Quantitation of Breast Sensibility following Reduction Mammaplasty: A Comparison of Inferior and Medial Pedicle Techniques

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The preservation of sensitivity within the nipple-areola complex is of paramount importance to patients presenting for reconstructive and aesthetic breast procedures. Previous attempts to measure sensation in the breast before and after surgery have relied primarily on the Semmes-Weinstein monofilament test, which is an imprecise study that measures the logarithm of force necessary to bend a series of six to 20 filaments. Within the last 10 years, various authors have published normative pressure threshold data for the breast that have varied by a magnitude of greater than 10-fold. Recently, precise anatomic studies have been performed that have elucidated the innervation of the nipple-areola complex medially and laterally from cutaneous branches of the intercostal nerves. Despite this knowledge, no quantitative sensibility studies have yet been performed that compare postoperative sensation when medially versus laterally innervated pedicles have been used in reduction mammaplasty. The present study is the first to use computer-assisted neurosensory testing to generate normal breast sensation data and to compare sensory outcomes between the inferior and the medial pedicle techniques of reduction mammaplasty.

A total of 34 patients were divided into four groups and underwent breast sensory testing (67 breasts total) using the Pressure-Specified Sensory Device, a computer-assisted force transducer that measures static and moving one and two-point discrimination. Sensation in the nipple and in the four quadrants of the areola was measured. Groups I and II were composed of 17 unoperated controls with breast sizes ranging from 34A to 36C (group I; 18 breasts) and 36DD to 46EE (group II; 16 breasts) who presented to a general plastic surgery clinic. Groups III and IV were composed of 17 patients who underwent either medial or inferior pedicle reduction mammaplasty between July of 1997 and March of 1999. Pressure thresholds in the most sensitive breasts were as low as 0.3 g/mm^2, a marked contrast to data from previous studies using Semmes-Weinstein monofilaments documenting the lowest recordable pressure threshold as greater than 2 g/mm^2. Several findings from previous studies using Semmes-Weinstein monofilament testing were confirmed in unoperated controls, including an inverse relationship between sensitivity and breast size, superior nipple sensitivity when compared with the areola, and significant interpatient variability with respect to static and moving two-point discrimination among women matched according to age and breast size. When comparing medial with inferior pedicle reduction mammaplasty patients, it was found that despite significantly greater reductions using the medial pedicle technique (mean of 1.7 kg versus 1.1 kg of breast tissue removed), there were no significant differences in postoperative sensory outcomes in the sample size of 17 patients. Furthermore, within each group of patients undergoing either the medial or inferior pedicle technique, the amount of breast tissue removed did not correlate with postoperative sensory outcomes.

Computer-assisted quantitative neurosensory testing is a highly accurate technique for measuring sensibility. The use of this technology demonstrates a 10-fold difference in measurable sensory thresholds in normal patients from preexisting data using Semmes-Weinstein monofilaments. Advances in measurement methods have allowed the authors to compare postoperative sensory outcomes reliably using two popular techniques of reduction mammaplasty. (*Plast. Reconstr. Surg.* 109: 2283, 2002.)

Previous studies of breast sensibility after reduction mammaplasty have used various testing modalities, including light touch, cotton-wool, pin-prick, two-point discrimination, pain perception to electrical currents, and the Semmes-Weinstein monofilament test. As one might expect, the ability to discern postoperative sensory changes has been limited by the technology used to perform these studies. A review of the most recent literature on normal breast sensibility using Semmes-Weinstein nylon monofilaments yields data varying by a magnitude that exceeds 10-fold.[1–4] Conflicting

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conclusions have also been drawn regarding the regions of the breast that are most sensitive and whether breast size influences sensation.

Computer-assisted quantitative neurosensory testing represents a significant advance in our ability to perform continuous measurements of both one and two-point static and moving pressure thresholds. Semmes-Weinstein nylon monofilaments, which were introduced in 1960, provide only an estimate of the range of cutaneous pressure thresholds, not a true measurement of that threshold. Each rod is manufactured to a graded diameter and calibrated to deliver a given force until the filament bends. The markings are logarithmic values, and thus they cannot be directly added and divided for statistical testing. Instead, they must be first converted to force or pressure values. The requirement for this conversion has been unrecognized in previously published studies of breast sensibility.[5] There is no way to recalibrate monofilaments or to ensure the reliability or accuracy of their measurements, especially after frequent use or when using older sets. Other limitations to the use of nylon monofilaments include the inability to measure fast-adapting receptors (Pacinian and Meissner corpuscles), which adapt rapidly to touch stimulus, and innervation density, which is best measured by two-point discrimination.

With the development of the Pressure-Specified Sensory Device (Sensory Management Services, Baltimore, Md.), a computer-assisted instrument that uses a hemispheric probe attached to a force transducer, continuous measurements of cutaneous pressure are possible. This allows for one-point static (Merkel cell-neurite complexes, Ruffini complexes), one-point moving (Pacinian and Meissner corpuscles), and moving and static two-point (innervation density) discrimination. Furthermore, recalibration of the instrument is performed with each new test on a patient, thus ensuring the reliability and accuracy of data.[6]

In the present study, we established normative data for breast sensibility of the nipple-areola complex using the Pressure-Specified Sensory Device in women with varying breast sizes. The Pressure-Specified Sensory Device was used to test the hypothesis that sensation within the nipple-areola complex decreases with increasing breast size. In addition, breast sensibility was compared in a series of 17 women who underwent reduction mammaplasty by either inferior or medial pedicle techniques at an average follow-up of 2 years. The vertical, inferiorly based, single dermal flap technique of reduction mammaplasty was introduced by Robbins[7] and Courtiss and Goldwyn[8] in 1977 and has since become a popular approach for reduction mammaplasty. The introduction of the medial pedicle technique has recently been described as a superior alternative to breast amputation with free nipple grafting for severe mammary hypertrophy.[9] For these groups, the Pressure-Specified Sensory Device was used to test the hypothesis that breast sensibility would be equally maintained because of the dual (medial and lateral) innervation of the nipple-areola complex.

Patients and Methods

Part I: Groups I and II (Normative Controls)

A total of 17 women presenting to a general plastic surgery clinic agreed to undergo a 1-hour breast sensory examination. The average age of participants was 35 years (range, 19 to 69 years; standard deviation, 14 years). Breast size among participants ranged from 34A to 46EE. Nine women enrolled in the study had breast sizes ranging from 34A to 36C (group I; 18 breasts), and eight women in the study had breast sizes ranging from 36DD to 46EE (group II; 16 breasts).

Part II: After Reduction Mammaplasty by Inferior Pedicle (Group III) and Medial Pedicle (Group IV) Techniques

A total of 17 women who underwent reduction mammaplasty by either the inferior pedicle technique (eight patients; 16 breasts) or medial pedicle technique (nine patients; 17 breasts) were studied. All operations were performed by an author of this study (M.Y.N.). One woman who underwent a unilateral medial pedicle reduction also had a contralateral mastectomy with implant placement at the time of surgery. Preoperative breast sizes ranged from 36D to 48DDD among study participants. The average duration between surgery and sensory evaluation was exactly 2 years (range, 14 to 46 months). The average age of participants at testing was 35 years (range, 18 to 54 years; standard deviation, 12 years). There were no significant differences in age at testing or in the interval between surgery and testing between the groups of women who underwent reduction mammaplasty by either in-

ferior or medial pedicle techniques. The average weight removed from each breast at the time of surgery was 1.1 kg in the inferior pedicle group (range, 440 to 2500 g) and 1.7 kg in the medial pedicle group (range, 930 to 2500 g).

Sensory Testing

All sensory examinations were performed in the presence of a female chaperone. No financial or other compensation was provided for enrollment in the study. The breast sensory testing protocol was accepted by our institutional review board, and all study subjects gave informed consent for sensory testing to be done. None of the women enrolled in the study had a known history of diabetes, thyroid disorders, collagen vascular disease, alcoholism, pernicious anemia, neurologic impairment, or previous breast surgery. Sensory evaluation was performed in all patients (67 breasts in 34 patients) by one examiner (M.M.M.) using the Pressure-Specified Sensory Device. Patients were seated in a reclining chair with one breast exposed for testing and the other draped with a sheet. Patients were asked to close their eyes so that they could not see the computer screen or the breast being tested. A button linked to the computer was placed in the hand opposite to the breast being tested, and subjects were instructed to press the button to indicate perception of the test stimulus.

The nipple and four quadrants of the areola (superior, inferior, medial, and lateral) were selected as testing sites. At each test site, five readings were recorded. The highest and lowest values were discarded, and the mean of the remaining three was reported as the pressure threshold in grams per square millimeter. One and two-point static and one-point moving pressure perception thresholds were measured within a continuous range of 0.1 g/mm^2 to 100 g/mm^2. Static two-point discrimination was performed as described by standard testing protocols.[10] A correct answer required that the button be pushed when two points were discriminated and a two-point stimulus was actually given. Data were entered into an Excel spreadsheet (Microsoft Corp, Redmond, Wash.). Statistical analyses were performed to compare the one-point moving and static and two-point static sensibility measurements between groups I and II and between groups III and IV using a two-tailed Student's *t* test. Data for each of a subject's breasts were treated independently for purposes of statistical analysis. The standard error (standard deviation divided by the square root of the sample size) was determined for tests within each group of patients.

RESULTS

Cutaneous pressure threshold values for the nipple-areola complex were determined for study participants in all groups (Tables I and II). There were no statistically significant differences in values between the four areolar quadrants by single-factor analysis of variance for each group for one-point moving and static tests; therefore, values for all four quadrants of the areola were averaged ($p > 0.65$ for each test). Women with breast cup sizes ranging from 34A to 36C (group I) were uniformly found to have the most sensitive breasts with respect to static and moving one-point sensation in the nipple-areola complex (Table I). In women with gigantomastia, which was defined by our study as breast cup size 36DD or greater (group II), mean cutaneous sensory thresholds were at least 10 times greater than those of group I study participants for static and moving one-point studies. This was statistically significant ($p < 0.02$) for all tests except for the one-point moving test at the nipple ($p = 0.11$). In patients in groups I and II, the mean cutaneous pressure thresholds at the nipple were significantly smaller than thresholds at the areola ($p < 0.002$, two-tailed paired Student's *t* test). The mean nipple pressure thresholds were found to be approximately half of the mean areolar thresholds for each test within each group. Two-point discrimination was assessed at the nipple and was considered intact if the study participant was capable of discriminating two points separated by any distance up to the diameter of the nipple at a cutaneous pressure threshold of 100 g/mm^2 or less. In no case was the nipple diameter found to be

TABLE I

Mean Cutaneous Measurements in Groups I and II

Site and Type of Examination	Group I ($n = 9$)	Group II ($n = 8$)	*p*
Nipple: one-point moving	0.40 (0.02)	4.54 (2.72)	0.11
Nipple: one-point static	0.65 (0.08)	10.2 (4.31)	0.02
Areola: one-point moving	0.80 (0.10)	8.15 (3.43)	0.01
Areola: one-point static	2.04 (0.30)	21.37 (7.29)	0.01

Values are expressed as mean (standard error) and are in g/mm^2. Group I included women with breast sizes of 34A to 36C; group II included women with breast sizes of 36DD to 46EE.

TABLE II
Mean Cutaneous Measurements in Groups III and IV

Site and Type of Examination	Group III ($n = 8$)	Group IV ($n = 9$)	p
Nipple: one-point moving	1.47 (1.72)	5.36 (2.09)	0.10
Nipple: one-point static	4.47 (2.00)	13.34 (5.40)	0.14
Areola: one-point moving	4.87 (2.37)	8.29 (2.49)	0.25
Areola: one-point static	14.79 (4.15)	22.99 (5.71)	0.26

Values are expressed as mean (standard error) and are in g/mm^2. Group III included patients who underwent the inferior pedicle technique; group IV, those who underwent the medial pedicle technique.

greater than 12 mm. In eight patients in group I ($n = 9$) and one patient in group II ($n = 8$), two-point discrimination was intact. This difference was statistically significant according to a two-tailed Fisher's exact test ($p < 0.005$).

In comparing study participants who had undergone reduction mammaplasty by the inferior pedicle technique (group III) and the medial pedicle technique (group IV), and untreated women with gigantomastia (group II), no statistically significant sensory differences were found using analysis of variance ($p \geq 0.33$ for each test; Table II). Although mean cutaneous pressure thresholds were lower in group III patients, as seen in Table II, variance within each group was large enough to negate statistical significance. Two-point discrimination at the nipple was intact in four patients in group III ($n = 8$) and in two patients in group IV ($n = 9$; $p = 0.33$). Finally, a regression analysis comparing sensory thresholds to mass of tissue removed was performed on study participants within groups III and IV. No correlation was found between sensory outcome (static and moving one-point studies at the nipple and areola) and mass of tissue removed ($r^2 < 0.1$ for all cases).

Discussion

This study represents the first quantitative sensibility analysis comparing postoperative sensation after medial and inferior pedicle techniques of reduction mammaplasty. Furthermore, advances in computer-assisted neurosensory testing technology have been integral to the discovery of accurate data on cutaneous pressure thresholds for the nipple-areola complex.

Precise anatomic studies have previously elucidated the dual innervation of the nipple-areola complex medially and laterally from cutaneous branches of the third through sixth intercostal nerves.[11,12] The dominant nerve supply to the breast from the fourth intercostal nerve pierces the serratus anterior muscle at the midaxillary line and travels along the serratus fascia to the lateral border of the pectoralis muscle. A lateral cutaneous branch and an anterior cutaneous branch innervate the nipple-areola complex inferolaterally and medially. Jaspars et al.[13] found that neither the medial or lateral branch seems dominant in size, which likely explains why sensation to the nipple and areola is preserved using both medial and inferior pedicle techniques.

Courtiss and Goldwyn's[14] landmark study of breast sensation in 1976 measured sensory outcomes by crude touch and with a device designed to elicit pain. They concluded from tests in more than 300 women that breast sensitivity was inversely proportional to breast size and that the nipple was the least sensitive region of the breast. Furthermore, they found that sensory changes after reduction mammaplasty reflected the amount of tissue resected rather than the method of resection. At 2 years after surgery, they found that 65 percent of women regained sensation after reduction mammaplasty when various pedicle techniques were used. Presumably, the remaining 35 percent of patients were largely insensate after surgery.

Sensory studies of the normal breast using Semmes-Weinstein monofilaments have yielded conflicting results. Unlike Courtiss and Goldwyn,[14] who found that the nipple was the least sensitive region of the breast, other studies have demonstrated that the nipple is the most sensitive region of the breast.[1–4] Unfortunately, despite the standardization of techniques used for sensory measurements in these investigations, normal sensation for the nipple-areola complex in the small to medium-sized breast has been stated to range from 2.7 g/mm^2 to 28.5 g/mm^2. No previously published studies of breast sensibility have found similar sensory thresholds within the nipple-areola complex. The inconsistency of these findings is probably due to measurement errors arising from the Semmes-Weinstein test itself.[15]

The poor testing reproducibility associated with the Semmes-Weinstein test, which results in interobserver variability as high as a factor of 10, is generally attributed to several engineering flaws, including careless application of the device; variations in the elastic modulus associated with age, temperature, and humidity; and design variation by manufacturers.[16] Unlike the

Semmes-Weinstein test, interobserver correlation using the Pressure-Specified Sensory Device has been found to be excellent (i.e., no significant difference between examiners) when the same patient has been tested by multiple examiners. In controlled studies of normal and nerve-impaired patients, a poor correlation has been found between the measurement of pressure obtained with the Pressure-Specified Sensory Device and Semmes-Weinstein tests.[17]

Using the Pressure-Specified Sensory Device, the mean measurable sensory threshold in small to medium-sized breasts was 0.4 g/mm^2 for fast-adapting receptors (one-point moving) and 0.65 g/mm^2 for slow-adapting receptors (one-point static) at the nipple. These significantly lower sensory thresholds, in contradistinction to previously published values, are comparable to normal values for the index finger using the Pressure-Specified Sensory Device (0.4 g/mm^2 one-point moving; 0.5 g/mm^2 one-point static).[18] Regardless of breast size, the nipple was found have approximately twice the sensitivity of the areola for both slow-adapting and fast-adapting sensory receptors, as measured by one-point static and moving tests.

The inverse relationship between breast size and sensitivity that has been noted by others was confirmed by our study. In fact, women with gigantomastia (36DD cup size or greater) were found to have a greater than 10-fold decrease in sensitivity within the nipple-areola complex compared with women with small to medium-sized breasts (34A to 36C cup size). Because two-point discrimination was largely found to be intact at the nipple in women with small to medium-sized breasts and absent in women with gigantomastia, this inverse relationship may be partly related to decreased innervation density resulting from a larger surface area relative to a constant number of nerve fibers. Others have postulated that large and heavy breasts produce a chronic nerve traction injury as a possible cause for the inverse relationship.[3]

No statistically significant differences in sensation were found among study subjects who had undergone reduction mammaplasty by either inferior or medial pedicle techniques or among preoperative control patients with gigantomastia. Mean sensory thresholds were greatest in medial pedicle patients; however, this difference was not found to be significant because of the large variances within each group. Although study participants in inferior and medial pedicle technique groups were well matched with respect to age and length of time since surgery, mass of breast tissue resected was greater among medial pedicle group subjects (1.7 kg versus 1.1 kg); this bias reflects the preference of the author who performed the procedure (M.Y.N.) for the medial pedicle technique for the largest reductions as an alternative to breast amputation with free nipple grafting. No correlation was found with the size of the reduction performed within each group of patients (inferior and medial pedicle groups) and sensory outcomes.

Recent advances in computer-assisted neurosensory testing technology have permitted accurate sensory mapping of the upper and lower extremities for diagnostic purposes. Because of problems inherent to sensory examination using Semmes-Weinstein monofilaments, we have used the Pressure-Specified Sensory Device in our studies of the breast at the nipple-areola complex. This has permitted us to define the range of normal sensation in women with small to large breasts and to compare sensory outcomes using two different pedicle-based techniques of reduction mammaplasty that rely on different sources of innervation. Future studies are needed to examine other surgical procedures of the breast, such as augmentation mammaplasty, in which differences in technique may have an impact on the maintenance of sensation to the nipple-areola complex.

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