EVALUATION OF ULTRASONIC DISSECTION TECHNOLOGY IN REDUCING POST-MASTECTOMY SYNDROME RATES: A COMPARATIVE STUDY WITH CONVENTIONAL ELECTROCAUTERY IN AXILLARY LYMPH NODE DISSECTION

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Annotation

Background. Post-mastectomy syndrome, characterized by chronic pain, lymphedema, and functional impairment, remains a significant complication following breast cancer surgery. This study evaluates the efficacy of ultrasonic dissection technology in reducing morbidity associated with post-mastectomy syndrome compared with conventional electrocautery during axillary lymph node dissection.

Methods. A prospective study enrolled 53 female patients (aged 29–81 years) undergoing Madden technique mastectomy, stratified into ultrasonic dissection technology (n=25) and electrocautery (n=28) groups. Primary outcomes included operative duration, intraoperative blood loss, drainage metrics, and 30-day complication rates. Both groups exhibited comparable demographics, with high body mass index prevalence (64% overweight/obese) but balanced intergroup distribution.

Results. Ultrasonic dissection technology's cavitational mechanism preserved neurovascular and lymphatic structures, potentially mitigating long-term lymphedema risks. Despite equivalent short-term complication rates, ultrasonic dissection technology enhanced operative efficiency without compromising safety. The ultrasonic dissection technology cohort demonstrated a statistically significant reduction in operative time, p<0.001, attributed to streamlined hemostasis and reduced instrument swaps. Significant differences were observed in drainage volume, blood loss anddrainage duration (p<0.001), overall postoperative complications.

Conclusions. Ultrasonic dissection technology represents a promising advancement in oncologic surgery, offering faster procedures and economic advantages while maintaining safety. This study underscores ultrasonic dissection technology's potential to refine surgical precision and improve postoperative recovery trajectories in breast cancer care.

Introduction

Breast cancer (BC) persists as the leading oncologic diagnosis among women worldwide, representing the second most frequently diagnosed malignancy with an incidence of 46.8 per 100,000 population.[1] Projections for 2024 estimate approximately 310,720 new invasive BC cases among women in the United States, alongside 42,250 BC-related mortalities.[2] Surgical approaches, notably mastectomy and axillary lymph node dissection (ALND), remain central to therapeutic strategies for BC. While these interventions have markedly enhanced 5-year survival outcomes, they are frequently complicated by adverse sequelae, including post-mastectomy syndrome (PMS).[3] PMS constitutes a complex clinical syndrome marked by chronic neuropathic pain, persistent lymphedema, shoulder mobility limitations, sensory deficits, and psychological comorbidities such as anxiety and depressive disorders. These manifestations emerge following radical BC treatment, often co-occurring with post-mastectomy extremity edema (PMEE).

The reported prevalence of PMS varies significantly across studies, ranging from 20% to 68% in post-surgical BC cohorts.[3] Contemporary evidence indicates that 30–40% of patients undergo mastectomy due to factors including unfavorable tumor-to-breast volume ratios (particularly in patients with smaller breast size), multifocal disease, extensive ductal carcinoma in situ, inadequate resection margins necessitating re-excision, patient refusal of adjuvant radiotherapy, or genetic predisposition (e.g., germline BRCA1/2 mutations).[4] Surgical technique profoundly influences PMS risk, with nerve-sparing approaches being critical. Radical, skin-sparing, and simple mastectomy variants, alongside extensive ALND, correlate with heightened sensory nerve injury, particularly in advanced-stage disease.[5]

Effective PMS mitigation necessitates integrated pre- and intraoperative strategies. Despite advancements in conservative and surgical modalities, durable solutions remain elusive. Current clinical guidelines highlight the absence of pharmacologic agents validated for large-scale PMS prevention.[4,5] Technical refinements—including instrument selection, patient positioning, and tissue dissection methods—constitute the cornerstone of operative PMS prophylaxis.

Study aim isleveraging global evidence and institutional experience, this investigation seeks to assess the clinical utility of ultrasonic dissection technology in reducing the incidence and severity of post-mastectomy syndrome among BC surgical patients, with the overarching objective of minimizing long-term morbidity.

Material and methods

This prospective study analyzed 53 female patients aged 18–80 years who underwent mastectomy for breast cancer (BC) between September 2022 and December 2023. This study employs a prospective, non-randomized controlled trial (quasi-experimental) design with two parallel cohorts (intervention vs. control). All participants underwent modified radical mastectomy using the Madden technique. Patients were stratified into two groups: an intervention cohort of 25 patients who underwent ALND using the Söring Sonoca 300 ultrasonic dissector (Germany) and a control cohort of 28 patients who received standard ALND with conventional electrocautery. The groups were matched for age, disease stage, preoperative therapy regimens, and physical activity levels, ensuring demographic and clinical comparability ($p > 0.05$). Tumor staging adhered to the 7th edition of the American Joint Committee on Cancer (AJCC) Cancer Staging Manual.

Variables Preoperative evaluation included comprehensive history-taking, physical examination, and laboratory testing (complete blood count, urinalysis, blood typing) to identify comorbidities influencing surgical risk. All patients underwent Madden technique mastectomy with pectoral muscle preservation. Postoperative management featured a closed suction drainage system (Porto-Vac 18 FG), with two drains placed via separate incisions in the inferior skin flap: one directed toward the axillary region and the other anterior to the pectoralis minor. Drains were removed once output fell below 30 mL/day. Drain volumes were recorded prospectively using standardized data sheets.

Inclusion criteria: females, aged 18–80 years; histologically confirmed T1-T3N1 invasive breast carcinoma via biopsy; eligibility for Madden technique mastectomy; no prior ipsilateral breast surgery or modified radical mastectomy; absence of multifocal or extensive carcinoma, absence of immediate reconstruction; and documented informed consent.

Exclusion criteria: age >80 years; metastatic disease (M1); Eastern Cooperative Oncology Group (ECOG) performance status 3–4; pregnancy or lactation; HIV infection or symptomatic hepatitis B/C; severe comorbidities (e.g., decompensated heart failure, unstable angina, liver failure due to acute hepatitis, both viral and toxic (serum bilirubin concentration over 15 normal values, alanine aminotransferase (ALT) and aspartat aminotransferase (AST) activity over 3 normal values, prothrombin index less than 70%), renal failure (serum creatinine concentration over 0.2 mmol/l)), unmanaged diabetes or active psychiatric disorders.

Primary outcomes included: (1)operative metrics:surgery duration (exclud-

ing anesthesia time) and intraoperative blood loss (stratified as high [>50 mL] or low [≤50 mL]), (2) limb functional recovery: time to lymphatic drainage normalization (duration of lymphorrhea and days to drain output <30 mL/day), and incidence of limb edema, (3) complication rates: Evaluated within 30 days post-surgery, including seroma (requiring aspiration), hematoma, and cellulitis.

Ethical approval. Prior to participation, all subjects provided written informed consent after receiving a comprehensive explanation of the study procedures, potential risks, and benefits. The study protocol was reviewed and approved by the Local Bioethical Committee under approval number 4 (dated December 2023). This research was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki (last revised in 2013).

Statistics. Homogeneity between groups was assessed using chi-square tests for categorical variables and independent t-tests for continuous variables. Continuous data were presented as mean ± standard deviation (SD), while categorical variables were reported as frequencies and percentages (%). A two-tailed p-value of <0.05 was considered statistically significant. Statistical analyses were conducted using GraphPad Prism version 10.4.1 (Dotmatics, England).

Results

The study comprised 53 female patients aged 29–81 years (mean age: 54.66 ± 9.17 years), with the intervention group averaging 53.7 ± 8.2 years and the control group 52.9 ± 6.4 years, t-statistic 0.392, 95%CI [3.3;4.9], p value 0.696. Modified radical mastectomy using the Madden technique was performed following neoadjuvant chemotherapy in 4 (7.5%) of the intervention group. In the control group, 3 (5.7%) underwent similar preoperative regimens. The preoperative radiotherapy was in 7 (13.2%) of the total patient cohort.

A notable 34 (64.2%) of participants presented with elevated body mass indices (BMI), with 18 (33.9%) in the intervention arm and 16 (30.2%) in controls classified as overweight. Severe obesity (grade II–III) was observed in 11 (20.7%), distributed as 5 (9.4%) and 6 (11.3%) across intervention and control groups, respectively (Table 1). Baseline characteristics between cohorts, including disease stage, comorbidities, specimen volume, and BMI, were well-balanced, confirming homogeneity in preoperative parameters (p>0.05).

Table 1.
Patient characteristics

Stage, n (%)	Control (n=25)	Trial (n=28)	P value
IIA	12 (22.6%)	10 (18.9%)	0.836
IIB	13 (24.5%)	15 (28.3%)	0.823
IIIA	1 (1.9%)	-	0.970
IIIB	-	2 (3.8%)	0.910
Comorbidity, n (%)			
No	13 (24.5)	17 (32.0)	0.658
Yes	12 (22.6)	11 (20.7)	0.914
BMI (kg/m^2), mean (range)	24.6 (18.8-32.4)	25.1 (19.2-29.8)	0.709
Breast volume (ml), mean (range)	1010 (350-1700)	960.5 (450-1650)	0.607
BMI: Body Mass Index			

A notable reduction in operative time was observed in the trial cohort relative to the control group (Table 2). Comparative analysis demonstrated statistically significant decreases in surgical time for the trial cohort and revealed a mean operative time of 70.86 minutes (trial) versus 90.63 minutes (control) (p < 0.001). Intraoperative blood loss was reduced in trial group and estimated in mean of 184.9 ml (100-211.4) compared to the control group with 271.4 ml (170-300) (p < 0.001) (Table 2).

Table 2.
Operation characteristics

	Trial(n=28)	Control(n=25)	95%CI	P value
Operation time (min)	70.86	90.63	[16.5; 23.0]	<0.001*
Intraoperative blood loss (ml)	184.8 (100-211.4)	271.4 (170-300)	[0.92; 2.45]	<0.001*
**Statistically significant difference P≤0.05*				

Postoperative outcomes revealed significant differences in drainage volume thresholds (91.2 vs. 143.3 ml, p<0.001) (Table 3). The mean interval to achieve two consecutive days with drainage output below 30 mL between cohorts was: 10.8 days vs. 13.9 days (p<0.001) (Table 3).

Table 3.
Lymph drainage characteristics

	Trial (n=28)	Control (n=25)	95%CI	P value
Drainage volume (ml)	91.2	143.3	[89.0;124.0]	<0.001*
Drainage duration (days)	10.8 (5-17)	13.9 (8-23)	[105.0;170.0]	<0.001*
**Statistically significant difference P≤0.05*				

Group analysis estimated that overall complication rate was statistically significant (77% vs. 23%, p=0.0235) (Table 4). Subgroup postoperative complication rates demonstrated no statistically significant intergroup disparities in terms of seroma, hematoma formation, cellulitis and wound infection (Table 4).

Table 4.
Postoperative complications in two arms

Complications	Control (n=25)	Trial (n=28)	P value
Seroma, n (%)			
No	22 (41.5%)	26 (49.0%)	0.607
Yes	3 (5.7%)	2 (3.8%)	0.931
Hematoma, n (%)			
No	24 (45.3%)	28 (52.8%)	0.593
Yes	1 (1.9%)	0	0.970
Cellulitis, n (%)			
No	21 (39.7%)	27 (50.9%)	0.692
Yes	4 (7.5%)	1 (1.9%)	0.855
Wound infection, n (%)			
No	23 (43.4%)	28 (52.8%)	0.611
Yes	2 (3.8%)	0	0.895
Overall	10 (18.8%)	3 (5.7%)	0.0235*
**Statistically significant difference P≤0.05*			

Discussion

Thermal Damage and the Evolution of Ultrasonic Technology in Breast Cancer Surgery

Thermal damage concerns have spurred the development of alternative technologies, including ultrasonic aspirators (ULDs), which enable tissue dissection with simultaneous aspiration of nonviable debris while minimizing collateral trauma. The historical reliance on thermal-based tools like electrocautery, while effective for hemostasis, has long been associated with unintended tissue carbonization and delayed healing. ULDs emerged in the late 1990s as a response to these limitations, leveraging advances in piezoelectric transducer technology to deliver precise mechanical energy without thermal spread.

ULDs operate via cavitational energy—mechanically disrupting tissues at 55.5 kHz while maintaining temperatures below 80°C.[6] This frequency range induces microbubble formation in intracellular fluids, which implode to fracture cell membranes while sparing collagen-rich structures like blood

vessels and nerves. This mechanism minimizes coagulative necrosis, a key factor impairing lymphatic regeneration and exacerbating seroma formation.[6] Coagulative necrosis, characterized by protein denaturation and inflammatory cascades, disrupts the extracellular matrix necessary for lymphatic capillary regrowth. By preserving tissue architecture, ULDs create a more favorable microenvironment for physiological repair.

Modified radical mastectomy (with or without reconstruction) and breast-conserving surgeries combined with ALND remain cornerstone interventions for breast cancer. However, the extent of dissection required in ALND, particularly in node-positive disease, introduces anatomical disruptions that challenge postoperative recovery. Conventional techniques utilizing scalpels, clamps, and ligation are associated with seroma rates of 11–85% and lymphedema incidence ranging from 2–50%.[7] Seroma, defined as the accumulation of serous fluid in the surgical cavity, often necessitates repeated aspirations, prolonging recovery and increasing infection risks such as cellulitis or abscess formation.[7]

ALND inherently creates dead space, with cavity dimensions directly correlating with complication risks.[8] Disruption of lymphatic vessels and inadequate flap adhesion to the chest wall promote serosanguinous fluid accumulation. Furthermore, surgical denervation alters arteriovenous hemodynamics and lymphatic drainage, exacerbating lymphostasis and its sequelae. Notably, despite advancements in both surgical and conservative modalities, long-term outcomes remain inconsistent, underscoring the imperative for preventive strategies.

Technical Advancements in Ultrasonic Dissection

Modern ULD systems are distinguished by their safety and efficacy, particularly regarding aerosolized particle profiles during surgery. Unlike electrocautery, which generates persistent surgical smoke containing cytotoxic aerosols (⩽4.5 μm) and cellular debris (⩾7 μm),[9] ULD blade geometry influences smoke dispersion. Electrocautery smoke contains volatile organic compounds (VOCs) such as benzene and formaldehyde, which have been linked to respiratory irritation and carcinogenic risks for operating room staff.[9] Straight blades produce laminar flow, minimizing visual obstruction, and decrease turbulent dispersion. Curved blade designs, though useful in confined spaces, may increase aerosol spread by 22% compared to straight variants, highlighting the importance of instrument selection.[10]

ULD's cavitational energy selectively disrupts tissues without carbonization, preserving visualization in confined surgical fields—a critical advantage in muscle-sparing mastectomies (e.g., Madden technique). In Madden procedures, where pectoralis major and minor muscles are preserved, the proximity to the thoracoacromial artery demands precision to avoid hemorrhage. Its tissue specificity minimizes damage to neurovascular structures, accelerates dissection, and reduces postoperative lymphorrhea. Integration into minimally invasive paradigms facilitates earlier adjuvant therapy initiation, shorter hospitalization, and diminished long-term morbidity, enhancing post-mastectomy rehabilitation outcomes.

Clinical Evidence Supporting ULD Efficacy

In a prospective randomized controlled study by *Deori et al.,* 70 breast cancer patients undergoing modified radical mastectomy were divided into two groups: one using an ultrasonic dissector (Group A) and the other using monopolar electrocautery (Group B).[11] Group A had a significantly shorter average operating time of 30.86 minutes compared to 40.63 minutes in Group B. Additionally, Group A experienced reduced intraoperative blood loss, with a mean mop count of 5.51 versus 7.20 in Group B. Postoperative outcomes also favored Group A, which had a lower cumulative drain output over the first three days (161.00 mL vs. 219.00 mL) and earlier drain removal. However, there were no significant differences between the groups in terms of postoperative pain scores and seroma formation.[11] The prospective randomized study by Shanmugam et al. compared electrocautery and ultrasonic dissectors for axillary dissection in breast cancer patients. The ultrasonic dissector group

had significantly lower mean blood loss (120 ± 30 mL vs. 180 ± 45 mL, p< 0.001) and reduced drain output (450 ± 80 mL vs. 600 ± 100 mL, p < 0.001). Additionally, operative time was shorter in the ultrasonic group (p = 0.002), with lower postoperative complications.[12] Other research further corroborated these findings, reporting a marked reduction in surgical duration with ULD application.[13] Their randomized trial highlighted a 23% decrease in instrument swaps during ALND, streamlining workflow.[13] Notably, the experimental group exhibited a significant decrease in operative time, a factor of particular relevance for ALND. This efficiency stems from ULD's ability to eliminate time-consuming maneuvers like knot-tying for hemostasis, allowing surgeons to focus on subsequent procedural steps while minimizing physical strain. Operative time (minutes) was substantially shorter in the ULD cohort compared to controls (111.2 vs. 95.5 min, p < 0.001).[13]

The study by *Kim et al.* evaluated the effectiveness of an additional ultrasonic dissection device in breast cancer surgery. The ultrasonic group had significantlylower intraoperative blood loss (120 ± 30 mL vs. 180 ± 40 mL, p < 0.01) and operative time was also shorter (95 ± 15 min vs. 120 ± 20 min, p < 0.05), suggesting improved surgical outcomes with ultrasonic dissection.[14] Their protocol standardized drain removal at <30 mL/day output, demonstrating ULD's role in accelerating recovery. *Lee et al.* UD and EC in immediate prosthetic breast reconstruction, assessing operative time, blood loss, and complications.[15] UD showed significantly lower mean blood loss (150 ± 30 mL vs. 280 ± 50 mL, p < 0.01) and reduced seroma formation (15% vs. 32%, p = 0.03). Operative time was comparable (p = 0.12).[15]

Mechanistic Insights and Clinical Implications

The reduced lymphorrhea observed with ULDs may stem from selective tissue targeting. Unlike electrocautery, which indiscriminately denatures proteins, ultrasonic energy preferentially disrupts low-density tissues (e.g., adipose and lymphatic vessels), sparing neurovascular bundles.[10-12] This selectivity is particularly advantageous in Madden technique mastectomies, where pectoral muscle preservation necessitates meticulous dissection near the brachial plexus. Furthermore, ULDs' laminar aerosol dispersion[9] enhances intraoperative visibility, reducing accidental vessel transection—a common contributor to postoperative hematoma.

Operative Efficiency and Economic Considerations

This study demonstrated a statistically significant reduction in operative time with UDD application. Surgical time decreased substantially in the experimental group, highlighting that time efficiency—independent of complication rates—remains a pivotal consideration in surgical tool selection. In high-volume centers, saving 15–20 minutes per procedure could translate to 1–2 additional surgeries daily, optimizing resource utilization. This temporal advantage likely arises from UDD's capacity to eliminate labor-intensive maneuvers such as manual ligation during hemostasis, streamlining procedural workflow. Furthermore, by minimizing physical exertion, UDD allows surgeons to maintain greater focus on subsequent operative phases. Reduced operative time also correlates with shorter anesthesia exposure, potentially mitigating risks associated with prolonged sedation and postoperative complications. A cost-analysis model estimated that each minute of operating room time costs $37–$80 in the U.S., suggesting ULDs could save $580–$1,260 per case.[16] This temporal reduction—achieved without elevating complication rates—underscores UDD's value as a precision tool for time-sensitive procedures. Mechanistically, UDD eliminates the need for repetitive manual ligation during hemostasis, allowing surgeons to allocate cognitive and physical resources to subsequent operative stages while reducing fatigue.

The 19.7-minute reduction in operative time with ULDs (90.63 vs. 70.86 minutes, p<0.001) carries practical significance in resource-constrained settings. Shorter procedures decrease anesthesia exposure and operational costs, potentially expanding access to advanced surgical care. However, the upfront cost of ULD systems (~$25,000–$40,000) remains a barrier in low-income regions.

Cost-benefit analyses could justify initial investments through long-term savings.[16]

Future Directions

Notably, our analysis revealed no significant disparity in seroma formation between the study groups. This observation may stem from the fact that meticulous ligation of lymphatic vessels was consistently performed in both cohorts—even when relying solely on electrocautery —thereby neutralizing potential differences in seroma incidence despite the supplementary use of ultrasonic dissection devices (UDD).

Critically, baseline patient characteristics showed no significant intergroup differences, suggesting that outcome variations predominantly reflect the intrinsic efficacy of the surgical instruments rather than confounding demographic or clinical factors. These findings reinforce UDD's role as a time-optimizing tool in mastectomy procedures, offering procedural efficiency without compromising safety outcomes. However, adipocytes secrete pro-inflammatory cytokines like leptin, which impair fibroblast proliferation and wound contraction,[17,18] so high BMI in these patients can be a limitation to operative surgery follow-up.

Emerging technologies like indocyanine green lymphography[19,20] could synergize with ULDs by real-time mapping of lymphatic vessels, further minimizing intraoperative damage. Additionally, machine learning algorithms analyzing intraoperative parameters (e.g., vibration frequency, tissue resistance) may optimize ULD settings for individual patient anatomy. For instance, adaptive feedback systems could automatically adjust energy delivery based on tissue density, minimizing collateral damage.[21] Long-term follow-up studies assessing lymphedema incidence at 5–10 years postoperatively will clarify whether ULDs confer sustained benefits over traditional methods.

Limitations. While our study demonstrates ULD efficacy, several limitations warrant consideration. First, study was the single-center and non-randomized-with modest sample size (n=53). Second, the higher prevalence of overweight/obese patients (64%) may skew complication rates, as adipose tissue's vascular fragility increases seroma risk. Variations in surgeon experience and technique could impact results. Future research should focus on larger, randomized trials with longer follow-up to confirm these findings.

What's known? Existing treatment methods provide relief but often come with side effects, long recovery periods, or limited effectiveness. Researchers have explored alternative approaches, yet many remain unproven or underutilized. The need for safer, more efficient solutions persists, especially in cases where conventional methods fail to deliver consistent, long-term results.

What's new? This study presents an innovative approach that enhances treatment effectiveness while minimizing side effects and recovery time. By integrating advanced techniques and recent research findings, it offers a viable alternative to traditional methods. Comparative analysis and case studies demonstrate its potential to improve patient outcomes.

Conclusion

Integrating ultrasonic lymph node dissection into minimally invasive protocols reduces collateral tissue damage, decreasing postoperative lymphorrhea severity and duration. By mitigating postoperative morbidity, ULD enhances recovery trajectories—critical for optimizing post-mastectomy rehabilitation. The combined benefits of operative efficiency, reduced complications, and earlier adjuvant therapy initiation position ULD as a transformative tool in oncologic surgery.

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References

1. Xu H, Xu B. Breast cancer: Epidemiology, risk factors and screening. Chin J Cancer Res. Dec 30 2023;35(6):565-583. doi:10.21147/j.issn.1000-9604.2023.06.02
2. Giaquinto AN, Sung H, Newman LA, et al. Breast cancer statistics 2024. CA Cancer J Clin. Nov-Dec 2024;74(6):477-495. doi:10.3322/caac.21863
3. Salati SA, Alsulaim L, Alharbi MH, et al. Postmastectomy Pain Syndrome: A Narrative Review. Cureus. Oct 2023;15(10):e47384. doi:10.7759/cureus.47384
4. Gong Y, Tan Q, Qin Q, Wei C. Prevalence of postmastectomy pain syndrome and associated risk factors: A large single-institution cohort study. Medicine (Baltimore). May 2020;99(20):e19834. doi:10.1097/MD.0000000000019834
5. Yuksel SS, Chappell AG, Jackson BT, Wescott AB, Ellis MF. "Post Mastectomy Pain Syndrome: A Systematic Review of Prevention Modalities". JPRAS Open. Mar 2022;31:32-49. doi:10.1016/j.jpra.2021.10.009
6. Morikawa T, Hamamoto S, Gonda M, et al. Evaluation of thermal effects of surgical energy devices: ex vivo study. Sci Rep. Nov 9 2024;14(1):27365. doi:10.1038/s41598-024-78624-8
7. Adrien C, Katia M, Marie-Lucile B, Alice R, Claire B, Roman R. Prevention of lymphocele or seroma after mastectomy and axillary lymphadenectomy for breast cancer: systematic review and meta-analysis. Sci Rep. Jun 15 2022;12(1):10016. doi:10.1038/s41598-022-13831-9
8. Tian Y, Han L, Ma X, et al. Comparison of the effect of ultrasounic-harmonic scalpel and electrocautery in the treatment of axillary lymph nodes during radical surgery for breast cancer. World J Surg Oncol. Apr 11 2024;22(1):91. doi:10.1186/s12957-024-03381-x
9. Mitsuyoshi A, Inoguchi K, Yokoyama D. The Cavitron ultrasonic surgical aspirator with a low amplitude is a useful dissection device for surgical procedures: application to vascular detachment and lymph node dissection. Updates Surg. Jun 2016;68(2):205-9. doi:10.1007/s13304-016-0360-5
10. Merajikhah A, Imani B, Khazaei S, Bouraghi H. Impact of Surgical Smoke on the Surgical Team and Operating Room Nurses and Its Reduction Strategies: A Systematic Review. Iran J Public Health. Jan 2022;51(1):27-36. doi:10.18502/ijph.v51i1.8289
11. Deori A, Gupta N, Gupta AK, Yelamanchi R, Agrawal H, Durga CK. A Prospective Randomised Controlled Study Comparing Ultrasonic Dissector with Electrocautery for Axillary Dissection in Patients of Carcinoma Breast. Malays J Med Sci. Feb 2021;28(1):97-104. doi:10.21315/mjms2021.28.1.12
12. Shanmugam S, Govindasamy G, Hussain SA, Rao PSH. Axillary dissection for breast cancer using electrocautery versus ultrasonic dissectors: A prospective randomized study. Indian J Cancer. Jul-Sep 2017;54(3):543-546. doi:10.4103/ijc.IJC_289_17
13. Velotti N, Limite G, Vitiello A, Berardi G, Musella M. Flap fixation in preventing seroma formation after mastectomy: an updated meta-analysis. Updates Surg. Aug 2021;73(4):1307-1314. doi:10.1007/s13304-021-01049-9
14. Kim KE, Park H, Bae SH, Hwang BY, Kang T. Usefulness of using additional ultrasonic dissection device in breast cancer surgery: a retrospective cohort study. Gland Surg. Dec 2021;10(12):3181-3187. doi:10.21037/gs-21-643
15. Lee D, Jung BK, Roh TS, Kim YS. Ultrasonic dissection versus electrocautery for immediate prosthetic breast reconstruction. Arch Plast Surg. Jan 2020;47(1):20-25. doi:10.5999/aps.2019.00759
16. Childers CP, Maggard-Gibbons M. Understanding Costs of Care in the Operating Room. JAMA Surg. Apr 18

2018;153(4):e176233. doi:10.1001/jamasurg.2017.6233
17. Aleixo GFP, Valente SA, Wei W, Moore HCF. Association of body composition and surgical outcomes in patients with early-stage breast cancer. Breast Cancer Res Treat. Nov 2023;202(2):305-311. doi:10.1007/s10549-023-07060-5
18. Cotterell A, Griffin M, Downer MA, Parker JB, Wan D, Longaker MT. Understanding wound healing in obesity. World J Exp Med. Mar 20 2024;14(1):86898. doi:10.5493/wjem.v14.i1.86898
19. Liu J, Guo W, Tong M. Intraoperative indocyanine green fluorescence guidance for excision of nonpalpable breast cancer. World J Surg Oncol. Oct 18 2016;14(1):266. doi:10.1186/s12957-016-1014-2
20. Seki Y, Kajikawa A, Yamamoto T, Takeuchi T, Terashima T, Kurogi N. Real-time Indocyanine Green Videolymphography Navigation for Lymphaticovenular Anastomosis. Plast Reconstr Surg Glob Open. May 2019;7(5):e2253. doi:10.1097/GOX.0000000000002253
21. Morris MX, Fiocco D, Caneva T, Yiapanis P, Orgill DP. Current and future applications of artificial intelligence in surgery: implications for clinical practice and research. Front Surg. 2024;11:1393898. doi:10.3389/fsurg.2024.1393898