Original Study

How to Assess Sensory Recovery After Breast Reconstruction Surgery?

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Abstract

Clinical sensory examination was compared with quantitative neurophysiologic, psychophysical, and neuropathological tests in assessing sensory alterations in breasts reconstructed with innervated free flaps in breast cancer patients. Clinical examination was insensitive, whereas quantitative methods could confirm postoperative nerve injury after mastectomy and breast reconstruction. Psychophysical tests best identified sensory regeneration. Neurophysiologic and neuropathological investigations revealed differences between surgical techniques.

Background: We evaluated clinical against psychophysical (tactile and thermal quantitative sensory test [QST]), neurophysiologic (somatosensory evoked potential [SEP]), and epithelial nerve fiber density (ENFD) examinations in detection and follow-up of sensory alterations after breast reconstruction done with or without nerve anastomoses. **Patients and Methods:** In a prospective 2-year follow-up design, 56 breast cancer patients underwent innervated and 20 patients noninnervated free rectus abdominis muscle-sparing flap (ms-TRAM) breast reconstruction. Healthy contralateral breasts (36 patients) and 20 healthy volunteer women served as control participants. The diagnostic values of clinical examination, QST, SEP, and ENFD tests were assessed at baseline, and 1 and 2 years postoperatively. **Results:** Sensation of mastectomized thoracic skin was impaired before reconstruction surgery, confirmed with QST ($P < .001$ for tactile, warm and cool detection; others not significant). All tests were further impaired at 1 year ($P < .012$-$.0001$), but mostly showed improvement during subsequent follow-up ($P < .001$-$.0001$), except for vibration and 2-point discrimination, ENFD, and SEP. QST improved diagnostic accuracy for large as well as small fiber function performing best in assessing sensory recovery at 2 years. Of clinical tests, sharp-blunt discrimination was modestly useful (sensitivity, 0.85; poor specificity, 0.17). Two-point and vibration discrimination tests had poor diagnostic values. SEP recording was modestly sensitive (0.50), but not specific (0.25). Because of sparse epithelial innervation already at baseline, ENFD performed poorly. **Conclusion:** Most tests could identify sensory nerve damage postoperatively. Tactile and thermal QST were most reliable, and sensitive also in confirming sensory recovery. SEP recording was useful especially in differentiating surgical techniques, whereas ENFD and clinical examination performed poorly, with the exception of sharp-blunt discrimination.

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Introduction

Nerve regeneration and sensory recovery are key determinants in the outcome of breast reconstruction surgery involving nerve injury and possible nerve repair.[1] After nerve injury, sensory recovery might occur either via collateral reinnervation from the neighboring areas, or via axonal regeneration if the neural tube is preserved or reconstructed with neurorrhaphy. There are scarce objective or quantitative data on the extent and type of sensory regeneration in humans after peripheral nerve injury, although clinical studies have shown that nerve regeneration after hand injuries, for example, depends on the age of the patient, on the mechanism of the injury, and on the degree of axonal injury.[2-4] When severe laceration or nerve transection occurs, neuroma formation normally prevents functionally meaningful axonal reinnervation. Sensory recovery

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might, in fact, occur via collateral sprouting from the neighboring areas even if neural repair surgery is not performed.[3] After neurorrhaphy, nerve regeneration has been suggested to occur as an outgrowth from the proximal stump of the severed nerve over the nerve repair site to the end organ.[5] Thus, axonal reinnervation after nerve repair probably plays a central role in the recovery of sensation in a reconstructed microneurovascular free rectus abdominis muscle-sparing flap (ms-TRAM) breast.[6] Some studies also indicate that radiation therapy might compromise sensory recovery after breast cancer surgery.[7] Data on autologous microneurovascular tissue grafts and their effects on sensory recovery are scant.[8]

For adequate sensory function, all sensory modalities are required, but there is no detailed information available on how tactile, vibratory, thermal, and noxious information is transmitted from a reconstructed breast. Tactile functions mediated via large myelinated A-β fibers are most often assessed in clinical examination. However, it is especially important for the patient that the breast regains protective heat and mechanical pain detection, mediated via small A-δ and C fibers.[9] Most (75%) of the nerve fibers in cutaneous nerves are small A-δ and C fibers, and their damage can be diagnosed and quantitated using thermal quantitative sensory test (QST) or by assessing the epithelial nerve fiber density (ENFD) in skin biopsies.[10] These specific tests have not been previously applied to investigate the extent to which small A-δ and C fibers are damaged and how they recover after TRAM breast reconstruction, or whether surgical neurorrhaphy techniques might have an effect on the regeneration of different sensory fibers.

Breast reconstruction surgery offers a convenient human model for a detailed study of sensory regeneration regarding different sensory modalities. Furthermore, surgery-related and patient-specific factors influencing sensory recovery can be evaluated in this model quantitatively with neurophysiological, psychophysical, and neuropathological methods. We have previously developed novel microsurgical nerve repair techniques that, on the basis of clinical examination and QST, seem to enhance sensory recovery after breast reconstruction surgery.[6] However, clinical sensory examination or even QST might be too inaccurate to reveal potential differences in the sensory outcomes associated with different types of surgery.[11,12]

The purpose of the present study was to compare the accuracy and usefulness of qualitative clinical examination as well as tactile and thermal QST with the more objective neurophysiological (somatosensory evoked potential [SEP]) and neuropathological (ENFD) methods in the diagnosis and follow-up of recovery of sensory nerve injury after mastectomy and breast reconstruction surgery. The surgical model applied was breast reconstruction either with an innervated free transverse rectus abdominis muscle-sparing flap (neuro ms-TRAM, either with single or dual neurorrhaphy) or with a free flap without nerve repair (ms-TRAM). In addition, we investigated whether the different sensory nerve fibers recover at the same rate and to the same extent, and whether the surgical technique has any effect on the recovery of different sensory modalities.

Patients and Methods

This study was approved by the ethical committee of Savonlinna Central Hospital, and all patients gave their written informed consent to participate in the study.

Seventy-two breast reconstructions were performed by applying the single or dual neurorrhaphy technique (neuro ms-TRAM) on breast cancer patients at Savonlinna Central Hospital in a prospective study between January 2006 and May 2013. Figure 1 shows the recruitment process of the 56 patients included in the present follow-up study. A subgroup of ms-TRAM patients without neurorrhaphy (ms-TRAM; n = 20) from a previously published retrospective group[7] was included to enable comparison of 2 surgical techniques, namely that with delayed dual neurorrhaphy (38 patients) and that with no nerve repair on the reconstructed breast (Figure 1). Single neurorrhaphy (8 patients) and immediate reconstruction (10 patients) groups were excluded from this comparison of surgical techniques because of the low number of patients and because on the immediately reconstructed breast, sensory measurements had been performed on the spared mastectomized skin rather than the skin of the ms-TRAM flap. Forty-six patients underwent delayed breast reconstruction (delayed neuro ms-TRAM).

The prospectively and the retrospectively studied patient groups were equal in age, adjuvant therapy of breast cancer, and the size of the flap, whereas the retrospective ms-TRAM group had a longer follow-up period (mean 54 months, range 27-77) than the other groups. The average of surgery time in the prospective neurorrhaphy group was 27.5 minutes longer than in the retrospective group with no neurorrhaphy.

Contralateral healthy breasts of 36 breast cancer patients and the sensitivity of intact scar-free abdominal skin of 20 healthy volunteer women were tested and used for calculation of the reference values to assess the normality of the test results (Table 1). Clinical sensory tests (vibration, static 2-point, and sharp-blunt discrimination tests), and QSTs for tactile (TDT), and thermal sensory modalities (warm detection [WDT], cool detection [CDT] thresholds), were performed on the skin of the healthy breast, the mastectomized chest skin, the ms-TRAM breast, the neuro ms-TRAM breast, and the healthy abdominal skin. In addition, SEPs were recorded on healthy, ms-TRAM and neuro ms-TRAM breasts. Skin biopsy for the examination of ENFD and subepithelial nerve endings (SENFD) was obtained from the abdominal skin during the reconstruction procedure as well as from the ms-TRAM and neuro ms-TRAM breast during follow-up.

Surgery

The surgical technique for neuro ms-TRAM flap reconstruction is described in detail in our previous publication.[6] The neuro ms-TRAM flap was dissected transversally with a small piece of rectus muscle around the vascular and nerve perforators. The vascular pedicle of the inferior epigastric vessel in the flap was anastomosed to inferior mammary vessels, except for the retrospective study, where it was anastomosed into the thoracodorsal vessel pedicle. One of the 3 lowest intercostal nerves (10th-12th) was dissected on 1 side (single neuro ms-TRAM) or both sides (dual neuro ms-TRAM) of the flap and connected medially to the third or fourth intercostal nerve in the chest and laterally to axillary nerves, most often to the intercostobrachial nerve. Figure 2 shows a preoperative plan for a dual neurorrhaphy in ms-TRAM flap. The nerve coaptation of the neuro ms-TRAM flap was performed in an end-to-end or end-to-side fashion using 3 perineural sutures (9/0 Dafilon, DRn5needle,