

Clinical Advances in Endoscopic Surgery for Breast Tumors

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Abstract: Breast tumors are broadly categorized into benign and malignant types. In younger women, fibroadenoma stands out as the most common benign entity, carrying an excellent prognosis and posing a minimal risk of malignant transformation. Conversely, breast cancer remains the leading malignant neoplasm in terms of both incidence and mortality among middle-aged and older women. As early diagnostic tools and comprehensive treatment protocols continue to advance, clinical attention has increasingly shifted toward postoperative quality of life—particularly the preservation of natural breast aesthetics. This growing emphasis has naturally paved the way for minimally invasive techniques in breast surgery, offering patients a broader spectrum of therapeutic options. In this review, we trace the evolution of endoscopic breast surgery, from its technical development to its current clinical applications in both benign and malignant tumors. We also highlight emerging research directions that aim to refine precision further and reduce invasiveness in the future of breast surgical practice.

Keywords: Breast tumors; Endoscopic techniques; Minimally invasive surgery

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1. Introduction

Beyond its role as a secondary sexual characteristic, the breast's contour integrity significantly influences patients' psychological well-being and social functional recovery after surgery. In oncological breast surgery, the ideal approach seeks to achieve negative tumor margins while maximally preserving breast shape and concealing scars, thereby promoting both physical and psychological healing^[1]. Breast-conserving surgery (BCS) has become the standard of care for early-stage breast cancer. Current evidence indicates that BCS followed by radiotherapy is non-inferior to modified radical mastectomy with respect to local control and long-term survival, while also offering better quality of life^[2-5]. To further enhance cosmetic outcomes, nipple-areola complex (NAC)-sparing mastectomy (NSM) is being increasingly adopted. However, conventional open procedures demand large incisions, leave visible scarring, and often struggle with

adequate exposure of the inferomedial quadrant, potentially jeopardizing nipple perfusion^[6-8]. In recent years, the advent of endoscopic techniques has introduced a new minimally invasive paradigm in breast surgery. By using small incisions placed in hidden locations—such as the axilla or areola—and leveraging magnified visualization and refined instrumentation, endoscopic breast surgery allows for precise anatomical dissection and tissue separation. This approach markedly improves postoperative breast cosmesis while maintaining oncological radicality^[9,10]. Despite its promising potential, the oncologic safety of endoscopic breast surgery still demands further validation through additional studies; moreover, standardization of surgical techniques and patient selection criteria remain to be clearly defined^[11,12]. This review systematically summarizes the evolution of endoscopic techniques in breast surgery, their current clinical applications for both benign and malignant tumors, and offers perspectives on future directions for the field.

2. Evolution of endoscopic techniques: Minimally invasive surgery from the abdominal cavity to the breast

The development of minimally invasive surgery is a story of continuous technological refinement—an evolution driven by iterative advances in optical and instrument systems, and a philosophical shift from “maximal resection” toward “minimal trauma”^[13]. It all began in 1901, when German surgeon Kelling used a cystoscope to peer into the peritoneal cavity of a living dog, marking the first step in endoscopic intracavitary exploration. Nine years later, Swedish physician Jacobaeus extended the technique to diagnosing thoracic and abdominal diseases in humans and introduced the term “laparoscopy,” bringing endoscopy into the clinic as a diagnostic tool. Over the following decades, key innovations—fiber-optic light guides, cold light sources, and high-resolution camera systems—dramatically improved visualization. At the same time, the invention and refinement of automatic insufflators solved the practical problem of maintaining a stable working space, effectively paving the way for endoscopy to move from diagnosis to active intervention^[14,15]. A true milestone came in 1987, when French surgeon Mouret performed the first video-laparoscopic cholecystectomy. The video imaging system freed the surgeon’s gaze from the eyepiece and made team-based collaboration possible—an achievement widely regarded as the birth of modern minimally invasive surgery. From there, laparoscopic techniques advanced rapidly, gaining broad acceptance in general surgery, gynecology, urology, and beyond, and spreading the minimally invasive philosophy across nearly every surgical discipline^[13,16].

Unlike hollow organs such as the gallbladder or uterus—which either possess natural cavities or can be readily distended by insufflation—breast tissue is dense and lacks well-defined anatomical planes. This fundamental difference means that simply inflating the space is seldom sufficient to create a stable working environment. Consequently, how to establish a three-dimensional operative field that allows safe instrument manipulation has emerged as a key technical hurdle in endoscopic breast surgery. The story of endoscopic breast surgery began in 1992, when Kompatscher^[17] first used an endoscope to remove silicone gel implants following augmentation mammoplasty—a pioneering step that marked the dawn of the endoscopic era in this field. Early exploration branched into two main technical pathways. One approach relies on lipolysis: a solution containing lidocaine and hyaluronidase is injected into the subcutaneous tissue, and then fat is aspirated under negative pressure to create a potential space. This method can relatively smoothly establish the working plane, but its oncological safety has drawn scrutiny—it remains unclear whether the lipolytic process might disrupt the tumor capsule or inadvertently increase the risk of tumor cell shedding^[18]. The

alternative, a non-lipolysis approach, uses mechanical retractors or hooks for blunt dissection and space maintenance. While this route offers greater oncological assurance, it brings its own set of drawbacks: instrument crowding, limited deep exposure, and difficulty maintaining adequate tension often prolong operative time, which has dampened its clinical uptake ^[19,20]. Thus, each strategy comes with a distinct trade-off, and the quest for an ideal solution continues.

For years, endoscopic breast surgery lingered in a peculiar state—technically doable, yet clinically underwhelming. Its advantages failed to shine through in practice, and it never quite gained traction within mainstream breast surgery. That landscape shifted in 2020, when Du Zhenggui’s team at West China Hospital of Sichuan University introduced the “reverse-sequence method,” a conceptual overhaul that reimagined the operative logic from the ground up ^[21]. Conventional endoscopic mastectomy followed a “superficial-to-deep” progression: first dissecting the subcutaneous layer, then moving to the deep glandular surface and pectoral fascia. The reverse-sequence method turns this order on its head. It begins by using insufflation to create a “pocket” on the deep surface of the pectoralis major, then tackles the deep glandular plane, and only finally addresses the superficial subcutaneous layer. This seemingly simple reordering resolved a core dilemma that had hampered the field for decades ^[22]. Opening the deep plane early provides natural tension guidance and clear anatomical landmarks for the steps that follow—making superficial dissection smoother, reducing instrument clashes and visual obstruction, and ultimately shortening operative time while enhancing safety ^[23,24]. Building on this concept, the same team further proposed an “auxiliary port” strategy to mitigate instrument crowding in single-port procedures, and developed a “parachute” patch technique to address reconstructive challenges in patients with breast ptosis. Together, these innovations form a comprehensive technical framework covering space creation, dissection, and reconstruction ^[21,25]. The reverse-sequence method has proven to be a game-changer, achieving simultaneous gains in operative efficiency, cosmetic outcomes, and oncological safety ^[26,27]. Looking back, from Kelling’s cystoscope to today’s reverse-sequence method and robotic platforms, endoscopic techniques in breast surgery have traveled a remarkable arc—from early experimentation, through theoretical hurdles, to genuine technical breakthroughs. This evolution not only enriches breast surgery but also offers a valuable blueprint for expanding minimally invasive approaches to other solid organs.

3. Clinical application of endoscopic techniques in breast malignancies

Over the past three decades, endoscopic breast surgery has come a long way—from its initial exploration of space-creating maneuvers that merely aimed at “smaller scars” to a fully fledged minimally invasive system that now integrates tumor excision, lymph node management, and breast reconstruction ^[28]. At the same time, the global burden of breast cancer shows no sign of easing. According to GLOBOCAN 2022, there were roughly 2.3 million new cases worldwide, representing 11.6% of all new cancer diagnoses, alongside about 666,000 deaths. Both incidence and mortality rank first among female cancers globally ^[29]. Rising clinical needs, coupled with increasingly refined technical capabilities, have mutually fueled the broader adoption of endoscopic approaches in breast cancer care ^[30]. In this section, we classify the main endoscopic procedures according to their surgical objectives and extent of resection—specifically, lymph node surgery, BCS, total mastectomy, and breast reconstruction—and discuss their key technical points and clinical applications in turn.

3.1. Endoscopic lymph node surgery

3.3.1. Endoscopic axillary lymph node dissection (EALND)

The status of axillary lymph nodes is a critical determinant in clinical staging, treatment planning, and prognosis for breast cancer patients. Among the earliest and most established applications of endoscopic techniques in breast surgery, axillary lymph node dissection has evolved significantly. Conventional open surgery often leaves noticeable scarring and carries a notable risk of upper limb lymphedema; in contrast, the endoscopic approach enables thorough nodal clearance through small, discreet incisions in the axilla, effectively reducing soft-tissue injury without compromising oncological safety^[31,32]. Early clinical experience from Luo Chengyu's team underscored these advantages, demonstrating both the cosmetic appeal and the practical feasibility of this minimally invasive strategy^[33]. Further supporting evidence comes from a meta-analysis by Lan et al.^[34], which included 20 randomized controlled trials with a total of 2,672 patients. Their findings showed that endoscopic axillary dissection outperformed open surgery across multiple perioperative measures—including intraoperative blood loss, postoperative drainage volume, length of hospital stay, and complication rates (all $P < 0.01$)—highlighting clear clinical benefits. Suitable candidates for EALND are breast cancer patients who meet standard indications for axillary clearance, have no prior axillary surgery, have clinically assessed nodal involvement $\leq N2$, and lack significant adhesion between enlarged nodes and the surrounding axillary vessels or nerves. From a technical perspective, the procedure uses a three-port configuration, with trocars placed 1–2 cm above the inframammary fold along the anterior axillary line, the posterior axillary line, and the lowest point of the axilla, arranged in a triangular pattern^[35]. A lipolytic solution is first injected, followed by liposuction to establish the working space, while CO₂ insufflation maintains a stable pneumocavity at around 8 mmHg. Dissection follows a systematic “six-step” routine, sequentially addressing the intercostobrachial nerve, the axillary vein, the subscapular vessels along with the thoracodorsal neurovascular bundle, the long thoracic nerve, the lateral thoracic artery and the axillary vein segment behind the pectoralis minor, and finally Rotter's lymph nodes in the interpectoral space^[36]. Once the lymphatic tissue has been fully mobilized, it is removed through the 10-mm trocar incision; the operative field is then rinsed with sterile distilled water, and a negative-pressure drain is routinely placed in the axillary cavity^[37].

3.1.2. Endoscopic sentinel lymph node biopsy (ESLNB)

Sentinel lymph node biopsy (SLNB) has become the preferred method for axillary staging in early-stage breast cancer, with indications that align fully with those of conventional SLNB. ESLNB is performed through a small, well-concealed axillary incision of about 2-2.5 cm, which translates into less tissue trauma, minimal bleeding, faster postoperative recovery, and excellent cosmetic results. Notably, it can be combined with endoscopic breast-conserving surgery or subcutaneous mastectomy through the same incision, offering a streamlined approach^[38]. A variety of tracers are available, including technetium-99m sulfur colloid combined with methylene blue, carbon nanoparticles, indocyanine green (ICG) with methylene blue, or methylene blue alone. Preoperatively, the surface projection of the sentinel node is identified and marked using radioisotope or fluorescence detection. Under endoscopic visualization, the blue-stained lymph nodes are readily seen and can be completely excised after careful division of the surrounding fibrous tissue^[39]. Notably, this technique allows—for the first time—direct, real-time observation of the location, depth, and number of draining lymphatic vessels from the primary tumor, which markedly improves detection

accuracy and helps reduce the false-negative rate. If intraoperative frozen-section pathology returns positive, the procedure is followed by a complete axillary lymph node dissection using the aforementioned six-step technique ^[40].

3.1.3. Endoscopic internal mammary lymph node dissection (EIMND)

Internal mammary lymph nodes (IMNs) represent a key metastatic pathway for breast cancer, and together with axillary nodes, they form the first tier of regional lymphatic spread. This risk is especially high in patients whose tumors arise in the medial or central zones of the breast, underscoring the prognostic significance of IMN status ^[41]. Because these nodes lie deep within the chest and metastatic deposits are often small, effective diagnostic and evaluative tools have long been lacking. EIMND is primarily indicated for breast cancer patients with medial or central tumors, filling the therapeutic gap left by conventional open dissection—which required resection of costal cartilages and carried considerable morbidity with high complication rates ^[42]. Technically, trocars are introduced through the 2nd, 4th, and 6th (or the 3rd, 5th, and 7th) intercostal spaces along the mid-axillary line. Under high-definition thoracoscopic guidance, an incision is made in the parietal pleura adjacent to the internal thoracic vessels. After mobilizing and dividing the internal thoracic artery and vein, the lymphatic chain from the first to the fifth intercostal space is resected en bloc with the vessels—achieving complete clearance while preserving the costal cartilages ^[43]. He et al. ^[44] confirmed the feasibility and technical ease of this approach, reporting detection of IMN metastases in 39.3% of patients, with no major vascular or pulmonary injuries and no postoperative complications such as atelectasis or pneumonia.

3.2. Endoscopic mastectomy

In China, total mastectomy remains the predominant surgical option for breast cancer, yet conventional open procedures entail lengthy incisions that leave highly visible scars, inevitably compromising breast aesthetics. Endoscopic total mastectomy offers a way to minimize scarring: through three trocar ports placed on the lateral chest wall, the entire subcutaneous glandular tissue is resected, and the specimen is extracted via the axillary trocar incision, leaving no visible scar on the breast surface. Beyond its excellent cosmetic outcome, this technique also creates favorable conditions for immediate breast reconstruction. NSM is defined as complete removal of the breast gland while preserving the entire skin envelope and the NAC ^[45]. Endoscopic NSM is typically indicated for early-stage breast cancer or prophylactic mastectomy, aiming to maintain breast appearance without compromising oncological safety, and to facilitate subsequent reconstruction. Patient satisfaction with this approach is significantly higher than that reported for conventional techniques ^[46,47]. The procedure follows a similar workflow: lipolysis and liposuction are first used to establish the working space, after which glandular resection is performed using a standardized “nine-step” sequence: dividing the lateral aspect of the gland, the anterior Cooper’s ligaments, the superolateral margin, the posterior attachments to the pectoral fascia, the superomedial margin, the inferolateral margin, the inferomedial margin, the gland directly beneath the nipple, and the medial margin. Postoperative liposuction and meticulous hemostasis are then carried out, followed by drain placement and compression dressing ^[48]. The axillary approach is currently the most widely adopted route; its incision is placed within the natural axillary fold, allowing concurrent sentinel lymph node biopsy or axillary lymph node dissection while yielding superior cosmetic results ^[46]. A 2025 meta-analysis ^[10], which included 51 studies on endoscopic

NSM, found no significant differences in oncological outcomes compared with conventional NSM, but did show markedly improved cosmetic satisfaction and a significantly reduced risk of necrosis with the single-port endoscopic approach.

3.3. Endoscopic breast-conserving surgery (E-BCS)

E-BCS is primarily indicated for patients with clinical stage I–II early-stage breast cancer who wish to preserve their breast and have no contraindications to BCS. By enabling precise tumor resection through concealed incisions, this approach maximizes the preservation of breast appearance while maintaining oncological radicality^[49,50]. A meta-analysis^[51], which included 11 studies with 2,562 patients, systematically compared endoscopic and conventional BCS. The results showed that the endoscopic group had significantly shorter incisions and markedly better cosmetic scores, with no significant differences between the two groups in recurrence rate, metastasis rate, positive margin rate, or complications. Based on variations in incision placement and surgical approach, two main techniques are currently used in clinical practice: periareolar E-BCS and axillary single-port E-BCS.

3.3.1. Periareolar endoscopic breast-conserving surgery

The periareolar incision is one of the classic approaches in E-BCS, capitalizing on the anatomical fact that the darker pigmentation of the areolar margin helps scars blend inconspicuously after healing. A curvilinear incision—typically about 3 cm long—is made along the areolar border, through which the glandular tissue in the tumor-bearing quadrant is resected^[52]. During the procedure, a suspension device retracts the incision to establish the working space, and dissection between the skin flap and the superficial fascia is performed under endoscopic guidance using an ultrasonic scalpel or tissue scissors. Preoperatively, methylene blue is injected around the tumor margin (approximately 1 cm from the tumor edge) under ultrasound guidance to delineate the resection boundary; intraoperatively, the tumor is excised along the marked line, and the margins are sent for rapid frozen-section pathology to confirm negativity^[53]. The main advantage of this approach lies in its relatively well-hidden incision and its ability to access lesions in all quadrants of the breast, making it suitable for early-stage cancers located at some distance from the nipple across various quadrants^[54].

3.3.2. Axillary single-port endoscopic breast-conserving surgery

Axillary single-port E-BCS has gained momentum in recent years and offers even more remarkable cosmetic outcomes^[55]. This technique requires only a single small incision—usually about 3–5 cm long—placed in the natural axillary fold, through which a single-port multi-channel device is inserted to accommodate both the endoscope and operative instruments. Tumor resection is then performed within the subcutaneous working space created by CO₂ insufflation or a suspension technique. As with the periareolar approach, preoperative ultrasound-guided methylene blue injection is used to mark the resection margins, and the tumor is completely excised along the boundary under endoscopic magnification^[56]. Compared to the periareolar route, the axillary single-port approach offers a more concealed incision and superior cosmetic results, with the added advantage of allowing concurrent sentinel lymph node biopsy or axillary lymph node dissection through the same incision^[57].

3.4. Endoscopic breast reconstruction (EBR)

EBR is primarily indicated for restoring breast contour in patients who have lost breast tissue or developed deformities following cancer surgery. Currently, this approach falls into two main categories: implant-based reconstruction and autologous tissue transfer ^[58].

3.4.1. Endoscopic Implant-based breast reconstruction (E-IBBR)

E-IBBR is the most widely adopted form of endoscopic breast reconstruction in current clinical practice. After completing an endoscopic nipple-sparing subcutaneous mastectomy through a concealed axillary incision, the same incision is used to dissect either the subpectoral or prepectoral space for immediate insertion of a silicone gel implant ^[59]. Depending on the placement plane, the procedure can be further divided into subpectoral and prepectoral reconstruction.

Subpectoral implant-based reconstruction represents the more traditional approach. Through the axillary incision, the subpectoral space is entered along the lateral border of the pectoralis major muscle. A pectoral dissector is then used to sufficiently mobilize the inferomedial and inferior attachments of the muscle on the rib surface, extending medially to the parasternal border and inferiorly to about 2 cm below the inframammary fold, so as to create a pocket large enough to accommodate the implant. After insertion, the superolateral opening of the subpectoral space is closed with absorbable sutures ^[60]. This approach allows the pectoralis major to cover the anterior aspect of the implant, offering a natural contour transition and reducing the likelihood of visible implant edges or rippling ^[61]. On the downside, however, dissection of the pectoralis muscle may cause postoperative pain, animation deformity, and capsular contracture; it can also lead to breast deformation and upward displacement of the NAC following radiotherapy ^[62].

Prepectoral implant-based reconstruction, by contrast, is a newer strategy that has gained considerable traction in recent years. In this technique, the implant is placed in the prepectoral space—that is, the natural cavity anterior to the pectoralis major muscle left after subcutaneous glandular resection ^[63]. Since the pectoralis muscle is not dissected, the procedure is associated with less surgical trauma and reduced postoperative pain ^[64]. However, without adjunctive mesh reinforcement, prepectoral reconstruction has historically carried higher rates of capsular contracture and rippling compared with the subpectoral approach ^[65]. With the widespread adoption of endoscopic techniques and the increasing use of mesh materials—such as titanium-coated polypropylene mesh and acellular dermal matrix—complications like wound dehiscence, infection, and capsular contracture have gradually declined, and prepectoral implant-based reconstruction has earned growing acceptance among clinicians ^[66,67].

3.4.2. Endoscopic omental flap reconstruction (E-OFR)

The omentum is richly endowed with vascular, lymphatic, and adipose tissue, making it a versatile option for breast reconstruction. E-OFR involves laparoscopic harvest of a pedicled omental flap, which is then transferred to the breast defect through a subcutaneous tunnel to restore natural breast contour and softness ^[68]. In this procedure, a viewing trocar is placed at the lower umbilical margin, while working trocars are inserted at the contralateral McBurney's point and a right paramedian site. Using an ultrasonic scalpel, dissection begins from the left of the midpoint of the transverse colon, about 1 cm away from the colon. The greater curvature of the stomach is divided close to the gastric wall, with careful preservation of the gastroepiploic vascular arcade to ensure adequate blood supply. Once fully mobilized, the omental flap is trimmed to an

appropriate width and passed through a subcutaneous tunnel created deep to the rectus abdominis muscle beneath the xiphoid process, into the breast area ^[69,70]. For patients with smaller breast volume, the flap can be directly used to fill the defect. For those with larger breasts, the omental flap is sutured to the divided and superiorly mobilized inferior border of the pectoralis major muscle, with the implant placed posterior to both the muscle and the flap, allowing the omentum, pectoralis major, and serratus anterior muscles to form a complete “pocket” that accommodates the implant ^[71].

3.4.3. Endoscopic latissimus dorsi flap reconstruction (E-LDFR)

The latissimus dorsi muscle is one of the most frequently used flaps in autologous breast reconstruction, prized for its robust blood supply, ample volume, high survival rate, and ease of harvest ^[72]. Conventional open harvest, however, leaves a large donor-site scar that can adversely affect back appearance ^[73]. Endoscopic harvest through a single axillary incision offers a well-concealed alternative, enabling a “scar-free” outcome on both the breast and back surfaces and significantly improving patients’ postoperative quality of life ^[74]. E-LDFR is performed through the original mid-axillary line incision, using either single-port or three-port equipment directed toward the back. Dissection proceeds both suprafascially and submuscularly between the skin and the latissimus dorsi muscle, with the ultrasonic scalpel used for coagulation and hemostasis, while the thoracodorsal vessels are carefully isolated and mobilized ^[75]. Based on the size of the resected specimen and the contralateral breast, a flap of sufficient volume is harvested—typically about one-quarter larger than the resected tissue to compensate for potential postoperative muscle atrophy. The patient is then repositioned supine, and the flap is transferred through a subcutaneous tunnel into the breast subcutaneous space for shaping and reconstruction ^[76].

4. Clinical application of endoscopic techniques in benign breast tumors

Benign breast tumors are common diseases in women, mainly including fibroadenomas, phyllodes tumors, and intraductal papillomas, among which fibroadenoma predominantly affects young women around the age of 20 ^[77]. For benign tumors that are symptomatic, >2 cm in diameter, rapidly growing, or with strong patient preference for surgery, surgical excision remains the primary treatment modality ^[78]. Unlike patients with malignant tumors, those with benign tumors have a longer postoperative life expectancy and have more urgent demands for aesthetic outcomes and functional preservation ^[49]. In recent years, surgical treatment for benign breast tumors has evolved toward greater minimally invasiveness. Yao Chengcai et al. ^[79] reported on endoscopic resection of benign breast tumors via the axillary single-port insufflation approach. Between June 2022 and July 2023, a total of 144 benign tumors were resected in 62 procedures, with a success rate of 100%. Lu et al. ^[80] used a gasless endoscopic-assisted technique via the axillary single-port approach to treat 83 cases of adolescent breast fibroadenomas, with patients aged 11–25 years and tumor diameters ranging from 0.5 to 6.5 cm. Notably, for patients with multiple nodules (≥ 3), the endoscopic group showed significantly better outcomes than the open surgery group in terms of operative time, incision length, and complication rates. Yang et al. ^[81] included a total of 363 patients with benign breast tumors (118 in the endoscopic group and 245 in the open surgery group), and demonstrated that although the axillary single-port endoscopic approach was associated with longer operative time and greater postoperative drainage volume, it resulted in less intraoperative blood loss. The gasless single-port endoscopic breast surgery via the axillary

approach has also been confirmed to offer advantages including concealed incisions, excellent cosmetic outcomes, and fewer complications, thereby maximally meeting the needs of young female patients with large benign breast tumors ^[82].

The core advantage of endoscopic breast surgery lies in its superior cosmetic outcomes. Lai et al. ^[82] reported that among 323 procedures of endoscopic resection of benign breast tumors, 85.4% of patients were satisfied with the postoperative cosmetic outcomes, with a complication rate of only 6.5%, all of which were minor wound-related complications. Yang et al. ^[81] compared the endoscopic group with the conventional surgery group and found that the endoscopic group significantly improved patients' postoperative sensory sensitivity of the NAC, incision scar aesthetics, and overall surgical satisfaction. In the study by Yao Chengcai et al. ^[79], intraoperative blood loss was less than 20 mL in all 62 patients, with no cases of postoperative bleeding, wound infection, or poor healing. In terms of oncological safety, endoscopic surgery can achieve the same safe margins as conventional open surgery. Lai et al. ^[82] reported that 5 cases (2%) were pathologically diagnosed as malignant postoperatively, all with negative margins. Yao Chengcai et al. also reported no tumor recurrence during 6 months of follow-up ^[79]. With regard to complications, common complications of endoscopic breast surgery include subcutaneous emphysema, hypercapnia (associated with CO₂ insufflation for space creation), flap necrosis, and nipple sensory loss (associated with periareolar incisions and excessive retraction) ^[79]. During the procedure, attention should be paid to maintaining a safe pressure range and closely monitoring the arterial partial pressure of CO₂.

Although endoscopic breast techniques have demonstrated significant advantages in the treatment of benign breast tumors, the selection of appropriate indications still needs to be standardized, long-term follow-up data remain to be accumulated, and issues regarding surgical costs and technical dissemination need to be addressed. With the continuous development of single-port endoscopy, gasless space creation, and robotic-assisted systems, the prospects for its application are promising.

5. Conclusion and future perspective

Endoscopic techniques have now firmly taken root across the major domains of breast tumor surgery, and a relatively mature minimally invasive system has gradually taken shape. In axillary lymph node management, EALND not only ensures thorough clearance but also effectively reduces complications such as postoperative scarring and upper limb lymphedema. ESLNB, performed through a small concealed axillary incision, can be conveniently combined with BCS or mastectomy in a single procedure. EIMND, meanwhile, has filled the therapeutic gap left by the abandonment of conventional surgery, which was hampered by excessive trauma. In the realm of mastectomy and BCS, endoscopic nipple-sparing mastectomy has already demonstrated oncological outcomes comparable to those of conventional surgery, with markedly improved cosmetic satisfaction; the single-port approach may further reduce the risk of nipple necrosis. E-BCS similarly excels in shortening incisions and preserving breast shape, with no significant differences in recurrence rate or positive margin rate when compared with open techniques. In breast reconstruction, E-IBBR, E-OFR, and E-LDFR harvest enable patients to achieve more favorable breast aesthetics while maintaining oncological radicality, thus promoting both physical and psychological recovery. For benign breast tumors, approaches such as the axillary single-port technique allow complete excision while concealing the incision within the natural axillary fold, yielding exceptionally high satisfaction rates among young female patients.

Although existing studies have preliminarily confirmed the oncological safety and cosmetic advantages of endoscopic breast surgery, its long-term efficacy, local recurrence risk, and overall survival benefit still require validation through high-level evidence from large-scale, multicenter, prospective randomized controlled trials. The field continues to evolve, and with the dissemination of innovations such as the “reverse-sequence method” and the integration of robotic surgical systems, the indications for endoscopic surgery are expected to gradually expand to more complex scenarios—including locally advanced breast cancer, patients with a history of prior surgery or radiotherapy, and those with breast ptosis. This expansion will necessitate the establishment of an evidence-based stratification system to guide patient selection. Moreover, the inherent advantages of endoscopic techniques in tumor resection and immediate reconstruction allow for the simultaneous achievement of oncological radicality, functional preservation, and aesthetic restoration—a triad that lies at the heart of modern surgical philosophy. Looking ahead, further efforts should focus on optimizing the biocompatibility of reconstructive materials, developing more minimally invasive donor-site harvesting strategies, and establishing standardized postoperative evaluation systems. With continued innovation in instruments and equipment, an ever-growing body of clinical evidence, and the further dissemination of the minimally invasive philosophy, endoscopic breast surgery is steadily advancing toward greater precision, less invasiveness, and more individualized care—bringing tangible benefits to an increasing number of patients with breast tumors.

Disclosure statement

The authors declare no conflict of interest.

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