



Intraoperative assessment of parathyroid perfusion using indocyanine green angiography in robotic thyroidectomy

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In recent da Vinci robot systems (Intuitive Surgical), near-infrared fluorescence imaging (Firefly technology) has been used. With this technique, it is possible for surgeons to see important structures well beyond the limits of their eyes; hence, surgeons can safely operate and make critical decisions accurately using image-guided surgery. Because parathyroid glands (PTGs) are small and embedded in the surrounding tissues, such as lymph nodes and fat, it is often very hard for surgeons to identify PTGs. To preserve PTGs well, the surgeon must be able to accurately identify PTGs, preserve the vasculature surrounding, and maintain the perfusion to PTGs. Herein, we report an assessment of PTG perfusion using indocyanine green angiography in transoral robotic thyroidectomy.

Keywords: Parathyroid glands, Indocyanine green, Angiography, Thyroidectomy, Robotics

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INTRODUCTION

Image-guided surgery makes it possible for individuals to see important structures well beyond the limits of the surgeon's eye. Therefore, this approach allows surgeons to perform operations safely and to make critical decisions well. Recently, a surgical method using fluorescence imaging was attempted in various surgical fields, and the application of this technique is increasing [1,2]. In thyroid surgery, a surgical method using fluorescence is currently being applied in the following procedures: (1) central lymph node dissection (CLND) through lymph node mapping by parenchymal injection of indocyanine green (ICG) and (2) evaluation of blood flow to the parathyroid gland (PTG) revealed by intravenous injection of ICG. We previously reported fluores-

cence imaging-guided robotic thyroidectomy and CLND using lymph node mapping in patients with thyroid cancer [3].

Major concerns in preserving the PTG are identifying the PTG precisely, preserving the vasculature of the PTG, and finally assessing the viability of the PTG. However, even for experienced surgeons, it is very difficult to accurately evaluate the viability of the PTG by eye. Until now, the way to assess the viability of the PTG has been checking the color, swelling, and vasculature of the PTG. It is a major problem that these methods are subjective and inaccurate. A PTG without viability should be autotransplanted to prevent permanent hypoparathyroidism. Herein, we report the assessment of PTG perfusion using ICG angiography in transoral robotic thyroidectomy.

MATERIALS AND METHODS

Patient

A 29-year-old female patient was diagnosed with papillary thyroid cancer through screening. Cancerous lesions were located in both lobes, and the sizes were 0.5 cm on the right and 0.3 cm on the left. The preoperative thyroid function test indicated euthyroid status and the preoperative parathyroid hormone (PTH) level was 54.2 pg/mL. There was no family history of thyroid cancer, and there was no specific past history, including allergies. Preoperative ultrasonography and neck computed tomography (CT) showed no extrathyroidal extension or lymph node metastasis of cancer. The patient underwent transoral robotic total thyroidectomy and prophylactic CLND with a da Vinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) (Supplementary Video 1).

Surgical procedures

The patient was placed in the supine position with her neck extended. Three incisions were made inside the mouth without axillary incision, and after blunt dissection, working ports were inserted on both sides and a camera port was placed in the middle. A flap dissection was performed from the thyroid cartilage to the suprasternal notch, and the da Vinci Xi Surgical System was docked. After opening the strap muscle and dividing the isthmus, a lateral dissection was performed. The external branch of the superior laryngeal nerve was mapped and saved using intraoperative neuromonitoring, the superior thyroidal vessel was cut, and the superior pole was dissected. Careful capsular dissection was performed to preserve the superior PTG and its surrounding vessels. The recurrent laryngeal nerve was found near the berry ligament using intraoperative neuromonitoring, and the nerve was preserved while the berry ligament was cut. Thyroidectomy was performed in the caudal direction while the recurrent laryngeal nerve was dissected downward. The terminal branch of the inferior thyroidal artery was cut to preserve the feeding vessels to the PTG. Since the right inferior PTG was located in the thyroid capsule, the PTG was barely saved through capsular dissection. Prophylactic CLND was performed, and suspicious metastatic lymph nodes were not detected. After inserting the specimen into the pouch, it was pulled out through the midline, and bleeding was controlled after irrigation.

For ICG angiography, 10-mL normal saline was added to one vial of Diagnogreen (25 mg; Daiichi Sankyo, Tokyo, Japan) and mixed; then, 6 mL (15 mg of ICG) was injected into the patient intravenously. Approximately 40 seconds after ICG injection, the inferior thyroidal artery started to be gradually enhanced under fluorescence imaging (Firefly mode), and the PTG started to be

enhanced after approximately 1 minute. The surgeon determined that the left inferior PTG was normal based on shape and color and was observed that the PTG was well-perfused based on good enhancement in ICG angiography. The left superior PTG looked normal when it was assessed by the surgeon, and it was expected that perfusion would be good because there was a feeding vessel around the area; however, there was no perfusion in the PTG when the area was evaluated by ICG angiography. The right inferior subcapsular PTG had a normal shape and color; however, it had no peripheral feeding vessels, and there was no perfusion by ICG angiography. Therefore, this PTG was safely autotransplanted into the sternocleidomastoid muscle. The right superior PTG was slightly darker in color; however, it was partially perfused by ICG angiography, so it was deemed as a moderately perfused PTG and left in place without autotransplantation. According to the results of left superior PTG reassessment, there was still no perfusion, so it was regarded as a nonperfused PTG, and autotransplantation was performed. Finally, the midline was closed, an oral incision was sutured, and the operation was finished.

RESULTS

During and after surgery, the patient's vital signs were stable, and there were no allergic reactions to ICG. Postoperative laboratory tests showed that calcium and PTH levels were within normal range (calcium, 9.5 mg/dL [normal range, 8.7–10.4 mg/dL]; PTH, 34.7 pg/mL [normal range, 18.5–88.0 pg/mL]), and the patient did not experience a tingling sensation. The patient was discharged without any complications on the second day after surgery.

DISCUSSION

Fluorescence imaging using ICG can be applied to identify and evaluate the perfusion of the PTG in thyroid and parathyroid surgery [4,5]. During thyroidectomy, ICG helps surgeons to localize PTGs assess the vascular supply of PTGs and determine possible avascularization of PTGs. And ICG is cost-effective because it is cheap at about \$10. Yu et al. [6] used ICG and Firefly technology to identify PTGs during robotic thyroidectomy using a bilateral axillo-breast approach. This study showed that the PTG was gradually illuminated 1 to 3 minutes after intravenous injection of ICG. The thyroid gland was illuminated only 3 to 10 seconds after PTG illumination. In total, 32 of 33 PTGs were targeted in 22 patients in an ICG group who were evaluated to demonstrate PTG identification by ICG fluorescence under near-infrared (NIR) light. Patients in the ICG group revealed a much lower percentage of incidental parathyroidectomy than patients in the control group (0% vs. 15.9%, $p = 0.048$). There was no difference in postoperative hypoparathyroidism between patients in the two groups. This study concluded that ICG with NIR light may

be a feasible way to identify and preserve PTGs during robotic thyroidectomy. However, this technique has the limitation that the PTG can be identified only after almost exposing the soft tissue near the PTG and looking at the suspected PTG because the surrounding thyroid gland is immediately enhanced. In addition, if the PTGs are devascularized, ICG cannot reach PTGs through the vessels and highlight them for identification.

In other clinical applications, Firefly technology could be administered after thyroidectomy to reevaluate the perfusion of PTGs. In our study, the surgeon preserved the PTGs well, the color and shape of the PTGs were good, and the blood vessels around the PTGs were visible. Thus, the surgeon determined that the PTGs and their vasculature were well preserved. However, after checking with actual ICG angiography results, it was confirmed that perfusion was not good in one PTG. Our study confirmed that even experienced surgeons may be inaccurate in their assessment of the blood flow and viability of PTGs. Because PTGs with poor blood flow can die and become dysfunctional if left *in situ*, which can lead to permanent hypoparathyroidism, it is thought that poorly perfused PTGs should be autotransplanted to prevent permanent hypoparathyroidism. Therefore, it is considered most important to accurately measure the blood flow of PTGs during thyroidectomy.

Postoperative dysfunction of the PTG is caused by congestion as well as poor perfusion. In our study, the right superior gland was slightly dark in color, but it was partially perfused on ICG angiography, suggesting congested PTG. It is difficult to precisely distinguish between poor perfusion and congestion, but it can be distinguished by color and shape. PTG without arterial perfusion has a color and shape close to normal. And venous drainage PTG is blocked with congestion, so the PTG gets swollen and turns into dark brown color.

A randomized clinical trial showed that ICG angiography reliably predicts the vascularization of PTGs and eliminates the need for postoperative measurement of calcium and PTH and supplementation with calcium in patients with at least one well-perfused PTG [7]. However, in 6% of the cases studied, ICG dye revealed false-negative results, where ICG dye was no longer observed after injection. However, ICG angiography has some limitations. It is also difficult to gain real-time information due to the delayed response. Because the dye is washed away in a few minutes, repeated, continuous evaluation of perfusion can be difficult. Another limitation is that ICG angiography is a qualitative assessment because the surgeon evaluates contrast enhancement by visual assessment, and there are no quantitative data about this procedure. Additionally, there is a high possibility of ICG leaking, which could lead to blurred visualization of PTGs when bleeding occurs during surgery. This technique should not be used in patients allergic to iodine. The toxic level for ICG is 5 mg/kg, so a dose of 15 to 20 mg is considered to be safe and not

clinically risky in patients without allergies. Although it is safe because side effects are very rare, it is not recommended for use in patients who have side effects on enhanced CT or iodine [8]. The ICG fluorescence imaging technique for PTG detection and evaluation for perfusion still lacks standardization, and further studies are needed to establish its clinical utility.

In summary, ICG angiography could be used to conduct a more objective evaluation of PTG perfusion than a surgeon's visual assessment could provide. This approach is very helpful for surgeons when they are deciding whether to perform autotransplantation or leave the PTG *in situ* after the PTG has been identified as having suitable perfusion or having no perfusion.

NOTES

Ethical statements

This study was approved by the Institutional Review Board of Kyungpook National University Chilgok Hospital in Daegu, Korea (No. 2019-09-026-001). Written informed consent was obtained from the patient.

Authors' contributions

Conceptualization: WWK, JHP
 Data curation, Formal analysis: WWK
 Investigation: JHJ, JL
 Methodology: HYP, JL
 Project administration: WWK, JHJ
 Visualization: JHP, HYP
 Writing—original draft: WWK, JHP
 Writing—review & editing: All authors
 All authors read and approved the final manuscript.

Conflict of interest

All authors have no conflicts of interest to declare.

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Supplementary materials

Supplementary materials can be found via <https://doi.org/10.7602/jmis.2022.25.3.112>.

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