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Energy-Based Devices in Superficial Parotidectomy: Bipolar Diathermy Versus Harmonic Scalpel

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Abstract

Superficial parotidectomy is the standard surgical treatment for benign parotid gland tumors. The selection of an appropriate energy-based device for dissection and hemostasis during this procedure has become increasingly important due to the close proximity of the facial nerve to the operative field. Bipolar diathermy and the harmonic scalpel differ in their mechanisms of energy delivery, thermal spread, and hemostatic efficiency.

Keywords: superficial parotidectomy, bipolar diathermy, harmonic scalpel, facial nerve, benign parotid tumors, energy-based devices

Introduction

The parotid gland is the largest of the paired major salivary glands, and tumors arising from it account for approximately 80% of all salivary gland neoplasms, the majority of which are benign. Superficial parotidectomy is the most widely performed procedure for benign lesions of the superficial lobe, yet it carries a well-documented risk of facial nerve injury. The introduction of advanced energy devices over the past two decades has prompted a reassessment of traditional hemostatic approaches in parotid surgery. Both bipolar diathermy and the harmonic scalpel are currently used, each offering distinct advantages and limitations related to thermal energy generation and tissue handling (1).

Surgical Anatomy of the Parotid Gland

The parotid gland occupies the preauricular and retroauricular regions, extending from the zygomatic arch superiorly to the angle of the mandible inferiorly, and is enclosed within a dense fibrous capsule derived from the investing layer of the deep cervical fascia. The gland is conventionally divided into superficial and deep lobes by the plane of the facial nerve, though this division is functional rather than truly anatomical. Histologically, the gland is composed of serous acinar cells generating watery, enzyme-rich saliva, with an extensive ductal system culminating in Stensen's duct, which opens into the oral vestibule opposite the upper second molar. The intimate relationship between the gland parenchyma and the facial nerve trunk makes the surgical anatomy of this region among the most technically demanding in head and neck surgery (2).

The Facial Nerve and Its Intraparotid Course

The facial nerve exits the skull via the stylomastoid foramen and enters the posteromedial surface of the parotid gland, where it divides into temporofacial and cervicofacial trunks before giving rise to five terminal branches: temporal, zygomatic, buccal, marginal mandibular, and cervical. Surgical identification of the main trunk relies on well-established anatomical landmarks including the tragal pointer, the tympanomastoid suture line, and the posterior belly of the digastric muscle. The tympanomastoid suture has been found to be a particularly consistent and reliable guide to the facial nerve, especially in cases where tumor bulk distorts the usual anatomical relationships. Cadaveric histological analysis has confirmed that the nerve is invested by a perineural sheath of variable thickness, and glandular parenchyma directly abuts this sheath without forming distinct anatomical compartments. The thickness of this perineural sheath increases toward the peripheral branches, partly explaining the vulnerability of distal branches to thermal and traction injury during dissection (3).

Advances in Anatomical Visualization

Three-dimensional digital anatomical models of the parotid gland, submandibular gland, and facial nerve derived from CT angiography data have been developed as both educational tools and preoperative planning resources. These models allow visualization of individual anatomical variation in nerve branching patterns, gland morphology, and vascular supply before the surgeon enters the operative field. Such technology has the potential to reduce intraoperative uncertainty and operative time, particularly for less experienced operators. Three-dimensional modeling of the parotid region is expected to play a growing role in surgical training and operative simulation as it becomes more widely accessible (4).

Epidemiology of Parotid Gland Tumors

Salivary gland neoplasms are relatively uncommon, comprising approximately 2 to 6.5% of all head and neck tumors worldwide, with the parotid gland being the source of the vast majority. Among parotid tumors, approximately 80% are benign, with pleomorphic adenoma and Warthin's tumor together accounting for the large majority of benign diagnoses. The global incidence of pleomorphic adenoma has been reported at 2.4 to 3.05 cases per 100,000 persons per year. A multicenter retrospective analysis of over 1,000 parotidectomy cases from southwestern Germany found that benign tumors comprised 84.7% of all resected parotid lesions, with Warthin's tumor being the most common benign diagnosis in that series, potentially reflecting declining smoking rates in the study population (5).

Pathology of Pleomorphic Adenoma and Warthin's Tumor

Pleomorphic adenoma is the most common benign neoplasm of the salivary glands, occurring most frequently in women during the fourth through sixth decades of life. It exhibits a biphasic composition of ductal epithelial cells and myoepithelial cells within a variable stromal matrix that may be myxoid, chondroid, or fibrous. Approximately 25% of pleomorphic adenomas harbor satellite nodules or pseudopodial projections extending beyond the fibrous capsule, a feature that contributes substantially to recurrence risk following simple enucleation. Warthin's tumor is the second most frequent benign parotid neoplasm, characterized by an older age at presentation, male predominance, and a propensity for bilateral and multifocal occurrence, with cigarette smoking conferring an approximately eightfold elevated risk of its development (6,7).

Preoperative Assessment

A systematic preoperative workup is essential for all patients presenting with a parotid mass, beginning with clinical history and physical examination and extending through imaging and cytopathological assessment. Ultrasound is the first-line imaging modality, providing real-time evaluation of size, echogenicity, vascularity, and relationship to adjacent structures, and serving as the principal guide for fine needle aspiration cytology. MRI with contrast is preferred when deep lobe involvement or malignancy is suspected, offering superior soft tissue contrast resolution compared with CT. Radiomics-based CT analysis and diffusion-weighted MRI using apparent diffusion coefficient values have emerged as promising adjuncts for preoperative differentiation between pleomorphic adenoma and Warthin's tumor, achieving areas under the curve consistently above 0.90 (8,9).

Surgical Technique of Superficial Parotidectomy

Superficial parotidectomy is performed under general endotracheal anesthesia with the patient supine, head extended and rotated to the contralateral side. A modified Blair incision is made beginning in the preauricular crease, curving around the ear lobule and descending into the upper neck along the anterior border of the sternocleidomastoid muscle. Following skin flap elevation in the subcutaneous plane, the anterior border of the sternocleidomastoid and the posterior belly of the digastric muscle are identified, and dissection proceeds toward the facial nerve main trunk. Once the main trunk is identified, antegrade dissection along each branch separates the superficial lobe from the underlying deep lobe using a combination of blunt dissection and the chosen hemostatic energy device. A closed suction drain is typically placed through a separate stab incision to prevent hematoma and sialocele formation (10).

Intraoperative Facial Nerve Monitoring

Intraoperative facial nerve monitoring using electromyographic needle electrodes placed in facial musculature has become an increasingly standard adjunct in parotidectomy, providing real-time feedback on nerve stimulation and function throughout dissection. Standardized protocols have been proposed encompassing setup standards, anesthesia requirements particularly avoidance or reversal of neuromuscular blocking agents and interpretation criteria for signal changes. A systematic review encompassing over 1,000 patients found that the incidence of immediate postoperative facial palsy was significantly lower in monitored patients compared with unmonitored patients. A survey of 348 head and neck surgeons documented that 97% used intraoperative monitoring selectively or routinely, with usage rates inversely correlated with surgeon experience, confirming its particular value for less experienced operators (11,12).

Principles of Bipolar Diathermy

Bipolar diathermy is a form of high-frequency radiofrequency electrosurgery in which both the active and return electrodes are incorporated within a single instrument, so that electrical current flows exclusively through the tissue interposed between the two tips. This confined current pathway eliminates the risk of stray current burn injuries seen with monopolar electrosurgery and removes the need for a dispersive patient pad. The underlying heating mechanism involves synchronous oscillation of intracellular ions in response to the alternating current, generating frictional heat sufficient to denature proteins and seal blood vessels. At temperatures between 60 and 70 degrees Celsius, tissue proteins undergo controlled denaturation forming a stable coagulum that effectively seals vessels against physiological blood pressures (13).

Thermal Spread and Limitations of Bipolar Diathermy

The lateral thermal spread of bipolar diathermy has been measured in experimental models at approximately 1.1 to 1.3 mm after two to four seconds of application under standardized conditions, though this value increases with higher power settings and prolonged application time. While considerably more contained than monopolar electrocautery, this lateral spread is larger than that achievable with ultrasonic devices and becomes clinically relevant when operating within one to two millimeters of a fine facial nerve branch. Modern bipolar generators incorporate tissue impedance feedback algorithms that modulate energy delivery in real time, reducing the risk of excessive overheating beyond the intended coagulation zone. Infrared thermographic imaging has confirmed that heat spread extends approximately 1 to 3 mm laterally depending on activation duration and tissue hydration, with practical implications for device selection near neural tissue (14).

Advanced Bipolar Vessel Sealing Systems

The LigaSure bipolar vessel sealing system combines mechanical tissue compression with precisely controlled bipolar energy delivery to achieve reliable sealing of vessels up to 7 mm in diameter. A systematic review and meta-analysis comparing LigaSure with conventional suture ligation across five parotidectomy studies demonstrated a statistically significant reduction in operative time in the LigaSure group, with a mean difference of approximately 22 minutes. No significant differences were found in rates of temporary or permanent facial palsy, postoperative bleeding, or salivary complications between the two groups. The primary driver of the operative time advantage was elimination of suture-tying steps rather than faster dissection speed, and the cost of disposable instruments remains a practical consideration in resource-limited settings (15).

Principles of the Harmonic Scalpel

The harmonic scalpel is an ultrasonic energy device that converts electrical energy into high-frequency mechanical vibration at the active blade, which oscillates at approximately 55,500 Hz over an excursion of 50 to 100 micrometers. These mechanical vibrations achieve simultaneous tissue cutting and vessel coagulation through a combination of frictional heat generation, cavitation, and direct mechanical disruption, without the passage of electrical current through the patient's body. The device operates at substantially lower temperatures than radiofrequency electrosurgery, with the active blade generating tissue temperatures in the range of 60 to 100 degrees Celsius — sufficient for protein denaturation and vessel sealing but below the threshold for

charring and carbonization. The curved shear blade configuration reliably seals vessels up to 5 mm in diameter through denaturation of collagen and elastin with mechanical pressure contributing to vessel wall apposition (16).

Thermal Advantages of the Harmonic Scalpel

The defining physical advantage of harmonic scalpel technology in parotid surgery is the markedly limited lateral thermal spread compared with electrosurgical alternatives. Because energy is delivered mechanically rather than electrically and operating temperatures remain below 100 degrees Celsius, thermal damage is restricted to a zone of no more than 1 to 3 mm from the active blade interface, and typically less than 2 mm in routine clinical use. This property makes the harmonic scalpel particularly well suited to dissection in anatomically constrained fields where important neurovascular structures lie in close proximity to the target tissue. The absence of electrical current also means that harmonic scalpel use is inherently compatible with simultaneous intraoperative facial nerve monitoring without signal interference. Reduced smoke and vapor generation further improves operative field visibility throughout the procedure (17).

Evidence from Umbrella Reviews and Multi-Specialty Data

An umbrella review synthesizing 24 systematic reviews and meta-analyses of randomized controlled trials across multiple surgical disciplines found that harmonic devices were associated with favorable improvements in every evaluated outcome, including operating time, hospital stay, blood loss, drainage volume, postoperative pain, and overall complication rates compared with conventional electrocautery. Most meta-analyses reported operating time reductions of at least 25 minutes favoring the harmonic device. Direct comparisons between harmonic and advanced bipolar devices showed broadly comparable outcomes in thyroidectomy and colectomy, suggesting that the primary advantage of harmonic technology lies in its reduced thermal spread relative to conventional electrocautery rather than blanket superiority over all advanced energy alternatives. The newest generation of harmonic devices incorporates adaptive tissue technology that continuously modulates energy delivery based on real-time tissue resistance sensing (18,19).

Comparative Outcomes in Parotid Surgery: Operative Time

A retrospective Spanish study analyzing 108 patients undergoing parotidectomy for benign tumors compared harmonic scalpel with cold knife dissection plus bipolar diathermy, finding that operative time was meaningfully shorter in the harmonic group at 114 versus 135 minutes, which was the only statistically significant difference between groups. A larger retrospective cohort study of 255 patients over fifteen years confirmed that harmonic scalpel use significantly reduced operative time for superficial parotidectomy at 216 versus 234 minutes and substantially reduced intraoperative blood loss at 28 versus 76 milliliters. The meta-analysis by Li and colleagues specifically examining harmonic scalpel versus electrocautery for parotidectomy concluded that harmonic use was associated with shorter operating time, reduced blood loss, and shorter hospitalization across all included studies. These consistent findings across different study designs and populations support the operative efficiency advantages of harmonic dissection over conventional bipolar-based techniques (20,21,22).

Comparative Outcomes: Facial Nerve Function

A comprehensive retrospective Italian study comparing three distinct energy platforms — classic bipolar electrocautery, ultrasonic harmonic device, and the combined-energy Thunderbeat instrument — in 102 patients undergoing superficial parotidectomy found that temporary facial nerve weakness was recorded in 45.9% of the electrocautery group compared with 12.5% of the harmonic group, a difference reaching statistical significance. Among patients who did experience postoperative dysfunction, recovery time was significantly shorter in the harmonic group than in either comparator group. Prospective randomized trial data have confirmed lower rates of early postoperative facial nerve impairment in harmonic groups. The mechanistic link between reduced lateral thermal spread and lower facial nerve morbidity, supported by both physical measurements and clinical data, provides the most biologically plausible explanation for the observed differences in nerve outcomes (23).

Facial Nerve Dysfunction: Incidence and Assessment

Postoperative facial nerve dysfunction is the most feared complication of parotidectomy, with reported incidence of transient weakness ranging from 9% to 66% across the published literature, a variability attributable to differences in surgical technique, tumor size, follow-up duration, and grading criteria. Permanent weakness occurs in approximately 0 to 9% of cases, with most contemporary series from experienced centers reporting rates below 4%. Facial nerve function is assessed using the House–Brackmann grading scale, a validated six-point ordinal instrument ranging from grade I (normal function) to grade VI (total paralysis). A ten-year retrospective study of 329 patients undergoing parotid surgery found that tumor size, operative time, and revision surgery history were significant independent predictors of postoperative injury on logistic regression analysis (2).

Sialocele and Salivary Fistula

Sialocele and salivary fistula are medium-term postoperative complications typically manifesting between seven and twenty days following surgery, arising from saliva leakage from the cut edge of the residual gland parenchyma. Their incidence varies from approximately 4% to 14% following partial superficial parotidectomy depending on the extent of resection and surgical technique. A prospective study comparing surgical closure of residual parotid parenchyma versus deliberate exposure found that sialocele rates were significantly higher in the exposure group, suggesting that meticulous management of the glandular cut surface plays a meaningful independent role regardless of device used. Most cases resolve with conservative management consisting of repeated aspiration and pressure dressings, with botulinum toxin injection reserved for persistent cases that fail conservative measures (24,25).

Frey's Syndrome

Frey's syndrome is the most common long-term sequela of parotidectomy, occurring in a clinically symptomatic form in approximately 20 to 30% of patients, and arises from aberrant regeneration of transected postganglionic parasympathetic fibers of the auriculotemporal nerve into sympathetic innervation of dermal sweat glands. The condition typically becomes symptomatic six months to two years postoperatively and ranges in severity from a mild cosmetic nuisance to significant functional impairment. Prospective comparative data have shown that the harmonic scalpel is associated with a substantially lower Frey's syndrome rate compared with cold instrument plus conventional electrocautery, with the proposed mechanism being that more precise and thermally contained dissection limits the substrate for aberrant fiber regeneration. Prophylactic surgical strategies including acellular dermal matrix placement and sternocleidomastoid muscle flap rotation have been evaluated with varying levels of supporting evidence (26,27).

Operative Time, Blood Loss, and Economic Considerations

Shorter operative time carries multiple downstream benefits including reduced anesthesia exposure, lower facility resource consumption, and potentially lower rates of wound complications associated with prolonged tissue handling and retraction. Health economic modeling has shown that reductions in operating time with harmonic devices consistently translate into cost savings that partially or fully offset the higher acquisition cost of disposable instruments in most surgical contexts. The cost calculus must also account for indirect economic consequences of complications, as transient facial nerve palsy necessitates additional outpatient follow-up and physiotherapy, sialocele requires drainage procedures, and Frey's syndrome may require long-term management with topical anticholinergics or botulinum toxin injections. Postoperative drainage volume and hospital stay are secondary outcomes that have been shown to be significantly lower in harmonic groups, supporting the inference that more precise hemostasis translates into a smoother postoperative course (18,23).

Practical Considerations and Resource Availability

Conventional bipolar diathermy is universally available in all operating room settings worldwide, requires no specialized generator beyond a standard electrosurgical unit, and carries no device-specific consumable cost beyond the reusable or disposable forceps. These economic advantages are particularly relevant in lower-

resource environments such as many teaching hospitals in the Middle East and Africa, where access to advanced energy devices may be constrained by procurement budgets. The universal familiarity of surgeons with bipolar diathermy and its proven safety record across decades of use in head and neck surgery constitute important practical considerations alongside its physical limitations. The decision between devices must therefore balance clinical outcome data with institutional resource availability and surgeon experience (28).

Conclusion

The available evidence supports the harmonic scalpel as a safe and effective alternative to bipolar diathermy in superficial parotidectomy for benign parotid tumors, with consistent advantages in operative time reduction and intraoperative blood loss, and favorable trends toward lower rates of transient facial nerve dysfunction, Frey's syndrome, and salivary complications. These benefits are attributable to the lower operating temperatures and limited lateral thermal spread inherent to ultrasonic energy delivery compared with radiofrequency electrosurgery. However, bipolar diathermy remains a reliable, widely accessible, and cost-effective option, particularly in resource-limited settings, and both devices yield comparable long-term outcomes with regard to permanent facial nerve injury and patient-reported quality of life measures. Larger multicenter randomized controlled trials with longer follow-up periods and standardized outcome reporting are needed to further define the role of each device and to guide evidence-based device selection in parotid surgery (27, 28).

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