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ORIGINAL ARTICLE

The effect of lateral pectoral nerve sparing technique and radiotherapy on the pectoralis major muscle applied with modified radical mastectomy

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Summary *Background/Objective:* The aim of this study was to evaluate with electromyography (EMG) the effect of lateral pectoral nerve sparing technique (LPNST) and radiotherapy (RT) on the lateral pectoral nerve (LPN) in patients applied with modified radical mastectomy (MRM).

Methods: The study included 66 patients who underwent MRM surgery. The patients were separated into 2 groups as those applied with LPNST and those who underwent standard surgery (Control group). Within these 2 groups, patients were again separated as those who received or did not receive RT. The EMG evaluations were made by a neurology specialist blinded to the patient groups.

Results: The mean age of the patients was 53.3 ± 10.6 years. Standard surgery was applied to 33 (50%) patients and LPNST to 33 (50%) patients, RT was applied to 32 (48.5%) patients and not to 34 (51.5%) patients. In the EMG evaluation, latency was 2.1 ms (1.4–3.2) in the LPNST and 3.7 ms (1.9–12.4) in the control *($p < 0.001$)* and amplitude values were 9650 mV (3120–36900) in the LPNST and 4780 mV (510–12.4) in the control *($p < 0.001$)*. The latency values in the

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Control receiving and not receiving RT were 4.0 ms (1.9—12.4) and 2.6 ms (1.9—6.2) respectively *($p < 0.05$)*. The latency values of the patients receiving and not receiving RT in the LPNST were 2.2 ms (1.8—3.2) and 2.0 ms (1.4—2.4) respectively *($p < 0.05$)*. In the Control and LPNST Group, no significant difference was determined between receiving and not receiving RT groups in respect of amplitude values *($p > 0.05$)*.

Conclusion: The results of this study demonstrated that electromyographically the latency and amplitude values were better protected in the LPNST group. It was also seen that RT increased the formation of nerve damage in both groups.

1. Introduction

Although there are ongoing changes and developments in the surgical methods for breast cancer, this is still a significant area of research and debate. Preservation of the pectoral major muscle (PMM) first started to be debated with the publication of studies in the 1980s of radical (Halsted) mastectomy as an extensive surgical approach.[1] With the addition to treatment protocols of radiotherapy since 2000, neoadjuvant/adjuvant systemic chemotherapies and hormonotherapies have effectively provided similar survival results and acceptable local recurrence rates and this has brought about a change in surgical preferences. These preferences have developed primarily from radical mastectomy to MRM and from MRM for early stage breast cancer to breast -sparing and oncoplastic breast surgery techniques.[2,3] In recent years in particular, due to the Sentinel Lymph Node Biopsy (SLNB) technique which has proven efficacy, it has been attempted to reduce the surgical morbidity associated with axillary lymph node dissection (ALND).[4]

Although there is increasing use of breast-sparing surgery and oncoplastic breast surgery techniques, MRM remains an important option in the surgical treatment of breast cancer. With local regional and systemic treatments applied together with surgical treatment, clinicians have attempted to reduce local recurrence rates, increase survival rates and protect all bodily functions. Modified surgical techniques that are applied and the protection of the pectoral muscles are important for the preservation of the chest anatomy, shoulder and arm movements and for cosmesis of the body.

In ALND applied during MRM, medial retraction of the PMM is necessary as a technique to provide sufficient visualisation of the axillary layer. To preserve the integrity of the PMM during axillary dissection, protection of the medial pectoral nerve (MPN) and lateral pectoral nerve (LPN) is necessary. The LPN is formed of nerve branches originating from the brachial plexus lateral cord or the upper and mid trunk.[5,6] The LPN passes anterior to the first section of the axillary artery and branches to the MPN. The MPN innervates the clavicular and sternal sections of the PMM while the LPN innervates the costa—abdominal junction of the muscle and the lower third section.[7] Protection of the pectoral nerves during surgery with the careful axillary dissection technique protects the PMM from morbidity as much as possible and provides reduced loss of muscle mass and activity.[5,8] When these nerves are damaged, fibrosis and atrophy of the PMM are seen, reduced muscle volume, restricted shoulder movements and impairments to the structure of the chest wall.[7—9] Muscle losses described after ALND in particular have shown similar reductions in volume and function in chest wall muscles with various radiological evaluations.[10]

Generalised activity loss of the shoulder muscles is primarily associated with RT and surgery in locoregional treatments of breast cancer.[11,12] During all breast and axillary treatments, normal organs such as the lungs and heart may be affected as they are unavoidably areas of uptake in the high dosage region.[13] Although early toxicity often forms in the skin, it is temporary and clinically insignificant. Late toxicity forms in tangential areas such as the lungs and heart and is clinically significant.[14] The fibrosis-forming effect of RT in soft tissues is associated with morbidities such as arm oedema, brachial plexopathy and restricted shoulder movements.[15]

The aim of this study was to evaluate with electromyography (EMG) the effect of lateral pectoral nerve sparing technique (LPNST) and RT on the lateral pectoral nerve in patients applied with MRM.

2. Material and method

Approval for the study was granted by the Local Ethics Committee. The study included a total of 66 patients who underwent MRM in the department of general surgery of our hospital for a diagnosis of breast cancer. Standard level II axillary dissection was applied protecting the pectoralis minor muscle. The patients were divided into 2 groups as LPNST group and standard axillary dissection (control) group. Within these 2 groups, patients were again separated as those who received or did not receive RT. In the LPNST group, patients were informed of the study and were operated on by the breast surgery unit and the control group was formed of patients unaware of the study who were operated on by breast surgeons. In the LPNST group, the LPN was preserved as we called the LPN Sparing Technique and as described below. In the application of careful nerve dissection together with the surgical treatment of patients, the MPN, LPN, thoracicus longus and thoraco dorsalis nerve were protected. The patients receiving RT in both groups received standard RT at a dose of 50 Gy in a

total of 25 fractions, 5 days per week. Patients thought to have nerve damage during surgery or determined with tumoral invasion to the nerve were excluded from the study. In addition, patients applied with level III dissection, those with resected pectoralis minor muscle and those applied with partial muscle resection to provide sufficient surgical nerve were excluded from the study.

The EMG evaluations were performed by a neurology specialist blinded to the groups. Informed consent forms were obtained for the EMG. A Nihon Kohden MEB-9200K electromyography device was used in the electrophysiological examinations. EMG was applied to the affected upper extremity of patients applied with mastectomy and postoperative RT. For LPN transmission, the latency and amplitude values were recorded from the PMM by stimulating the Erb region with a concentric needle electrode (Fig. 1) and then the needle EMG of the PMM was studied. EMG evaluation was applied at least 3 weeks after the operation for those who did not receive RT and at least 3 weeks after the end of treatment for the group that received RT.

2.1. LPN sparing technique

During routine axillary dissection when interpectoral space was visualized, we can see the pectoral branch of thoracoacromial artery and most likely the LPN just emerged from the brachial plexus in the cranial part of this area. LPN is generally placed near to the thoracoacromial artery and approximately three to four fingers away from the lateral border of sternum. When we see the pectoral branch of thoracoacromial artery or LPN itself on the upper part of interpectoral space, we control the unusual placement of the lymphadenopathy by finger palpation behind this point. If there isn't any palpable lymphadenopathy, we continue the dissection of interpectoral space in the downward direction which will ultimately protect the iatrogenic damage of the LPN. We called this technique, the LPN Sparing Technique.

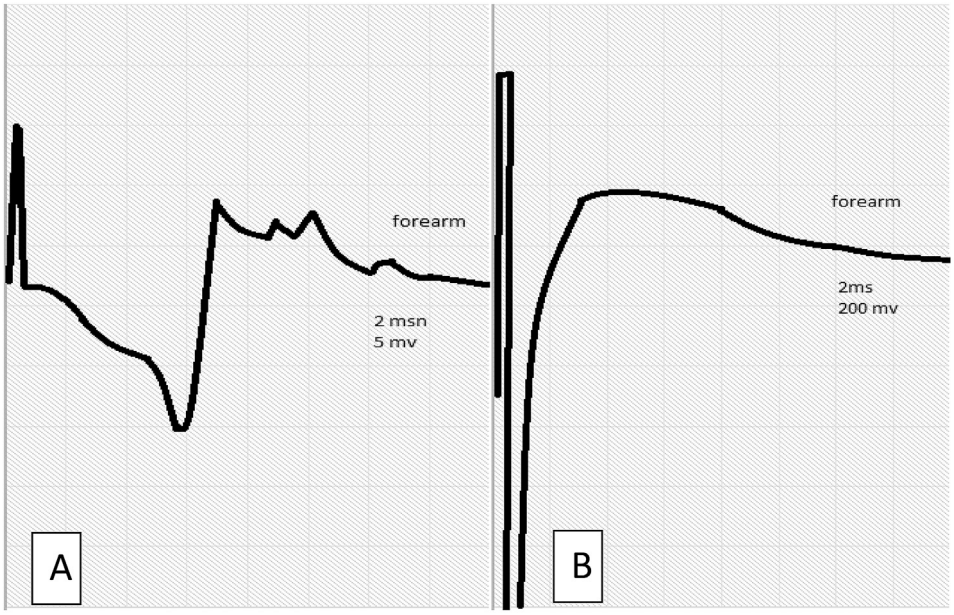
2.2. Statistical analysis

Statistical analyses were performed using IBM SPSS for Windows Version 22.0 software. Numerical variables were stated as mean $\pm$ standard deviation (SD) and median (minimum—maximum) values and categorical variables as number (n) and percentage (%). Conformity of the data to normal distribution was examined with the Kolmogorov—Smirnov test. To determine whether or not there was a difference between two groups in respect of numerical variables, the Mann Whitney U-test was applied. Differences between categorical variables were determined with the Chi-square test. A value of $p < 0.05$ was accepted as statistically significant.

3. Results

The mean age of the 66 patients included in the study was 53.3 $\pm$ 10.6 years. Standard surgery was applied to 33 (50%) patients and LPNST to 33 (50%) patients, RT was applied to 32 (48.5%) patients and not to 34 (51.5%) patients. The demographic data of all the patients, latency and amplitude values are shown in Table 1.

In the EMG evaluation, latency was 2.1 ms (1.4—3.2) in the LPNST group and 3.7 ms (1.9—12.4) in the control group



a) LPNST -RT (-)

(Latency and amplitude in normal nerves)

b) Standard axillary dissection RT (+)

(Latency prolonged, amplitude diminished)

Figure 1 EMG trace of the PM muscle of 2 patients from 2 different (x axis:latency ms, y axis:amplitude mV).

Table 1 Demographic data of the patients and group information (n = 66).

		Number (n)	Percentage (%)
Side	Right	32	48.5
	Left	34	51.5
Chemotherapy	Absent	14	21.2
	Present	52	78.8
Radiotherapy	Absent	34	51.5
	Present	32	48.5
Nerve-sparing status	LPNST	33	50.0
	Standard axillary dissection (control)	33	50.0
Nerve-sparing—RT	LPNST -RT (-)	18	27.3
	LPNST -RT (+)	15	22.7
	Control group - RT (-)	16	24.2
	Control group - RT (+)	17	25.8
		Mean ± SD	**Median [Min-Max]**
Age (year)		53.3 ± 10.6	52 [29—77]
Latency (ms)		3.2 ± 2.0	2.5 [1.4—12.4]
Amplitude (mV)		7801 ± 5876	6475 [510—36900]
Postoperative period (month)		29.0 ± 26	23 [1—102]

LPNST: Lateral Pectoral Nerve Sparing Technique; RT: Radiotherapy

and amplitude values were 9650 mV (3120—36900) in the LPNST group and 4780 mV (510—12.4) in the control group. The difference between the groups was determined as statistically significant in both parameters ($p < 0.001$) (Table 2). The latency values of the patients applied with LPNST were seen to be lower than those of the control group and the amplitude values were higher. In both groups the patient age, time since operation and chemotherapy intake values were similar (Table 2).

The latency values in the groups receiving and not receiving RT were 4.0 ms (1.9—12.4) and 2.6 ms (1.9—6.2) respectively and the difference was statistically significant ($p < 0.05$) (Table 3). In the group applied with standard axillary dissection, although the amplitude values of the patients who received RT were lower at 3850 mV (510—8010) than the 5210 mV (1000—16410) values of those who did not receive RT, no statistically significant difference was determined ($p = 0.245$) (Table 3).

The latency values of the patients receiving and not receiving RT in the LPNST group were 2.2 ms (1.8—3.2) and 2.0 ms (1.4—2.4) and the difference was statistically significant ($p < 0.05$) (Table 3). Although the amplitude values of the patients who received RT in the LPNST group were higher than those who did not receive RT (9650 mV [3120—12850] vs 9400 mV [4390—36900]), no statistically significant difference was determined ($p = 0.135$) (Table 3).

4. Discussion

The significant finding of this study is that it was shown electrophysiologically that damage could have formed in the pectoral nerve when the LPN was not protected with the LPNST in breast cancer surgery. That a statistically significant difference was determined in the combined muscle action potential amplitude and latency in the pectoral nerve transmission study between the group applied with LPN-sparing surgery and the control group and that neurogenic changes were seen in the needle EMG, led to the conclusion that there was partial axonal degeneration in the nerve. In patients determined with clinical atrophy in the PMM, there was found to be a correlation with the electrophysiological findings. The statistically significant effect on the nerve in the group applied with standard surgery and RT demonstrated the superiority of the use of nerve-sparing surgical techniques over standard surgery. Furthermore, the application of RT was seen to increase the formation of damage in the nerve in both the LPNST group and the control group applied with standard surgery. Therefore in patients for whom it is necessary to have RT, the careful selection of the surgery technique becomes important in respect of preventing an increase in possible damage to the pectoral nerve. These results suggested that the basis of PMM atrophy after mastectomy or RT could be associated with damage to the pectoral nerves.

Apart from transection, nerve damage during surgery can occur related to various factors such as excessive traction of the nerve, damage caused during dissection or thermal damage associated with the close use of electrocautery. In the diagnosis of denervated muscles, electromyography is useful. In electromyographic examinations, nerve transmission studies and needle EMG examination are the most valuable methods that objectively determine the

Table 2 Comparison of the lateral pectoral nerve sparing technique group with the standard axillary dissection group.

	Lateral Pectoral Nerve Sparing Technique Group (n = 33)	Standard Axillary Dissection Control Group (n = 33)	*p*
Latency (ms)	3.7 [1.9—12.4]	2.1 [1.4—3.2]	<0.001
Amplitude (mV)	4780 [510—16410]	9650 [3120—36900]	<0.001
CT (+)	24 (72.7%)	28 (84.8%)	0.366
RT (+)	17 (51.5%)	15 (45.5%)	0.805
Age (year)	52.6 ± 11.6	54.0 ± 9.6	0.581
Postoperative period (month)	29.6 [1—90]	17 [1—102]	0.386

Table 3 Comparison of the lateral pectoral nerve sparing technique group with the standard axillary dissection group in respect of RT.

Control Group	RT (-) (n = 16)	RT (+) (n = 17)	*p*
Latency (ms)	2.6 [1.9–6.2]	4.0 [1.9–12.4]	0.012
Amplitude (mV)	5210 [1000–16410]	3850 [510–8010]	0.245
Age (year)	54.4 ± 12.4	50.8 ± 11.0	0.381
Postoperative period (month)	23 [1–66]	27 [7–90]	0.260
Lateral Pectoral Nerve Sparing Technique Group	**RT (-) (n = 18)**	**RT (+) (n = 15)**	***p***
Latency (ms)	2.0 [1.4–2.4]	2.2 [1.8–3.2]	0.002
Amplitude (mV)	9400 [4390–36900]	9650 [3120–12850]	0.135
Age (year)	51.5 ± 10.3	57.1 ± 7.9	0.097
Postoperative period (month)	13 [1–102]	27 [7–101]	0.062

localisation, severity and degree of damage occurring in the peripheral nerves.[16] In the current study, damage in the pectoral nerve was shown with EMG in patients with clinical pectoral muscle atrophy.

In the last decade, the desired preservation of thoracic integrity, shoulder movements and quality of life of patients have become a reality with significant technical changes and approaches in breast cancer surgery. When the MPN and LPN are not protected with careful dissection, fibrosis and atrophy develop in the PMM, volume is reduced and shoulder and chest wall integrity is impaired and this situation is opposite in principle to the transfer from radical mastectomy to MRM. When the results of this study are evaluated, the effect of surgical damage to the LPN and PMM can clearly be seen. Taking the latency values defined with EMG into account, RT was seen to have partially impaired PMM functions in both groups. Goncalves et al showed that there was a significant reduction in PMM strength with the cutting of the MPN during mastectomy.[9] When the nerves innervating the pectoral muscles are not protected, the muscle losses that form lead to significant morbidity and functional losses.

The ionisation effect of RT is known to create destruction in tissues. Brachial plexitis is an uncommon cause of shoulder pain. Following RT of the brachial plexus, there is a reduction in repair capability against moderate severity recurrent traumas and this can be explained with hypotheses that this could be related to the cumulative effect of these over the years. Neural fibrosis, tension in the endoneurium, demyelinisation and narrowing in the small vessels that feed the plexus have been reported in the pathology of the event.[17,18] Weakness in the arm, paresthesia, hypoesthesia, a reduction in deep tendon reflexes and pain are important symptoms. The evident effect of RT on the nerve and especially chronic effects occur in the long term such as over several years.[19] In the current study, the effect of RT on the LPN was examined in the early stage. No severe paresthesia or brachial plexopathy were seen clinically or electrophysiologically as RT complications. To be able to observe the long-term effect of RT, which has been described in literature, it may be productive to examine the current study patient groups again with EMG in the long term.

The expected complication rates have been reported to be significantly reduced with the SLNB technique compared to ALND.[20] However, significant nerve damage and hypoesthesia leading to complications may still be seen with the SLNB technique.[21,22] Nerve damage may be overlooked by clinicians and may be suppressed by pain symptoms. Nerve damage resulting in a wing scapula has been determined at 8% after ALND and as 2.9% after SLNB.[23] Despite developments and changes in surgical techniques, nerve damage which can be overlooked constitutes a significant problem. In the current study, evaluation with EMG of the early stage effects on peripheral nerves and functional capacity was seen to be useful for breast cancer patients.

In conclusion, knowledge of the anatomy of the axillary region during surgery and especially of the pectoral nerve and protection of these nerves with LPNST during ALND is useful in the preservation of pectoral muscle functions and the prevention of morbidities. To reduce morbidities seen following ALND and SLNB during axillary region surgery, future clinical studies related to dissection together with nerve monitorisation would be useful for the protection of nerves and muscle functions.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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