Effect of LigaSure™, Monopolar Cautery, and Bipolar Cautery on Surgical Margins in Breast-Conserving Surgery

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Keywords

Breast cancer · Lumpectomy · Breast-conserving surgery · Electrosurgery · Thermal destruction

Summary

Background: We compared the differences in thermal damage at the surgical margin between monopolar cautery, bipolar cautery, and LigaSure™ in breast cancer lumpectomy specimens and assessed the effect of these techniques on the evaluation of the surgical margins.

Methods: 30 patients scheduled for breast-conserving surgery for breast cancer were included in this study. During lumpectomy, each of the superior, inferior, lateral, and medial borders of the tumour was excised using one of the following: a scalpel, monopolar cautery, bipolar cautery, and LigaSure technology. The surgical margins of frozen and paraffin-embedded tissue sections of the lumpectomy specimen were evaluated. Thermal damage was defined as the maximum depth of thermal damage (in mm) from the surgical margin, and the level was categorized as none, low (≤ 1 mm), or high (>1 mm).

Results: There was no statistically significant difference between monopolar cautery, bipolar cautery, and LigaSure in terms of thermal damage. There was no thermal damage at the surgical margin in tissues dissected by scalpel. **Conclusion:** Thermal damage due to the excision

method may cause false-negative and false-positive results in the surgical margin evaluation of lumpectomy specimens. More research is needed on the effects of different energy modalities on surgical margin evaluation in breast-conserving surgery.

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Introduction

In contemporary surgical practice, breast-conserving surgery has replaced modified radical mastectomy for the treatment of early-stage breast cancer, and long-term follow-up studies have demonstrated equivalent survival rates between the 2 procedures [1]. Ensuring tumour-free surgical margins in breast-conserving surgery is the most critical factor in reducing the risk of local recurrence [2, 3]. Although opinions vary regarding the minimum distance between the tumour and the surgical margin, many surgeons perform re-excision if cancer cells are identified within 2 mm of the surgical margin [4, 5]. Accordingly, factors that affect surgical margin evaluation by frozen tissue examination are of great importance [6]. In this study, we compared the levels of tissue damage induced by monopolar cautery, bipolar cautery, and LigaSure™ (Valleylab, Boulder, CO, USA) in frozen and paraffin-embedded tissue sections of lumpectomy specimens, and assessed their effects on surgical margin evaluation.

Fig. 1. Loss of collagen fibrous structure due to denaturation. Breast parenchyma structure is not affected (paraffin section).

Fig. 2. Lumen and endothelium cannot be seen due to damage (frozen section).

Fig. 3. Thin elongated cells, increased cytoplasmic eosinophilia, and elongated nuclear structures (frozen section).

Materials and Methods

After obtaining ethics committee approval, 30 patients scheduled for breast-conserving surgery for breast cancer were included in this study. During lumpectomy, each of the superior, inferior, lateral, and medial sides of the tumour specimen was dissected using one of the following: scalpel, monopolar cautery, bipolar cautery, and LigaSure. The anterior and posterior sides were not evaluated because of the presence of skin and pectoral fascia, respectively. The surgical margins were marked with routine orientation sutures and the specimens sent off for frozen tissue examination. In the pathological examination, the following markers were used to evaluate thermal damage: loss of collagen fibre structure due to denaturation, basal membrane degradation and oedema in the ductal epithelium, increased cytoplasmic eosinophilia, nuclear crush artefact and nuclear elongation, vessel endothelial breakdown and oedema (figs. 1–3). If the surgical margin consisted only of fibrolipomatous stroma, we evaluated the loss of collagen fibre structure due to denaturation in the connective tissue and vascular endothelial injury in areas close to the surgical margin that contained no breast parenchyma. In 3 patients, the margins

could not be assessed because of the presence of fat tissue alone or the absence of parenchyma or stroma, and their data were excluded from analysis. The tissue sections were examined under a microscope (BX51, Olympus, Tokyo, Japan), and sections with the best visualization and assessability were selected for each surgical margin specimen. Photographs were obtained of each section (DP71, Olympus). Thermal damage, defined as the maximum depth of thermal damage (in mm) from the surgical margin, was measured for each specimen and was categorized as none, low (≤ 1 mm), or high (>1 mm).

The dissection methods were as follows: scalpel (no. 10, Ribbel, Sonapat, Haryana, India), monopolar cautery (HT-1-B Electrosurgical Pencil, NEXtech, Shanghai, China), bipolar cautery (BP540 bipolar scissors, Ethicon, North Las Vegas, NV, USA), or LigaSure. All devices except for the scalpel were used in conjunction with an electrosurgical generator (ForceTriad, Valleylab).

Each patient's specimen was dissected by monopolar cautery at 35 W in cut mode, bipolar cautery at 80 W in standard mode, and LigaSure at level 2. All patients were operated on by the same surgical team.

Statistical Analysis

IBM SPSS Statistics for Windows, version 21.0 (2012 release, IBM Corp., Armonk, NY, USA) was used for the statistical analyses and calculations, and Microsoft Excel 2007 was used to generate column charts. Normal distribution of the data was assessed using the Shapiro-Wilk test. As the Shapiro-Wilk test revealed a non-normal distribution of the thermal damage induced by monopolar cautery, bipolar cautery, and LigaSure, the thermal damage values are expressed as medians (interquartile range (IQR)). Categorical variables such as age, symptoms, family history, and smoking are given as the number (percentage). Friedman 2-way variance of analysis was used to compare methods in terms of damage levels. Cochran's Q test was used to compare categorical variables (i.e., thermal damage groups). The level of statistical significance was accepted as $p < 0.05$.

Results

The demographic characteristics and radiographic and histopathological findings are listed in table 1. No thermal damage due to the scalpel method was observed in any patient; accordingly, the scalpel data were excluded from the statistical analysis. Regarding the depth of tissue damage at the surgical margin, the ranges (median (IQR)) for monopolar cautery, bipolar cautery, and LigaSure

Table 1. Demographic, radiological, and histopathological characteristics of the study participants

	n (%)
Age, years	
<40	7 (23.3)
≥40	23 (76.7)
Family history	
Yes	10 (33.3)
No	20 (66.7)
Smoking	
Yes	4 (13.3)
No	26 (86.7)
Parity	
Children	28 (93.3)
Childless	2 (6.7)
History of breastfeeding	
Yes	27 (90)
No	3 (10)
Hormone replacement therapy	
Received	3 (10)
Not received	27 (90)
cerbB2	
Negative	22 (73.3)
Positive	8 (26.7)
Menopause	
Premenopausal	18 (60)
Perimenopause	3 (10)
Postmenopausal	9 (30)
Mammography	
Normal	3 (10)
Spiculated mass	7 (23.3)
Cluster calcification	2 (6.7)
Nodular density	6 (20)
Asymmetric density	6 (20)
Cluster calcification and spiculated mass	1 (3.3)
Cluster calcification and nodular mass	1 (3.3)
Cluster calcification and asymmetric density	2 (6.7)
No mammography	2 (6.7)
Ultrasonography	
Normal	1 (3.3)
Solid mass	27 (90)
Other	2 (6.7)
Pathology	
Infiltrative ductal carcinoma	27 (90)
Infiltrative lobular carcinoma	1 (3.3)
Other	2 (6.7)
Tumour quadrant	
Upper lateral	19 (63.4)
Upper medial	7 (23.3)
Lower lateral	4 (13.3)
Oestrogen receptor	
Negative	4 (13.3)
Positive	26 (86.7)
Progesterone receptor	
Negative	5 (16.7)
Positive	25 (83.3)
Grade	
1	6 (20)
2	11 (36.7)
3	13 (43.3)
Tumour diameter	
T1	20 (69)
T2	9 (31)
Oral contraceptive	
Received	7 (23.3)
Not received	23 (76.7)
Complaint	
None	5 (16.7)
Mass	20 (66.6)
Other	5 (16.7)
Examination	
Normal	5 (16.7)
Palpable mass	16 (53.3)
Other	9 (30)

Fig. 4. Distribution of thermal damage levels for 3 instruments.

Fig. 5. Distribution of damage levels in tissues excised by monopolar cautery, bipolar cautery, and LigaSure™.

were 0.10–5.00 (0.80 (1.00)) mm, 0.15–5.00 (0.80 (1.30)) mm, and 0.20–3.00 (1.00 (1.40)) mm, respectively (table 2, fig. 4). There was no statistically significant difference between monopolar cautery, bipolar cautery, and LigaSure in terms of tissue damage ($p = 0.053$).

When the level of tissue damage was categorized, 18 (66.7%) and 9 (33.3%) sides dissected by monopolar cautery, 17 (63%) and 10 (37%) dissected by bipolar cautery, and 14 (51.9%) and 13 (48.1%) dissected using LigaSure technology exhibited low and high levels, respectively, of damage at the surgical margin (table 3, fig. 5). The 3 instruments had similar results ($p = 0.444$) in terms of the extent of tissue damage.

Discussion

The instruments used for haemostasis and dissection during surgery produce heat in the target and adjacent tissues, which may

Table 2. Amounts of damage for monopolar cautery, bipolar cautery, and LigaSure™ (mm)^a

	Monopolar cautery	Bipolar cautery	LigaSure	Test statistic (χ^2)	p
Median (IQR)	0.80 mm (1.00)	0.80 mm (1.30)	1.00 mm (1.40)	5.891	0.053
Minimum	0.10 mm	0.15 mm	0.20 mm		
Maximum	5.00mm	5.00 mm	3.00 mm		

^aFriedman 2-way variance analysis.

IQR = Interquartile range.

Table 3. Distribution of low and high affected tissues using monopolar cautery, bipolar cautery, and LigaSure™^a

	Monopolar cautery, n (%)	Bipolar cautery, n (%)	LigaSure, n (%)
Low-level effect	18 (66.7)	17 (63.0)	14 (51.9)
High-level effect	9 (33.3)	10 (37.0)	13 (48.1)

^aCochran Q test statistic, Q = 1.625, p = 0.444.

increase tissue damage and delay wound healing [7]. Areas exhibiting thermal damage secondary to thermal injury may obscure the histopathological details and complicate the pathological assessment of the surgical margin in excised tumour specimens. Consequently, this increases the potential for false-negative and false-positive results, which can adversely affect treatment [8]. Various studies have been performed to evaluate monopolar and bipolar modalities. Those pertaining to breast surgery generally reported evaluated bleeding levels, seroma formation, wound-healing disorders, and postoperative pain levels related to the use of these methods. In our study, we aimed to compare the thermal damage levels caused by monopolar cautery, bipolar cautery, and LigaSure in breast cancer patients who underwent lumpectomy.

The scalpel is easy to use during surgery, it does not adhere to tissue or induce heat damage in adjacent tissues, is capable of full-thickness incision, and is inexpensive. Despite these advantages, obscured visualization due to scalpel-related bleeding and prolonged operative time have led to the development of new instruments that provide easy dissection, good haemostasis, and minimal tissue injury. Monopolar cautery is the oldest coagulation method still used extensively. The system operates by the principle of current passing through the active electrode at the surgical site and completing the circuit through the patient's body to the return electrode in a different region of the body. As the current passes through, tissues heat up according to resistance differences. There is a risk of injury to neighbouring organs because of increased thermal spread due to local heating, spark generation, and variability in the path of the current [9]. In conventional bipolar cautery, the current passes between 2 electrodes, and a lower current level is sufficient; therefore, bipolar cautery is considered safer than monopolar cautery [10]. LigaSure (bipolar vessel sealing) technology is a radiofrequency-driven bipolar electrosurgical device. A tissue-

based feedback program is used to regulate the dose of energy administered, which is appropriate for bulk tissue or vessel density, and the aim is to limit the heat generated in the target tissue. The collateral thermal damage associated with LigaSure is probably low because of these features [11]. All 3 electrosurgical methods can induce thermal damage due to heat build-up in tissues.

Various studies have investigated the thermal tissue damage caused by different thermocautery devices. Lantis et al. [10] compared thermal spread of monopolar cautery (25 W), traditional bipolar cautery (40 W), harmonic scalpel (level 3), and laser energy (5 W) in rabbits by placing a 0.5-cm heat probe proximal to coagulated vessels and measuring thermal damage in histological sections. Thermal spread and damage were significantly greater for monopolar cautery (12.17 °C and 2.94 mm, respectively), but no significant difference was found among the other 3 methods. However, the criteria used for microscopic evaluation of tissue damage were not discussed in detail. In our study, loss of collagen fibre structure due to denaturation, basal membrane degradation and oedema in ductal epithelium, increased cytoplasmic eosinophilia, nuclear crushing artefact and nuclear elongation, and vessel endothelial breakdown and oedema were regarded as indicators of thermal damage. The maximum depth of damage from each surgical margin was measured in every section.

In a study conducted by Landman et al. [12] in pigs, renal veins and arteries were cut using conventional bipolar cautery (40 W), LigaSure (level 3), Trimax bipolar forceps (40 W), and harmonic scalpel (level 3), and collateral thermal damage was assessed histopathologically. The depth of collateral thermal damage was 2–6 mm with conventional bipolar electrocautery, 3–4 mm with LigaSure, 1–5 mm with Trimax bipolar forceps, and 0–1 mm with the harmonic scalpel. In a rabbit study, Diamantis et al. [13] compared the coagulation of short gastric arteries and veins among monopolar cautery, bipolar cautery, harmonic scalpel, and LigaSure in terms of efficacy and safety. Monopolar cautery was used at 8/10 of the maximum power in coagulation mode, bipolar cautery was used at 8/10 of the maximum power, the harmonic scalpel was used at level 4, and LigaSure was used at 50% of the maximum power. The animals were killed after 3, 7, 14, or 21 days, and the coagulation zones and adjacent stomach wall were examined histologically. Thermal injury was assessed by determining the degree of degeneration, necrosis, lesion transmural extent, mucosal ischemia, and secondary inflammation (neutrophil count). Thermal damage was the greatest in the monopolar cautery group and the

least in the LigaSure group. There are no criteria for the power level that should be used when comparing these devices. In our study, monopolar cautery was used at 35 W in cut mode, bipolar cautery at 80 W in standard mode, and LigaSure at level 2. In studies conducted by Harold et al. [14] using pig arteries and Goldstein et al. [15] using pig ureters, collateral thermal damage induced by LigaSure and harmonic scalpel was assessed histomorphologically by measuring the level of coagulation necrosis. In both studies, the differences were not statistically significant. In a study by Lambertson et al. [16] conducted in a simulated laparoscopic environment on bovine arteries, lateral thermal damage induced by the LigaSure, PlasmaKinetic, harmonic scalpel, and EnSeal PTC systems was measured using heat sensors placed 2 mm from the dissector. Thermal spread was lowest with the harmonic scalpel (49.9 °C compared with 55.5 °C with LigaSure, 64.5 °C with PlasmaKinetic, and 58.9 °C with EnSeal).

In a study by Brzeziński et al. [17], 76 thyroidectomies were performed with a thermal camera placed at a 90° angle at 80 cm from the surgical site, and photographs were obtained during coagulation. Monopolar cautery, bipolar cautery, and ThermoStapler bipolar vessel sealing were compared in terms of temperature changes during coagulation using 30 W and 50 W power levels. At 30 W power, the ThermoStapler system produced the least amount of thermal spread, with no statistical difference between monopolar and bipolar cautery. At 50 W, there were no statistical differences among the 3 instruments. In our study, there was no significant difference in thermal damage between monopolar and bipolar cautery at the surgical margin, similar to the results by Brzeziński et al. [17]. However, many studies have reported greater collateral thermal damage with monopolar cautery [10, 13, 18]. We believe that the discrepant results were caused by differences in instrument power levels, and this issue could be resolved in future studies by comparing instruments operated at similar power levels. In addition, we think that the statistically similar results among our monopolar cautery, bipolar cautery, and LigaSure measurements may be related to using monopolar cautery in cut mode, which is associated with low rates of thermal damage, similar to those of new-generation dissection tools.

Ruidiaz et al. [8] histopathologically examined the level of thermal damage induced by PlasmaBlade electrosurgery and electrocautery at the surgical margin in breast-conserving surgery. They devised their own thermal damage criteria, as there is no standard definition or method for the histopathological evaluation of thermal damage. Morphologically, they identified 2 fibrocollagenous thermal injury zones (collagen-denatured and undisturbed tissue) and 4 cellular thermal injury zones (zone 1, complete charring with no cellular structure; zone 2, fused tissue with severe tissue denaturation, few identifiable structures, indistinguishable nuclei and tissue breakdown; zone 3, distressed cellular architecture with a wispy appearance, irregular elongated and spindled nuclei, smudged chromatin, visibly distorted fibroblast nuclei, no clear cellular outlines, and visible cells but undetermined whether they are epithelial or stromal; zone 4, no thermal damage, all structures can be identified distinctly). The authors stated that denatured tis-

sue regions would be unreadable in the fibrocollagenous thermal injury examination, and zones 1 and 2 would be unreadable in the cellular thermal injury examination, and only 50% of zone 3 would be readable by a pathologist. Accordingly, they predicted an 11% false-negative rate due to the increase in unreadable areas using traditional monopolar electrocautery compared with a method inducing less thermal damage. In our statistical evaluation, the level of tissue damage was categorized into 3 groups: none, low, or high. In patients with laryngeal carcinomas, Mannelli et al. [19] compared the damage induced by monopolar cautery, harmonic scalpel, and CO₂ laser in macroscopically tumour-free mucosa after laryngeal excision, according to the thermal damage assessment system proposed by Ruidiaz et al. [8]. They detected significantly greater thermal damage with monopolar cautery compared with the other modalities.

We believe that in addition to the technical characteristics of the dissection instrument used, differences in thermal tissue damage are affected by duration of use, tissue properties, and vascular density, and that these may be related to the differences among study outcomes. To exclude patient-dependent variables in the present study, we applied all of 4 instruments in every patient, and all surgeries were performed by the same team to exclude effects caused by differences in device usage. Histopathological examination of all surgical margin sections was performed by the same pathologist, who was blinded to the instrument used for each tumour side. No damage was found at surgical margins cut by scalpel, and the histopathological details could be assessed clearly. Although the scalpel has disadvantages such as bleeding and poor visualisation of the operative site due to bleeding, it remains effective because there are minimal false-negative and false-positive results. In cases where the surgical margin is close to the areola, re-excision could necessitate removing the areola; in such cases, using a scalpel for dissection allows more accurate surgical margin evaluation, thereby minimizing the possibility of re-excision.

Conclusion

Thermal damage in tissue induced by the surgical dissection method may cause false-positive and false-negative results in the evaluation of the surgical margin, whereas dissection using a scalpel showed the advantage of minimizing false-negative and false-positive results. Although a number of studies on thermal tissue damage caused by different energy modalities have now been performed, we believe that more research with higher patient numbers is needed to assess the effects on surgical margin evaluation in breast-conserving surgery.

Disclosure Statement

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