2 Defining Minimally Invasive and Remote Access Surgery of the Thyroid and Parathyroid Glands

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Introduction

Minimally invasive and remote access surgery for the thyroid and parathyroid glands has evolved over the last two decades. The emphasis of minimally invasive surgery is limiting the amount of tissue dissection while achieving the same surgical results. Alternatively, the emphasis of remote access surgery is to achieve better cosmetic results by avoiding a cervical scar. Therefore, although minimally invasive surgery and remote access surgery may use similar tools, they ultimately provide different advantages and drawbacks.

The concept of minimally invasive parathyroidectomy (MIP) has been widely embraced, but includes a variety of operations, and the term may be confusing. The approaches and techniques of minimally invasive thyroidectomy (MIT) have been less universally adopted. MIP and MIT encompass an assortment of procedures ranging from simply shortening the cervical incision to using the endoscope and robot. In this chapter we review the evolution of the concepts, principles, and techniques of MIP, MIT, and remote access surgery for the thyroid and parathyroid surgery with the intent of giving surgeons a framework to understand these diverse and frequently misunderstood operations.

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Minimally Invasive and Remote Access Parathyroid Surgery

Background

Bilateral four-gland parathyroid exploration for patients with primary hyperparathyroidism (HPT) through a 5–6 centimeter (cm) lower neck incision has been the standard surgical approach for decades. With the widespread adoption of high-quality preoperative localization studies such as ultrasound (US) and sestamibi scanning (MIBI), as well as the introduction of intraoperative parathyroid hormone (ioPTH) monitoring to exclude hyperplasia or multiple adenomas, surgeons were able to modify their approach to use smaller incisions and focus on a single side of the neck or a single enlarged parathyroid adenoma. The term *minimally invasive parathyroidectomy* is used to convey the potential advantages of this approach over traditional bilateral exploration, with shorter hospital stays, less pain, and better cosmesis.

In the mid-1990s, concurrent with the development of laparoscopic abdominal surgery, some neck surgeons began to explore the possibility of

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using the endoscope for parathyroid operations. In contrast to the abdomen, the neck has no preformed space to accommodate the scope. Instead, this space is created bluntly and can be maintained with positive pressure, similar to laparoscopy, or by lifting up the superficial tissues with instruments or lifting devices. Endoscopic parathyroidectomy can thus be classified into two categories based on how the operative space in the neck is maintained. Totally endoscopic minimally invasive parathyroidectomy (EMIP) relies on gas insufflation, and minimally invasive video-assisted parathyroidectomy (MIVAP) uses instruments and lifting devices.

As the techniques of endoscopic parathyroidectomy matured, surgeons realized that the same operation could be accomplished by placing the port sites outside the neck, typically in the chest, breast, and axilla. This was the birth of remote access parathyroid surgery. Remote access surgery trades the potential advantage of not having any visible incision in the neck for the potential disadvantage of a larger dissection required for the instruments to reach the target. Figure 2.1 outlines the various approaches to minimally invasive and remote access parathyroidectomy.

Mini-open Parathyroidectomy

The open, focused parathyroidectomy has gained widespread acceptance as having statistically equivalent outcomes to traditional bilateral exploration. For a well-localized parathyroid adenoma, a focused approach can be performed through an incision of 2.5 cm with a success rate of 96 %.

One key to a successful focused parathyroidectomy is accurate preoperative localization. Patients with primary HPT and a concordant preoperative MIBI and US very likely have a single adenoma at that location (96 %). In contrast, those who have no parathyroid localized on MIBI and US have a 30 % chance of having multigland disease and usually require bilateral exploration.

An anterior mini-open parathyroidectomy is performed through a small skin crease incision in the central, inferior neck between the strap muscles and is well suited for exploring the lower parathyroid glands which tend to be more anterior. The lateral, or so-called back-door, approach is better for upper parathyroid adenomas which tend to be located posteriorly. In this approach the space between the strap muscles and sternocleidomastoid muscle is entered to expose the plane

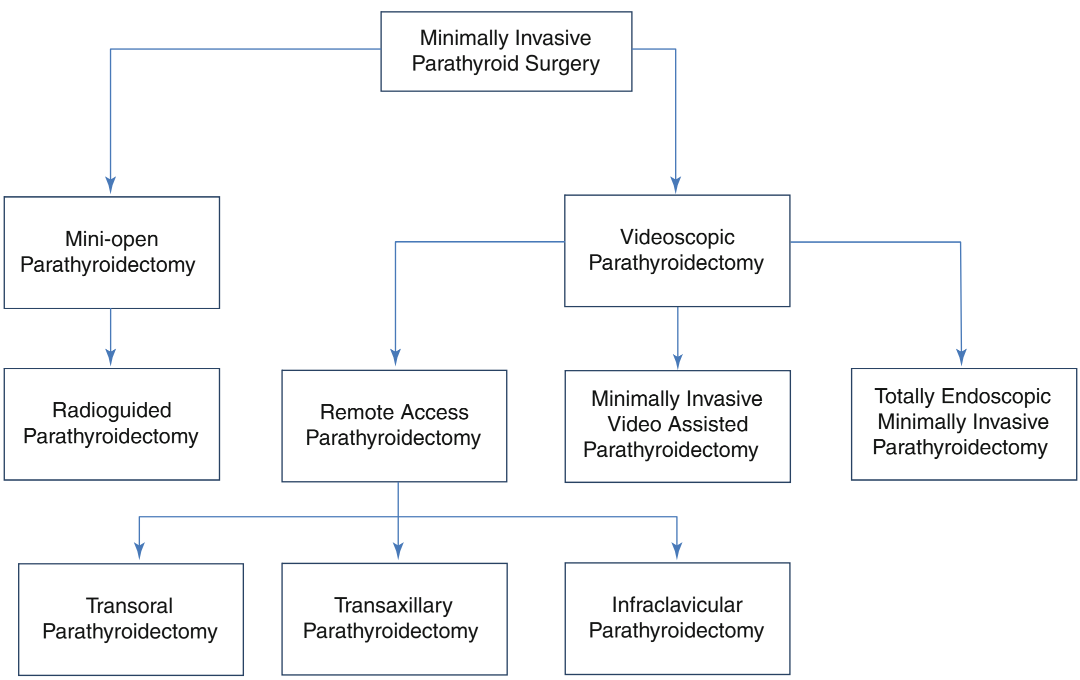

Fig. 2.1 Different approaches to minimally invasive and remote access parathyroid surgery

behind the thyroid. The disadvantage is the potential for a larger incision or bilateral incisions if the contralateral side needs to be explored.

Mini-open parathyroidectomy has an equivalent cure rate to the traditional bilateral exploration with shorter operative times and shorter hospital stays. Mini-open parathyroidectomy has also been shown to decrease the overall cost per procedure compared to traditional exploration. Its success depends on good preoperative imaging and ioPTH monitoring, which may not be universally available.

Radioguided Parathyroidectomy

Intraoperative radioguided localization, with sestamibi technetium-99m (TC-99m) can be used to aid the standard mini-open parathyroidectomy. In this technique, the patient is injected with a TC-99m radiotracer 1–2 h prior to surgery. The radiotracer collects preferentially in the mitochondria of enlarged parathyroid glands and can therefore be identified using a handheld gamma probe. The surgeon uses a gamma probe to explore the operative field, looking for counts greater than background.

Reports on the utility of radioguided parathyroidectomy have been mixed with localization rates between 40 and 100 %. Some of this variability may be due to the learning curve associated with this technology. Advocates suggest that using the gamma probe helps select the location of the skin incision and allows for identification of ectopic parathyroid tumors. Drawbacks may include the increased cost of the technology, its learning curve, and its lack of substantiated benefit.

Videoscopic Parathyroidectomy

Videoscopic parathyroidectomy has gained considerable attention over the last decade. The potential advantages of videoscopic techniques include the magnification provided by the optics, improved cosmesis, and reduced postoperative pain. Gagner et al. performed the first videoscopic parathyroidectomy in 1996. The procedure took almost 5 h to perform, and the patient developed hypercarbia and subcutaneous emphysema from his eyelids to his scrotum that took 3 days to resolve. Since Gagner's initial description, videoscopic parathyroidectomy has continued to evolve and currently can be divided into two subgroups, EMIP and MIVAP, depending on how the operating space in the neck is maintained.

Endoscopic Minimally Invasive Parathyroidectomy

Henry et al. described endoscopic minimally invasive parathyroidectomy (EMIP) using a lateral approach in 1999. One 12-mm and two 2.5-mm trocars are inserted at the anterior border of the sternocleidomastoid muscle. The plane between the strap muscles and the carotid is bluntly dissected and carbon dioxide (CO_2) insufflation is used to maintain the working space. The posterior surface of the thyroid is approached and the parathyroid adenoma is dissected free using 2-mm endoscopic instruments. A modified approach was report by Ikeda et al. in 2002.

Several large series comparing EMIP to open parathyroidectomy demonstrate equivalent cure rates with minimal morbidity. EMIP is generally reserved for single-gland disease with adequate preoperative localization. The major advantage of EMIP is the improved lighting and view provided by the endoscope and the limited size of incision regardless of the patient's body habitus. The major drawbacks are the cost of endoscopy, increased operative time, and possible gas insufflation complications such as hypercarbia, subcutaneous emphysema, and gas embolism.

Minimally Invasive Video-Assisted Parathyroidectomy

MIVAP differs from EMIP in that it does not require gas insufflation. MIVAP was first described by Miccoli et al. in 1998. In MIVAP, a small transverse skin incision is made 1 cm above the sternal notch. The strap muscles are separated. A 5-mm, 30° scope is inserted through the incision, and dissection is done using specially designed open instruments and external retractors, but under a videoscopic view. The operation is similar to mini-open parathyroidectomy, except special instruments and a videoscope are used, which allows the operation to be performed through a 1.5-cm instead of a 2.5-cm incision.

As with endoscopic MIP, MIVAP can be performed with high cure rates and minimal morbidity. The videoscope provides improved lighting and a magnified view. Because of the anterior central approach, it can be used to perform a bilateral exploration. One major drawback is the need for two experienced assistants, one to maintain external retraction and the other to handle the scope. Large parathyroid adenomas, large goiters, prior neck operations, lack of preoperative localization, and suspicion of hyperplasia are relative contraindications to MIVAP.

Remote Access Parathyroidectomy

Remote access parathyroidectomy developed as an extension of endoscopic parathyroidectomy by moving the trocar sites and incisions away from the anterior neck to achieve better cosmetic results. In 2000, Ikeda and Takami reported on six patients who underwent successful parathyroidectomy via an axillary approach and four patients that underwent exploration via an anterior chest approach. Although the operative time was long (180 min for a unilateral axillary approach), all the operations were successful with no significant morbidity. Small series by Landry et al. and Foley et al. also suggested successful outcomes can be achieved via the transaxillary approach but that it is associated with longer operative times and increased costs. In 2011, Karakas et al. described successful transoral parathyroidectomy in two patients.

Conclusion

In summary, MIP, especially mini-open parathyroidectomy, is available in most high-volume endocrine surgery centers and is associated with high success rates and minimal morbidity. It has become a costandard with traditional bilateral four-gland exploration for treating patients with primary HPT. The mini-open technique, with a 2.5-cm neck incision, is the most commonly performed parathyroid procedure. Endoscopic parathyroidectomy and MIVAP are performed at fewer centers, but also have excellent outcomes. Remote access parathyroidectomy appears safe and may have cosmetic advantages, but requires more extensive dissection and is more expensive. Successful MIP and remote access parathyroidectomy depends on accurate preoperative localization studies and intraoperative adjuncts such as ioPTH monitoring. Table 2.1 summarizes the advantages and drawbacks to the various approaches.

Table 2.1 Benefits and drawback to various approaches to parathyroidectomy and thyroidectomy

Approach	Incision length	Benefit	Drawback
Parathyroidectomy			
Traditional	4–5 cm	Excellent exposure to both sides of thyroid. Gold standard with cure rates in excess of 95 %	Relatively long incision. Bilateral exploration is often unnecessary
Mini-open "focused" parathyroidectomy	2–3 cm	Shorter incision. Able to explore both sides with aid of retraction. Reduced operative times and costs	Can be difficult in obese patients. Relies on adequate preoperative localization and ioPTH which may not be available
Radioguided parathyroidectomy	2–3 cm	Helps focus skin incision. May help localize ectopic adenomas	Difficult to learn. May increase patient costs
Totally endoscopic parathyroidectomy	(a) 5 mm ×3 (anterior approach) (b)1.2 cm, 2.5 mm x2 (lateral approach)	Improved magnification and lighting with the endoscope. Shortest incision	Gas insufflation can cause subcutaneous emphysema, air embolism, hypercapnea. Increased cost and operative time

Table 2.1 (continued)

Approach	Incision length	Benefit	Drawback
Minimally invasive video-assisted parathyroidectomy (MIVAP)	1.5 cm	Improved magnification and lighting with videoscope. No need for insufflation. Easy to convert to bilateral operation	Requires two experienced assistants to maintain exposure
Axillary approach to parathyroidectomy	4.5–6 cm	No neck scar	More extensive dissection. Increased operative times and cost. Difficult learning curve
Transoral approach to parathyroidectomy	1.5 cm	No neck scar	Concerns for infection. Minimal reported experience
Thyroidectomy			
Standard open thyroidectomy	4–6 cm	Excellent exposure. Able to perform neck bilateral exploration and lymph node dissection	Relatively long scar in the neck
Mini-open thyroidectomy	2.5 cm	Easy to learn. Easy to convert to bilateral thyroidectomy	Limited to thyroid lobes <7 cm. Lateral approach only for thyroid lobectomy
Completely endoscopic thyroidectomy			
Anterior approach	5 mm ×4	Short neck incisions and quicker return to normal activity. Magnified view	Limited to selected patients. Longer operative time. Insufflation may cause complications (hypercarbia, subcutaneous emphysema)
Lateral approach	10 mm ×1; 2.5 mm ×2	Short neck incisions and quicker return to normal activity. Magnified view	Limited to selected patients. Only hemithyroidectomy. Insufflation may cause complications
Minimally invasive video-assisted thyroidectomy (MIVAT)	1.5 cm	Use open instruments. Easy to learn. Less pain and better cosmetic outcomes	Requires two experienced assistants to maintain exposure
Remote access thyroidectomy – infraclavicular approach	3 cm; 5 mm ×2	No scar in the neck	More extensive dissection. Risk of subcutaneous hemorrhage
Remote access thyroidectomy – axillary approach	3–6 cm	No scar in the neck. Ipsilateral central neck dissection possible	More extensive dissection. Longer operative time. More expensive. Difficult to dissect contralateral thyroid lobe
Remote access thyroidectomy – breast approach	15 mm ×1; 12 mm ×1; 5 mm ×1	No scar in the neck	More extensive dissection. Scar in the breast
Remote access thyroidectomy – axillo-bilateral breast approach	2.5 cm areolar; 10 mm ×2 axillary	Improved angles of dissection between instruments and thyroid	More extensive dissection. Scar in the breast
Remote access thyroidectomy – bilateral axillo-breast approach	12 mm ×2 in each areolar; 5 mm × 2 in each axilla	Improved angles of dissection between instruments and thyroid. Bilateral dissection easy	More extensive dissection. Scar in the breast
Transoral thyroidectomy	2.5 cm in the floor of the mouth	No neck scar	Very limited data on the utility and complications of this procedure
Robotic facelift thyroidectomy	N/A	No neck scar. Supine position	Greater auricular nerve at risk

ioPTH intraoperative parathyroid hormone monitoring, *mm* millimeters, *cm* centimeters

Minimally Invasive and Remote Access Thyroid Surgery

Background

Traditional thyroid surgery was developed by Theodor Kocher at the beginning of twentieth century and was performed through an 8–10 cm collar incision. Currently open thyroidectomies are routinely performed through an incision that is 4–6 cm. Minimally invasive thyroidectomy (MIT) strives to minimize the length of incision in the neck, sometimes with the help of an endoscope. MIT encompasses a diverse set of procedures including (1) completely endoscopic thyroidectomy with CO_2 insufflation, (2) minimally invasive video-assisted thyroidectomy (MIVAT) without gas insufflation, and (3) mini-open thyroidectomy. All three approaches can be performed using an anterior (between the strap muscles) or lateral (between strap muscles and the sternocleidomastoid muscle) approach. Remote access thyroidectomy moves the incision from the neck to the chest, breast, axilla, upper back of the neck, or the mouth, but it is not truly minimally invasive surgery because of the additional surgical dissection required from the remote site. Figure 2.2 shows the various approaches of MIT and remote access thyroidectomy.

Mini-open Thyroidectomy

The typical incision for an open thyroidectomy is about 4–6 cm. Several institutions have reported performing thyroidectomies through mini-open incisions ranging from 2.5 to 3 cm. Ferzli et al. used a 2.5-cm incision in a skin crease above the isthmus. Subplatysmal flaps are raised, the upper pole is retracted inferiorly, and the superior pole vessels are ligated. This is followed by dividing the inferior pole vessels and the lateral attachments. Gosnell and colleagues described a similar technique through a small incision over a palpable thyroid nodule using the standard lateral approach to dissect the thyroid lobe.

The advantage of the mini-open thyroidectomy is that it is easily teachable because of its similarities to a traditional thyroidectomy with shorter operative times compared to endoscopic thyroidectomy. The size of gland, which should be less than 7 cm, is the major limiting factor to performing a mini-open thyroidectomy.

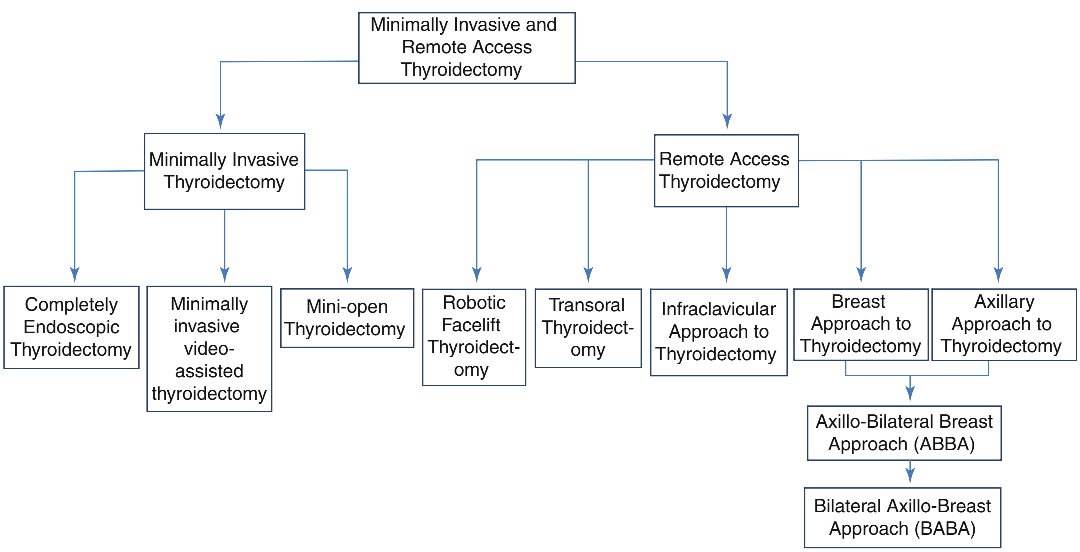

Fig. 2.2 Different approaches to minimally invasive and remote access thyroid surgery

Completely Endoscopic Thyroidectomy

The first completely endoscopic thyroidectomy was performed by Huscher et al. in 1997. In 2001, Gagner et al. presented a series of 18 patients who underwent endoscopic thyroidectomy via an anterior approach. Endoscopic thyroidectomy commonly uses a 5-mm scope at the sternal notch to bluntly create a subplatysmal space. The working space is maintained using CO_2 insufflation, and three additional working trocars are used. Using this approach, Gagner et al. reported no major complications, better cosmetic results, and an earlier return to activity when compared to conventional thyroidectomy. They recommended the technique for benign nodules smaller than 3 cm, and the technique may not be used in the reoperative setting, in obese patients or those patients with short, wide necks, and the elderly who could not tolerate CO_2 insufflation.

Henry described the lateral approach for endoscopic thyroidectomy in 2006. In this approach, the trocars are placed at the anterior border of the ipsilateral sternocleidomastoid muscle. Endoscopic thyroidectomy via the lateral approach is used for benign nodules smaller than 3 cm in size. Contraindications are previous neck surgery and neck irradiation.

Minimally Invasive Video-Assisted Thyroidectomy

The technique of MIVAT is similar to that of MIVAP. It uses traditional instruments that have been modified to fit through a smaller incision and does not require insufflation. MIVAT uses a 1.5-cm skin crease incision above the sternal notch. The working space is created by blunt dissection without gas insufflation and maintained with external retractors. The thyroid is mobilized and pulled through the incision and the remainder of the thyroidectomy is performed under direct vision without the endoscope. Because of the smaller neck incision and decreased dissection, MIVAT is associated with improved patient satisfaction, less postoperative pain, a shorter postoperative stay, decreased wound healing time, and improved “voice and swallowing” measures compared to traditional open thyroidectomy. A lateral MIVAT has been described by Yamashita et al. in Japan.

Remote Access Thyroid Surgery

Some surgeons, especially those in Asia where even a small scar in the neck is a significant cosmetic concern, adapted the tools of endoscopic thyroidectomy to move the trocar incisions to sites remote from the neck. Shimizu and colleagues reported the first remote access thyroidectomy in 1998 when they reported on five patients who underwent thyroidectomies via incisions below the ipsilateral clavicle. Subsequently remote access thyroidectomy has been described via incisions in the axilla, breast, mouth, and posterior upper neck. Because remote access surgery is technically more challenging, some surgeons began to use robotic assistance to improve the surgical view and instrument movement.

Infraclavicular Approach

Shimizu and colleagues described the infraclavicular approach for remote access thyroidectomy. Three infraclavicular incisions are used, and two Kirschner wires are used to lift up and expose the subplatysmal space and allow for gasless dissection of the thyroid. The strap muscles are divided and the thyroid lobe is dissected using open and endoscopic instruments.

Shimizu and colleagues reported excellent results in 193 patients. All underwent a unilateral thyroidectomy. The maximum tumor size was 7 cm. The mean operative time was 97 min. Four patients had temporary recurrent laryngeal nerve (RLN) palsies, and three had seromas that required aspiration. Shimizu et al. reported improved cosmetic results compared to open thyroidectomy as well as a shorter hospital stay and rehabilitation.

Axillary Approach

Ikeda and colleagues reported the first transaxillary remote access thyroidectomy in 2000. This approach can be performed with or without gas insufflation. When using gas insufflation, the subplatysmal space is insufflated to 4 mmHg, and a flexible endoscope is inserted. Three additional ports are inserted in the ipsilateral axilla. The thyroid gland is exposed by splitting the sternothyroid muscle. In the gasless approach, an external lift retractor is inserted through a 6-cm incision in the axilla to maintain the operative space.

Kang and colleagues reported their results using the transaxillary approach on 581 patients. In addition to improved cosmesis, they were also able to dissect the ipsilateral central lymph nodes when necessary. The disadvantages included a larger dissection for the remote access and difficulty seeing the contralateral thyroid lobe. There were no conversions to a traditional cervical incision and the mean operative time 129 min. Transient hypocalcemia occurred in 19 patients (3 %), temporary RLN palsy in 13 patients (2 %), and permanent RLN injury in 2 patients (0.3 %).

The assistance of the robot (da Vinci Surgical System, Intuitive Surgical, Sunnyvale, California) alleviated some of the limitations of remote access thyroidectomy. The benefits of using the robot include a three-dimensional view of the operating field, more flexible articulated instruments with greater degrees of freedom of movement and filtering of hand tremors. Robotic thyroidectomy is more expensive, requires training, and has not yet proven to be better than non-robotic remote access thyroidectomy in outcomes or cosmesis.

Breast Approach

Ohgami and colleagues were the first to describe using circumareolar incisions for trocar sites in remote access thyroidectomy. Two incisions are made on each breast at the upper areolar margin, and the subplatysmal space is bluntly created. The working space is maintained using gas insufflation. The inferior and superior pole vessels are ligated using ultrasonic shears, and the specimen is retrieved through one of the circumareolar port sites.

Park and colleagues reported their results of 100 patients using the breast approach for remote access thyroidectomy. They found no complications from gas insufflation and an overall excellent cosmetic result. Initially it was felt that patients with known malignancy or previous neck surgery or radiation were not good candidate for this operation, but subsequently several surgeons have reported excellent short-term oncological results with remote access thyroidectomy.

Hybrid Approaches

There are several hybrid approaches using both the breast and axilla for access to improve the angle between the endoscopic instruments and the thyroid gland. Shimazu and colleagues described the axillo-bilateral breast approach (ABBA) in 2003. In the ABBA, a trocar is placed in the ipsilateral axilla in addition to the breast port sites. Choe and colleagues described the bilateral axillo-breast approach (BABA) in 2007, in which a port is used in each axilla. With this approach, a central neck dissection is technically more feasible than with other remote access approaches. Some have criticized BABA for being overly invasive due to its extensive dissection.

Transoral Thyroidectomy

In 2010 Wilhelm and Metzig reported the first endoscopic transoral thyroidectomy. In this approach, a sublingual incision is made, and a trocar is placed into the subplatysmal layer, anterior to the thyroid cartilage, and insufflation is established. Two additional trocars are placed in the mouth. The surgeon then meticulously divides the isthmus and uses ultrasonic shears to ligate the upper and lower pole vessels. Once dissected free the thyroid is removed out of the sublingual incision.

In 2013, Nakajo and colleagues reported on a gasless transoral video-assisted neck surgery for thyroid resection. While similar to the approach reported by Wilhelm and Metzig, Nakajo et al. use an incision at the vestibulum and dissect anterior to the mandible and create the subplatysmal space. The working space is maintained using Kirschner wires to suspend the anterior cervical area. While both of these approaches by Wilhelm et al. and Nakajo et al. are promising, it is important to note that they are still in their infancy and have yet to be widely adopted by thyroid surgeons.

Robotic Facelift Thyroidectomy

In 2011, Terris et al. reported on a novel, remote access approach to performing a thyroidectomy using a postauricular facelift incision. The patient is positioned supine on the operating table, and an incision is made in the postauricular crease and continued within the occipital hairline. A musculocutaneous flap is raised, and a fixed retractor system is introduced to maintain the working space. The da Vinci surgical system is used to facilitate the dissection of the ipsilateral thyroid lobe.

The benefits of the robotic facelift thyroidectomy when compared to other remote access techniques such as the axillary approach include its easier positioning and shorter distance to the thyroid. The primary disadvantage includes dissection near the greater auricular nerve which may develop temporary or permanent hypesthesia. Only the ipsilateral thyroid lobe can be removed through a unilateral facelift incision, while a total thyroidectomy requires bilateral incisions.

Conclusions

Minimizing or completely avoiding a scar in the anterior neck is appealing to many patients who need thyroidectomy. Surgical invasiveness, however, is not just related to the length of or site of the incision, but includes the surgical trauma rendered to create the space for dissection. The standard open thyroidectomy has excellent results and minimal morbidity and complications. MIT and remote access thyroidectomy continue to evolve. Efforts to improve cosmesis, by shortening the incision or moving it from the neck must be balanced against the increased operative time and cost. For now, these techniques are limited to high-volume centers with specific interest and experience to achieve good results.

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