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Preserving Parathyroid Integrity in Thyroid Surgery: Innovative Techniques and Advanced Strategies for Minimizing Pain and Complications-Narrative Review Article

Rostam Poormousa[1], Goli Aezzi[2]*, Hossein Meskar[2], Alieh zamani kiasari[3], Ali Abbaskhani Davanloo[4], Amirsaleh Abdollahi[5], Melika Silakhor[5]

[1]*Department of Otolaryngology, School of Medicine, Mazandaran University of Medical Sciences, Sari, Iran.*
[2]*Fellowship Pain Medicine, Department of Anaesthesiology, Mazandaran University of Medical Sciences, Sari, Iran.*
[3]*Department of Anaesthesiology, Faculty of Medicine, Mazandaran University of Medical Sciences, Sari, Iran.*
[4]*Professor of Anesthesiology, Department of Pain management, Mazandaran University of Medical Sciences, Sari, Iran.*
[5]*Medical Student Mazandaran University of Medical Sciences, Sari, Mazandaran, Iran.*
**Corresponding author: Goli Aezzi.*

Abstract

Thyroid surgery, while generally safe, poses risks of parathyroid gland injury leading to postoperative hypocalcemia. Incidental excision during thyroidectomy is not uncommon, with reported rates as high as 22%. Identification challenges stem from the variable location of parathyroid glands, their small size, and shared blood supply with the thyroid. Factors like thyroiditis, radical neck dissection, and malignancy increase the risk. Preservation methods include meticulous dissection, real-time identification, and innovative techniques like Near-Infrared Autofluorescence (NIRAF) and Indocyanine Green (ICG) angiography. Recent studies suggest that NIRAF significantly reduces postoperative hypocalcemia rates. Additionally, ICG angiography proves reliable in parathyroid detection during surgery. Carbon nanoparticles (CNs) enhance lymph node visualization while sparing parathyroid glands. Understanding vasculature preservation principles is crucial, and methods like auto-transplantation can safeguard parathyroid function. Studies on pain experiences following thyroid and parathyroid surgery highlight the prevalence of sustained pain beyond the expected recovery period. Collaborative efforts between surgical and anesthetic teams are essential to tailor pain management strategies, incorporating regional anesthesia techniques and minimizing opioid use. A review of regional pain control strategies, such as cervical plexus blocks, underscores their potential benefits in optimizing postoperative pain relief. Lastly, insights from studies optimizing outpatient pain management reinforce the importance of tailored interventions and closer follow-up for patients experiencing prolonged pain. The culmination of these approaches ensures comprehensive care in thyroid surgery, minimizing pain and inadvertent parathyroid damage and associated complications.

Keywords: parathyroid integrity; thyroid surgery; innovative techniques; advanced strategies; minimizing pain

Introduction

Through the contributions of several pioneers in thyroid surgery such as Billroth, Halsted, and Kocher, and such technical advances as antisepsis and hemostatic clamps, thyroid surgery has become a relatively safe operative procedure.' However, operative complications, although rare, are still observed [1]. Thyroidectomy is a relatively safe surgical procedure. The main postoperative complications include injury to the parathyroid glands [2] and Permanent hypoparathyroidism [3-5]. Incidental excision of parathyroid glands is a common event during thyroid surgery [6]. Anyway, reduced parathyroid gland (PG) viability leads to decreased PG functional capacity, resulting in impaired PTH secretion, and leading to postoperative hypocalcemia [7]. Inadvertent damage to or excision of a healthy PG following a total thyroidectomy could result in transient hypocalcemia (< 6 months) in 5 – 35% of cases or permanent hypocalcemia (> 6 months) in up to 7% of the patients [8-11]. Unintentional damage or removal of PGs has been reported in up to 22% of patients who undergo total thyroidectomy [12,13]. The preservation of PGs during neck surgery is crucial to avoid postoperative hypoparathyroidism [12].

Factors of incidental parathyroidectomy due to thyroid surgeries

Damaging to parathyroid glands during thyroid surgeries may be due to a variety of factors:

The variable location of the parathyroid glands (particularly the intracapsular or intrathyroidal location in some cases) make their identification during surgery difficult or impossible and contributes to the risk of incidental parathyroidectomy [2,14]. This variable location is observed specially about inferior parathyroid glands [15]. Patients undergoing thyroidectomy may have inadvertent damage or removal of the parathyroid gland(s) due to difficulty in real-time parathyroid identification [16,17]. Because the small size, color, and shape of a parathyroid gland can make it difficult to distinguish from surrounding tissues such as fat and cervical lymph nodes [14]. Some authors have described thyroiditis as a risk factor for incidental parathyroidectomy [18]. Modified radical neck dissection and Malignant thyroid disease have been recognized as risk factors for unintentional parathyroidectomy [2,19]. as Reoperative and Bilateral thyroid surgery was reported by Sippel et al. to be a risk factor for incidental parathyroidectomy [19,20]. The thyroid and parathyroid glands commonly share their supplying vessels at the thyroid capsular level [21]. so devascularization and obstruction of venous drainage of the parathyroid glands can be another factor [4]. Some studies reported young age and male sex as risk factors for incidental parathyroidectomy [20,22]. This contrasts with the findings of other studies where age and sex were not risk factors [19].

methods to reduce damaging parathyroid glands in thyroid surgeries: Preservation in situ with good vascular supply is the mainstay of safe thyroid surgery Halsted and Evans2 described in detail the blood supply to the parathyroid and discussed their preservation during thyroid surgery in 1907 [1]. Identifying parathyroid glands during thyroid surgery can result in a lower incidence of incidental parathyroidectomy [24,25]. Successful intra-operative identification of parathyroid glands is largely dependent on the surgeon's experience in thyroid surgery and knowledge of parathyroid gland anatomy [4,14,26]. Existing methods for identifying parathyroid glands include ultrasound, sestamibi scintigraphy, computed tomography (CT), and magnetic resonance imaging (MRI). These current modalities for localizing parathyroid glands are limited in their sensitivity, rendering them inadequate to prevent surgical complications. These techniques are primarily utilized for preoperative localization of an enlarged, hyperfunctioning parathyroid gland(s) and cannot be used to find a normal gland (before or during thyroidectomy [16].

Careful parathyroid gland dissection and in situ preservation was the time-honored approach to prevent parathyroid failure after total thyroidectomy [27,28]. Based on some studies, Careful dissection and examination of the thyroid capsule during thyroidectomy would decrease the incidence of incidental removing more than one parathyroid gland [19,26]. Use of a meticulous surgical technique and dissection close to the thyroid gland aiming at the preservation of the intact blood supply to the parathyroid, and keeping away from unnecessary manipulation of parathyroid in due course of the dissection are well-established factors contributing to the reduced prevalence of temporary and permanent hypocalcemia [23,28]. A technique that accurately and rapidly identifies PGs would represent a useful intraoperative adjunct [12]. Domestic and foreign techniques for retaining the parathyroid gland mainly include the meticulous capsular dissection technique, in-situ protection technique, using carbon nanoparticles, and parathyroid auto-transplantation technique [15]. The use of NIRAF for the identification can help too [29,30]. Recently a comprehensive review of novel techniques for intraoperative PG identification has been reported and found NIR-PAF to be among the most promising and reliable [7]. Also, if the parathyroid glands are damaged, auto-transplantation should be undertaken to preserve their function [23].

Pain management

In the realm of thyroid surgery, where preserving parathyroid integrity is paramount, it is crucial to address not only the surgical techniques but also the aspects of pain management and anesthesiology. While thyroid surgery is generally considered safe, the potential for complications necessitates a comprehensive approach that includes strategies to mitigate pain and optimize patient comfort. The study led by Lee et al. delves into the postoperative pain experiences of patients undergoing outpatient thyroid or parathyroid surgery. Utilizing a real-time Short Messaging Service (SMS) survey, the researchers collected data on pain levels, opioid use, voice quality, and energy levels. Out of 155 enrolled patients, with an 81.6% response rate, the study focused on 133 individuals with a response rate exceeding 50%. The findings highlighted that 36.1% of patients did not

require opioids postoperatively. Thyroidectomy, preoperative opioid or tobacco use were identified as independent risk factors for higher total pain scores. Moreover, increased opioid use was associated with age below 60, a body mass index above 30 kg/m2, preoperative opioid or tobacco use, and a history of anxiety or depression. A noteworthy result was that up to 10% of patients reported sustained pain and opioid use beyond one week postoperatively. This data suggests that a subset of patients may face prolonged pain experiences, emphasizing the need for closer follow-up and potentially early intervention for those still grappling with pain and opioid dependence beyond the expected recovery period. The study underscores the importance of continuous pain monitoring and tailored interventions to enhance the postoperative experience for thyroid and parathyroid surgery patients [31].

Pain Management and Anesthesiology Considerations

Effective pain management during and after thyroid surgery contributes significantly to patient recovery. Anesthesiologists play a pivotal role in tailoring anesthetic plans to minimize postoperative discomfort. Regional pain control techniques, such as cervical plexus blocks or local anesthetic infiltration, can be employed to enhance postoperative pain relief and reduce the reliance on systemic analgesics. The systematic review by Ochoa et al. addresses the issue of opioid over-prescription in perioperative pain management for thyroid and parathyroid surgery, potentially contributing to the US opioid epidemic. The authors examined 51 randomized clinical trials, 9 prospective cohort studies, 7 retrospective studies/reviews, and 1 survey related to pain management in cervical endocrine surgery. The majority of studies focused on in-hospital pain scores and opioid consumption, with limited data on post-discharge pain scores. The review suggests that evidence-based, non-opioid interventions can be integrated into standardized pain management protocols for cervical endocrine surgery. However, gaps in knowledge exist regarding the impact of these interventions on post-discharge pain scores and patient quality of life during recovery [32].

Regional Pain Control Strategies

Regional anesthesia techniques, when judiciously applied, can provide targeted pain relief in the surgical area. Cervical plexus blocks, including superficial and deep cervical plexus blocks, have been explored for thyroid surgery, demonstrating potential benefits in reducing postoperative pain intensity and opioid consumption. Anesthesiologists, working closely with surgeons, can employ these techniques to optimize pain control while maintaining patient safety. The study by Rago et al. investigates day-case parathyroidectomy, specifically focusing on patient experience and recovery at home. The research compares two anesthesia techniques—regional anesthesia (RAg) and general anesthesia (GAg)—in the context of minimally-invasive video-assisted parathyroidectomy (MIVAP) performed as day surgery. Key findings include that patient in the RAg group reported no pain lasting longer than 1 day after discharge, while 15% of GAg patients reported pain relief on the third day after discharge. The study also noted quicker discharge times in the RAg group, with 78.1% discharged within 4 hours, compared to the GAg group where 53.8% were discharged within 5 hours. Overall, patients highly appreciated day-case parathyroidectomy, and the combination of regional anesthesia with MIVAP was favored for better results compared to general anesthesia with MIVAP. The study underscores the importance of considering patient preferences and their personal experiences during hospitalization, emphasizing the significance of tailoring care to individual needs [33].

Collaborative Approach for Optimal Patient Outcomes

The synergy between the surgical team and anesthesiologists is paramount in achieving optimal patient outcomes. A collaborative approach ensures that pain management strategies align with the surgical plan, addressing not only the immediate postoperative period but also considering long-term comfort and recovery. Clear communication between the teams is crucial to tailor anesthetic interventions to the unique needs of each patient undergoing thyroid surgery. The review by Uhlmann et al. focuses on postoperative pain management for patients undergoing thyroidectomy and parathyroidectomy. The study aimed to assess analgesic regimens and identify strategies to decrease opioid use while ensuring adequate pain control. A literature review of 951 studies over the past 20 years led to the inclusion of 10 relevant studies. The findings indicated that half of the studies demonstrated a decrease in pain with multimodal regimens. However, there was no established optimal postoperative analgesic regimen in the current medical literature for these procedures. Notably, nonopioid adjuncts in some studies were

associated with a reduced need for postoperative opioids, emphasizing the potential for alternative pain management approaches in thyroid and parathyroid surgery [34]. The study led by Lou et al. focuses on optimizing outpatient pain management after thyroid and parathyroid surgery, a field with limited data despite the increasing trend of completing these procedures on a same-day basis. The aim was to describe the postoperative narcotic medication needs for patients undergoing thyroid and parathyroid surgery and identify predictors of higher requirements. Data from 313 adult patients undergoing thyroidectomy or parathyroidectomy at two large academic institutions were analyzed. Results indicated that 83% of patients took ten or fewer oral morphine equivalents (OMEQs), and 93% took 20 or fewer OMEQs by their postoperative visit. Younger age, higher overall mean pain scores, previous narcotic use, and the type of surgery (parathyroid or thyroid) independently predicted the use of more than ten OMEQs postoperatively. The study concludes that, overall, 93% of patients undergoing thyroidectomy and parathyroidectomy require 20 or fewer OMEQs by their postoperative visit. The recommendation is to discharge these patients with 20 OMEQs to minimize waste and enhance patient safety, providing valuable insights into optimizing outpatient pain management strategies for thyroid and parathyroid surgery [35].

Innovative Techniques in Regional Pain Control

Advancements in regional pain control techniques, such as ultrasound-guided nerve blocks, present opportunities to refine the precision and efficacy of pain relief strategies. Integrating these innovations into the perioperative care plan can contribute to enhanced patient satisfaction, quicker recovery, and potentially reduced complications associated with pain-related stress. The study by Kulkarni et al. assesses bilateral deep cervical plexus block regional anesthesia for thyroidectomy and parathyroidectomy in healthy and high-risk patients. The focus is on evaluating the effects on respiratory function. In the procedure, bilateral blocks were performed in 20 out of 21 patients using bupivacaine with epinephrine. Intraoperative management included supplemental intravenous sedatives/narcotics and allowing patients to listen to music via headphones for anxiety. Results show that 18 patients tolerated the procedure well with supplemental sedation. Two required supplemental inhalation anesthesia, and one needed tracheal intubation. Three high-risk patients tolerated the procedure well with intraarterial line monitoring. Postoperatively, 11 patients had minimal incisional pain, 13 had mild pain on swallowing, and 2 complained of nausea. Forced vital capacity measurements showed no significant differences between baseline and post-block recovery room assessments. The study concludes that regional anesthesia is a suitable alternative to general anesthesia for selected patients undergoing these surgeries, without compromising respiratory function. This suggests that bilateral deep cervical plexus block regional anesthesia is a viable and safe option for thyroidectomy and parathyroidectomy procedures [36].

Discussion

Because inadvertent damage of parathyroid glands can lead to postoperative hypocalcemia, their identification and preservation, which can be challenging, are pivotal during total thyroidectomy [29]. There are some methods for identification and preservation of parathyroid glands during thyroidectomy: Near-infrared autofluorescence (NIRAF) has been demonstrated as a label-free modality for intraoperative parathyroid identification with high accuracy [16,30].

A randomized clinical trial was conducted from September 2016 to October 2018, with a 6-month follow-up at 3 referral hospitals in France. Adult patients who met eligibility criteria and underwent total thyroidectomy were randomized. The exclusion criteria were preexisting parathyroid diseases. In this randomized clinical trial of 241 adults, the use of NIRAF during total thyroidectomy helped lower the temporary postoperative hypocalcemia rate from 22% to 9% and the parathyroid auto transplantation and parathyroid inadvertent resection rates from 16% to 4% and 14% to 3%, respectively. Meaning NIRAF based identification of parathyroid glands during thyroid surgery may limit parathyroid risk [29]. A recent literature review by Spartalis et al. examined 612 patients who underwent thyroid surgery (71parathyroidectomies and 541 thyroidectomies) using ICG angiography. The review found that intra-operative ICG angiography is a more reliable tool to detect parathyroid adenomas compared to pre-operative imaging modalities in parathyroidectomy and a simple and reproducible method to visualize

parathyroid glands and assess their perfusion in thyroidectomy [14].

As the anatomic location of the parathyroid glands (particularly the inferior parathyroid gland) varies greatly, these glands can be mistakenly identified as metastatic lymph nodes within the central neck. Therefore, effective methods to visualize additional lymph nodes while preserving the parathyroid glands are needed. carbon nanoparticles (CNs), a new class of lymph node tracers, consist of nanosized carbon particles with an average diameter of 150 nm and are immediately able to enter the lymphatic capillaries (diameters of 500 nm) rather than blood vessel capillaries (diameters of 30-50 nm). Upon injection into the tissues around the tumor, CNs are rapidly engulfed by macrophages. Recent studies have shown that when CNS is injected around a tumor within the ipsilateral thyroid, the thyroid tissue stains black, as do the surrounding lymph nodes, but the surrounding thyroid tissue without lymph-vessel connections (eg, the recurrent laryngeal nerve and the parathyroid glands) remains unstained. So, the CN method can partially improve the extent and accuracy of neck dissection and can preserve the normal anatomic structure and physiologic function of the parathyroid glands after thyroid cancer surgery [37].

Also, there are some techniques for preserving the surrounding vasculature of parathyroid glands, principles like following items:

1. Maintaining normal parathyroid function after thyroidectomy is possible by preserving both the parathyroid glands and their vasculature.
2. Vessels supplying the superior parathyroid gland are very thin around the ligament of Berry and sometimes run within the thyroid capsule. Thus, dissection in this area must be done very carefully to avoid interrupting blood flow. If the vessel runs within the thyroid capsule, a small portion of adjacent thyroid tissue can be left in place to preserve the vasculature.
3. To avoid disrupting the downward blood flow to a parathyroid gland, the nearest vessel supplying it should be separated from the thyroid gland and ligated 1–2 mm outside of the parathyroid gland.
4. If a vessel supplying the inferior parathyroid gland is not connected to the ITA trunk but runs parallel to the trachea in an intra-capsular course, a long segment of the vessel should be preserved, taking care not to injure the original vessel around the lower pole of the thyroid gland.
5. A parathyroid gland located in the middle of the thyroid gland with no or a very thin blood vessel can be auto-transplanted to Sternocleidomastoid (SCM) muscle, or preserved by leaving a small amount of thyroid tissue around it.
6. If all the parathyroid glands left in situ after removal of the thyroid gland have a slight discoloration, more than one of the glands should be auto-transplanted into the sternocleidomastoid muscle as a precautionary measure.
7. Because en bloc resection of the thyroid gland and central lymph node can increase the risk of inadvertent vascular damage to the parathyroid gland and also of hypoparathyroidism, central neck dissection should be performed after parathyroid preservation and thyroid removal [21].

Conclusion

In conclusion, this study underscores the critical importance of meticulous techniques and innovative approaches in minimizing the risk of parathyroid gland injury during thyroid surgery. The challenges associated with variable parathyroid gland locations, small sizes, and shared blood supply with the thyroid necessitate careful consideration and skillful execution during surgical procedures. The identification methods, such as Near-Infrared Autofluorescence (NIRAF) and Indocyanine Green (ICG) angiography, prove promising in reducing postoperative hypocalcemia rates. The use of NIRAF has demonstrated its efficacy in lowering temporary postoperative hypocalcemia rates significantly, emphasizing its potential as a valuable intraoperative adjunct. Similarly, ICG angiography emerges as a reliable tool for parathyroid visualization, especially in the context of thyroid surgery. Carbon nanoparticles (CNs) offer an innovative solution to enhance lymph node visualization while preserving parathyroid glands, contributing to improved surgical precision.

Preservation strategies, such as auto-transplantation, are highlighted as effective measures to safeguard parathyroid function. Understanding the principles of vasculature preservation, including careful dissection and ligation, is paramount to maintaining normal parathyroid function post-thyroidectomy. while the primary focus of thyroid surgery revolves around preserving parathyroid integrity, attention to pain management and anesthesiology is equally pivotal. Incorporating regional pain control strategies

into the multidisciplinary approach ensures a holistic and patient-centered care model. By synergizing advancements in both surgical and anesthetic techniques, healthcare professionals can strive towards further improving outcomes and enhancing the overall experience for individuals undergoing thyroid surgery. By integrating these advanced techniques and preservation methods, surgeons can significantly mitigate the risks associated with inadvertent parathyroid damage, ensuring comprehensive patient care in thyroid surgery. Continued research and adoption of these innovations have the potential to further enhance surgical outcomes, reduce complications, and improve overall patient well-being in the field of thyroid surgery.

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