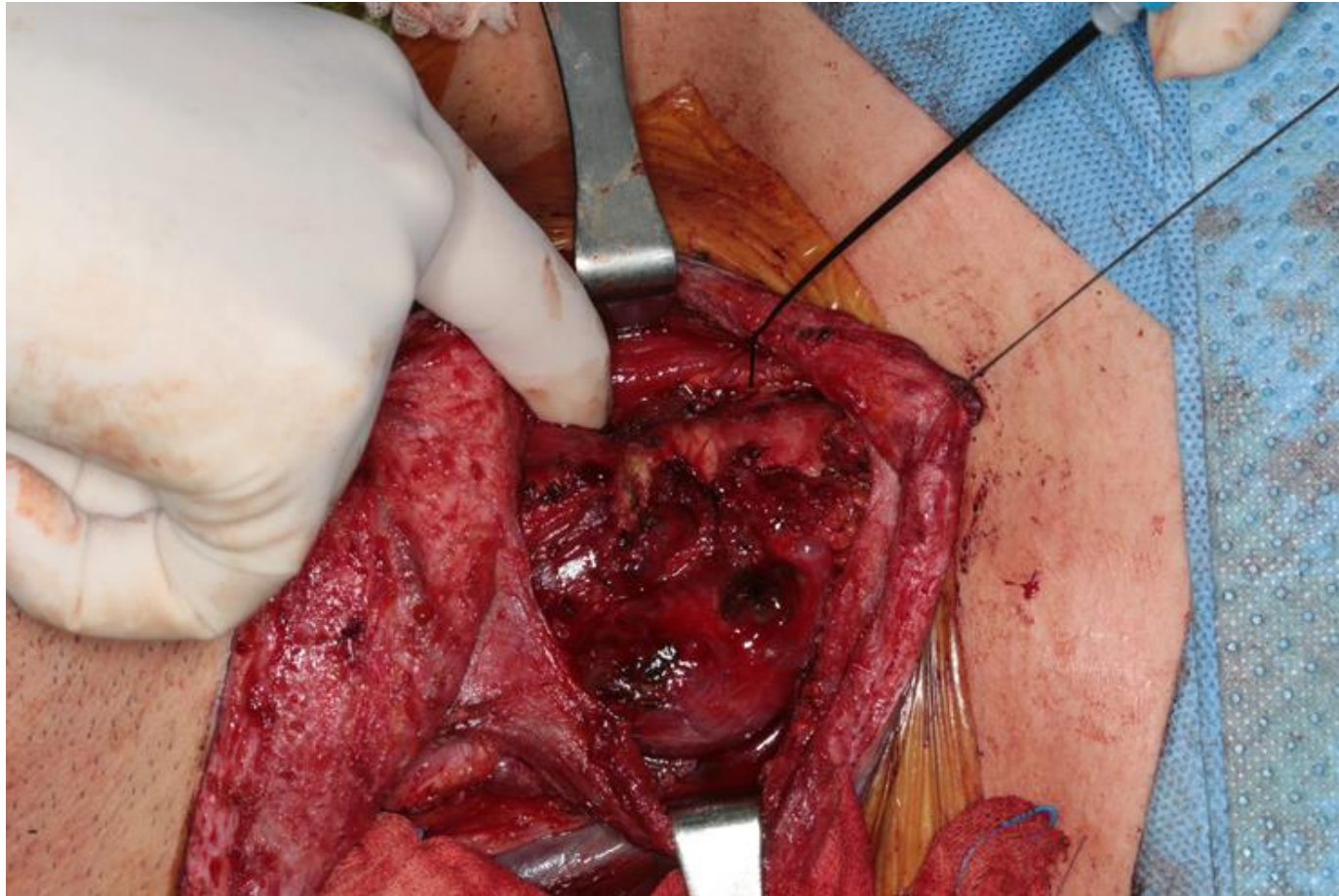
Left RLN invasion

'LOS' occurred at both RLN after neck rotation

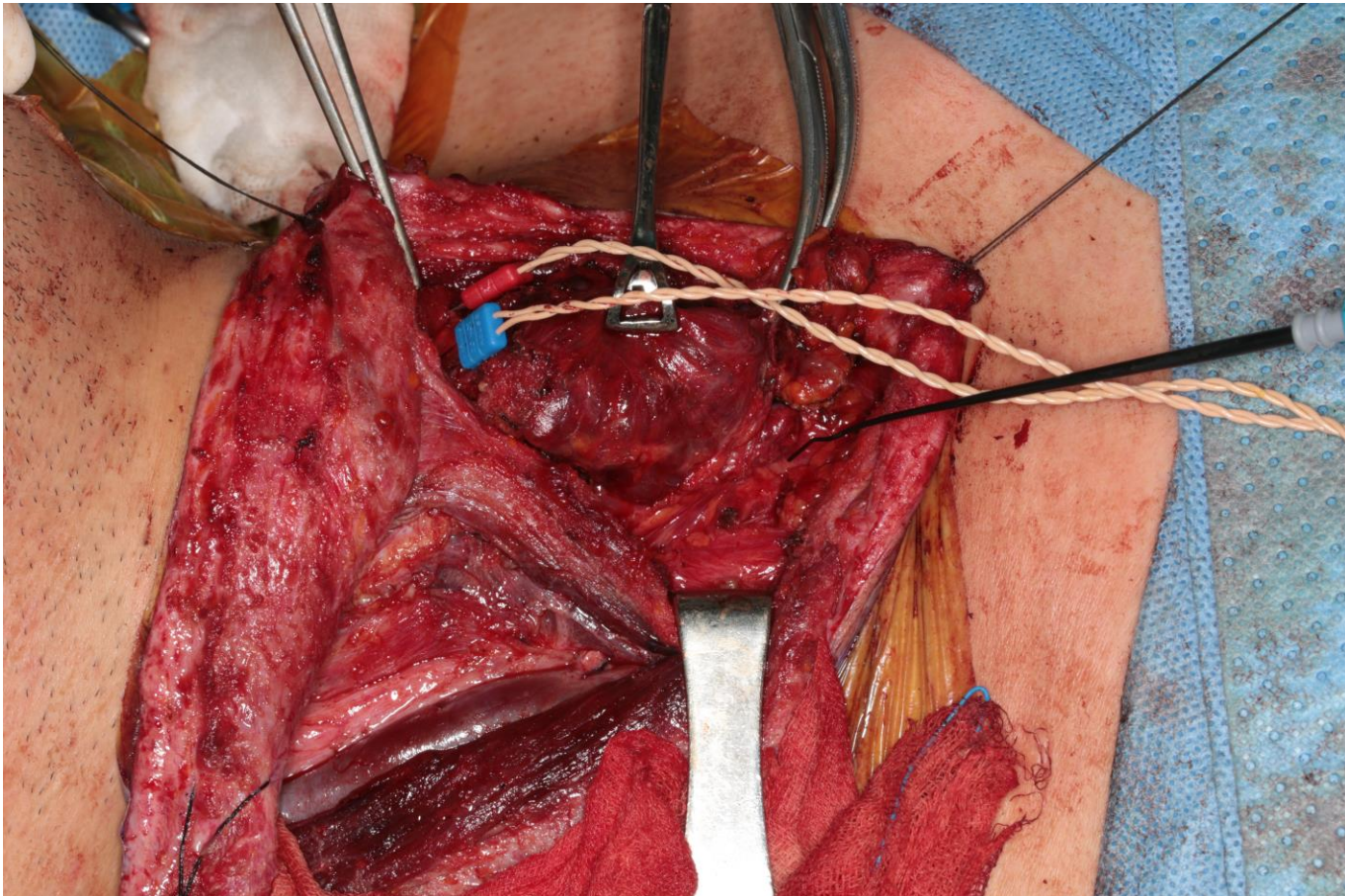
- Due to Bilateral RLN injury?
- Due to Displacement of EMG endotracheal tube?
- ❖ How can you discriminate false LOS from true LOS?

Laryngeal twitching

- one off test for RLN function

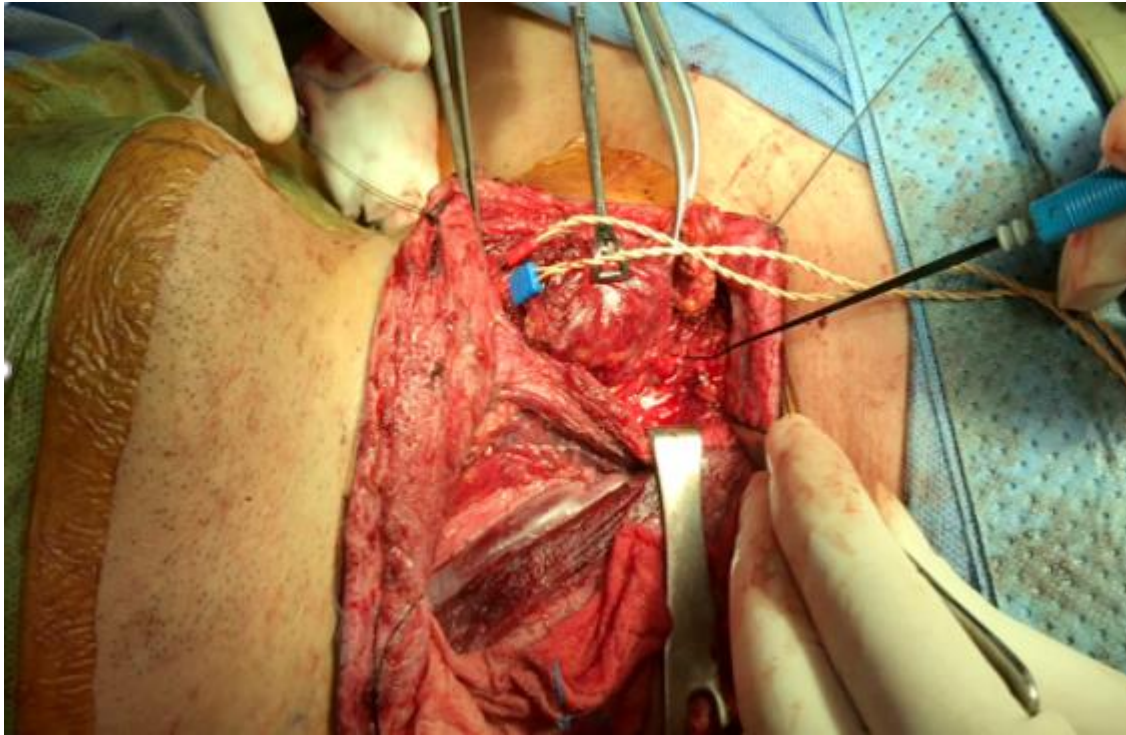


Alternative way of troubleshooting
to test RLN function and maintain IONM
- transcartilagenous needle electrode

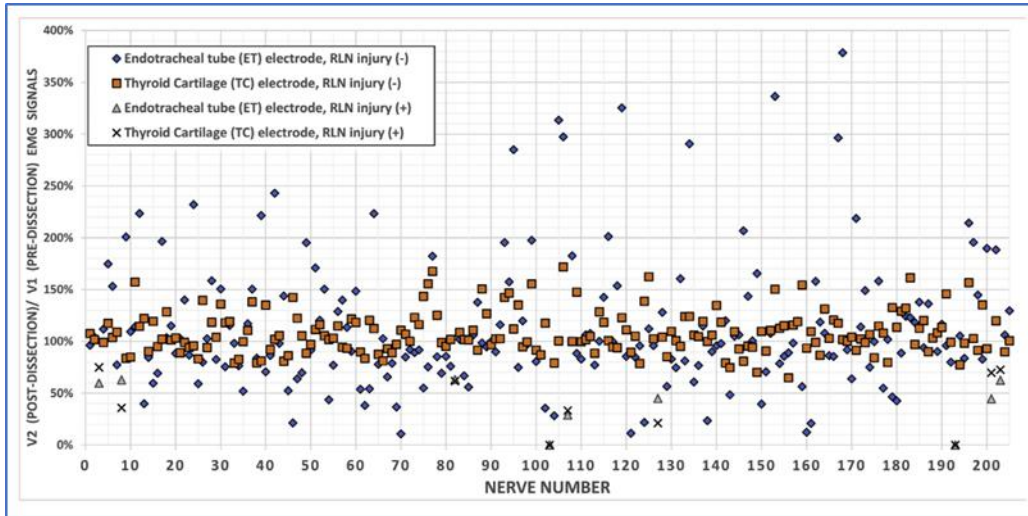


Transcartilagenous needle electrode

- concluded initial LOS was a false LOS



IONM using needle electrodes



•EMG ET



•Needle electrode

- showed typical biphasic EMG waveform and same latency time
- presented higher amplitude and more stable EMG signals than that of EMG tube
- showed no false loss of signal with needle electrode
 - while IONM with EMG tube showed false LOS in 15%

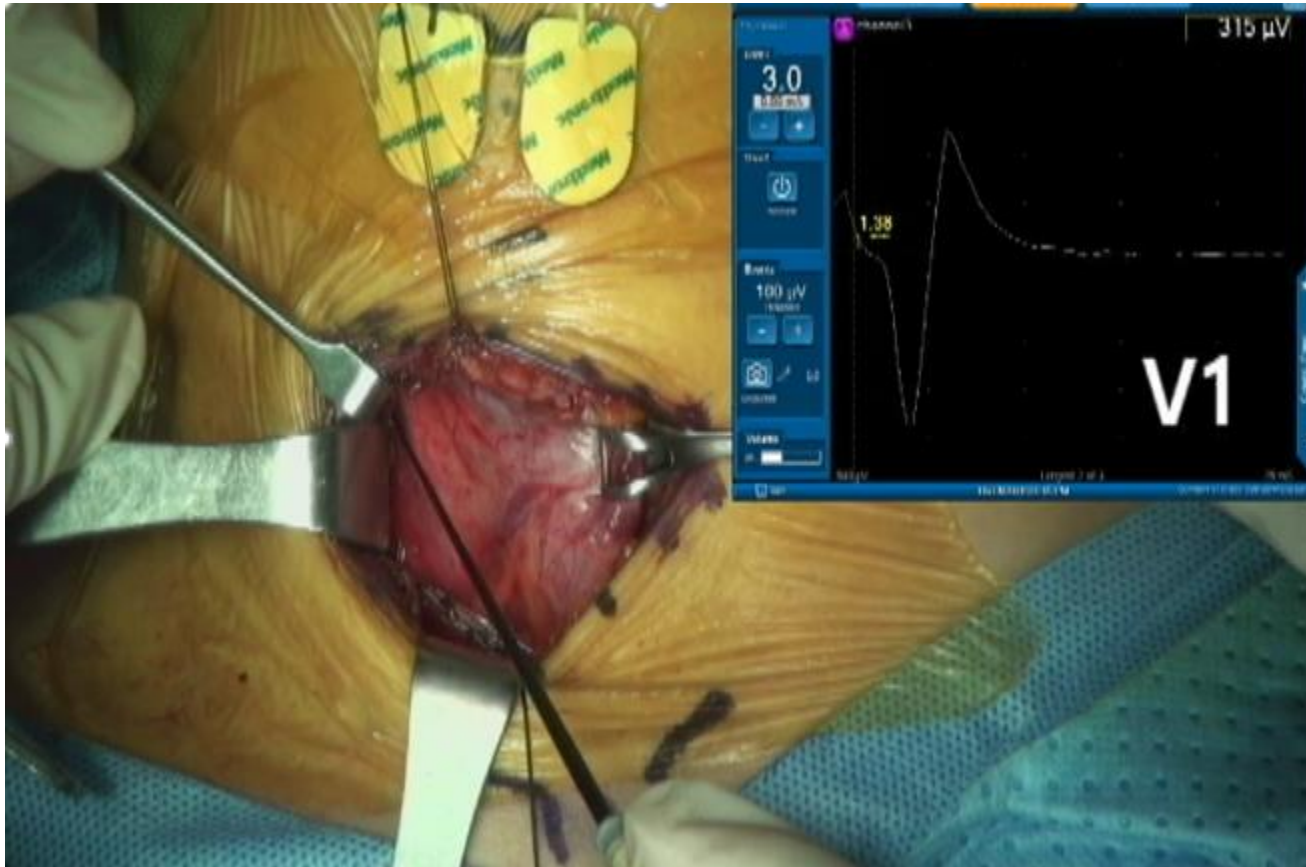
IONM with transcutaneous adhesive skin electrode

- No reports on human thyroidectomy

IONM with transcutaneous adhesive skin electrode in Kosin University Gospel Hospital



Nerve monitoring with transcutaneous adhesive skin electrode in a patient with non-RLN



Comparison of IONM with EMG endotracheal tube with skin adhesive electrode in 39 RLNs



IONM with transcutaneous adhesive skin electrode

- IONM using adhesive skin electrodes was successful with biphasic EMG signal in all 39 nerves
- although the amplitude was lower in skin electrode than that of EMG tube, latency time of EMG signal was similar
- Advantage of adhesive skin electrodes
 - May **prevent false LOS** interpretation of EMG tube
 - **Very low cost** : 5 USD (1/50 of EMG tube)
 - **Easy** to set (< 1 min)
- Amplitude < 100 μ V but still with normal biphasic EMG wave

Summary

- Needle electrode and skin adhesive electrode may be used for alternative method of IONM in selected cases, especially in case of
 1. false LOS due to EMG tube displacement
 2. when EMG tube is hard to prepare

Acknowledgement



Sung Won Kim



Hyoung Shin Lee



Jeong-Ho Oh



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*Department of
Internal Medicine*



Yeh-Chan Ahn



Yigeun Kim

Department of Biomedical Engineering Center

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