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What is This?
Spinal Accessory Nerve Monitoring and Clinical Outcome Results of Nerve-Sparing Neck Dissections

Yucel Birinci, MD1, Arzu Genc, PhD2, Mustafa Cenk Ecevit, MD1, Taner Kemal Erdag, MD1, Enis Alpin Guneri, MD, MSc1, Ibrahim Oztura, MD3, Ahmet Evlice, MD3, and Ahmet Omer Ikiz, MD, MSc1

Abstract
Objective. To investigate the role of intraoperative spinal accessory nerve monitoring in predicting postoperative shoulder function in spinal accessory nerve-sparing neck dissections.

Study Design. Prospective, double-blind clinical trial.

Setting. Academic, tertiary care center.

Subjects and Methods. This study was performed on 20 neck sites of 17 consecutive patients who had neck dissections sparing the spinal accessory nerve. Threshold increment ≥0.25 mA and amplitude decrement ≥72% were classified as significant intraoperative neuromonitoring changes while lesser differences were classified as insignificant intraoperative neuromonitoring changes. All patients had intraoperative neuromonitoring recordings when the spinal accessory nerve was first identified and at the end of surgery. Postoperative shoulder function was evaluated neurophysiologically with electromyography and clinically with Constant-Murley Score; daily activity restrictions were evaluated with Activity Restriction Scale.

Results. Clinical assessment of shoulder functions at postoperative first and second months showed statistically significant deteriorations when compared with preoperative values (P < .05). The shoulder function deterioration was statistically significantly less for patients with insignificant intraoperative neuromonitoring changes than patients with significant intraoperative neuromonitoring changes (P < .05). Daily activity restriction deteriorations were present in both groups at first postoperative month (P < .05). While they persisted in the group with significant intraoperative neuromonitoring changes during the second postoperative month (P < .05), there was continuing recovery in the insignificant intraoperative neuromonitoring change group and statistical significance disappeared (P > .05).

Conclusion. Our results support the predictive value of spinal accessory nerve intraoperative neuromonitoring for determining shoulder function deterioration and activity restriction scores.

Keywords
accessory nerve, monitoring, intraoperative, neck dissection, shoulder.

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Introduction

Preserving the spinal accessory nerve (SAN) and maintenance of normal shoulder function is the ultimate goal of modified radical neck dissections (MRND) and selective neck dissections (SND). However, neck dissection–related shoulder disabilities still occur despite preservation of the SAN. This subject has been investigated after SAN-sparing neck dissections in a number of studies.1-7 In some studies, electromyography (EMG) was also included for more detailed evaluation of shoulder function.8-11 In recent years, the use of intraoperative neuromonitoring (IONM) brought a new perspective to these investigations. During IONM it is possible to determine the least electrical stimulation intensity causing the first detectable EMG waveform as well as the amplitude of EMG response for constant stimulus intensity both at the beginning and at the end of the surgery, enabling evaluation of neural function during the operation. To our knowledge, few studies have investigated the clinical correlation of IONM recordings
with postoperative shoulder function in the English literature. Therefore, the aim of our study was to investigate the correlation of IONM results with postoperative shoulder function in patients who had SAN-sparing neck dissections.

**Materials and Methods**

This prospective study was performed at the Dokuz Eylül University Medical Faculty on a total of 20 neck sites (14 unilateral, 3 bilateral neck dissections) of consecutive 17 patients after approval of Dokuz Eylül University Medical Faculty Clinical and Laboratory Investigations Ethics Committee. Fourteen patients had a SAN-sparing superselective/SND and 3 patients had a MRND sparing the SAN, internal jugular vein (IJV), and sternocleidomastoid (SCM) muscle. All patients had planned operations for head and neck malignancies, and all patients gave their informed consent for this investigation. The inclusion criteria were determined as dissection of both IIa and IIb levels without using cautery at minimum and exposure of the SAN from the skull base until its entrance into the SCM muscle. In MRND, the SAN was dissected and preserved until its entrance into the trapezius muscle in level V, in addition to level II. Patients who had preoperative shoulder movement restrictions, in whom the SAN or the SCM muscle was not preserved, or who needed a myocutaneous muscle flap for reconstruction and/or adjuvant radiotherapy were not included in the study ([Figure 1](#fig1)). There were 5 female and 12 male patients with a median age of 55 (range, 49-60) years. Intraoperative SAN neuromonitoring was performed using a NIM-Response 2.0 Nerve Integrity Monitor (Jacksonville, Florida). Subdermal needle electrodes were used as recording electrodes. They were inserted into the trapezius muscle, 5 and 7 cm lateral to the midline at the level of C7, with 2 electrodes for each neck site studied. The ground electrode was placed into the shoulder ([Figure 2](#fig2)).

During neck dissection, the SAN was stimulated when it was first identified, 1 cm proximal to its entrance into the SCM muscle, using a monopolar nerve stimulator. Stimulation was repeated 6 times with 1 milliampere (mA) stimuli, and the amplitudes of the EMG waves obtained from the trapezius muscle were recorded in millivolts (mV). The median of these 6 amplitude values was calculated and recorded. Later, the stimulus threshold was determined using the rise and fall method. The stimulus intensity was increased at 0.1 mA intervals starting from 0 mA until a significant waveform was obtained in the trapezius muscle, then the stimulus amplitude was decreased gradually at 0.1 mA intervals to determine the minimum stimulus intensity producing a visible EMG amplitude. The median of 6 values was also calculated to determine the minimum intensity threshold. At the end of neck dissection, the amplitude and threshold values were also determined using the same methods. A threshold difference ≥0.25 mA between the first and last measurements was considered a significant threshold change ([Figure 3](#fig3)). The maximum stimulus intensity used for SAN stimulation after surgery was 2 mV; in 3 patients in whom a visible EMG wave could not be obtained at this intensity at the end of neck dissection, the stimulus intensity was accepted as 2 mA for statistical analysis. An amplitude difference ≥72% between the first and the last recording with 1 mA stimulus intensity was considered a significant amplitude difference. The groups with significant or insignificant IONM changes were determined according to these cutoff values.

EMG examination was performed 1 month after surgery in all patients at the EMG Laboratory of the Neurology Department using Medelec, Synergy EMG equipment. All tests were performed by the same neurology specialists, who were blinded to IONM results. The M (muscle) response was obtained from the trapezius muscle using the Cherrington method, and motor latency measurements were performed. Using concentric needle electrode recordings, the degree of neurogenic involvement and the presence of spontaneous denervation potentials were investigated. The data were classified into 4 groups as normal, mild neurogenic involvement (MND), partial axonal degeneration (PAD), and total axonal degeneration (TAD).15

![Figure 1. Patient flow diagram.](#fig1)

![Figure 2. Placement of the electrodes.](#fig2)
Clinical evaluation of patients was performed using the Constant-Murley Score (CMS) for shoulder function and the Groningen Activity Restriction Scale (GARS) for daily activity restrictions by the same physiotherapist, who was blinded to the IONM results of the patients. The patients were informed about the planned physiotherapy program, and they were provided with individualized physiotherapy exercise programs according to their personal evaluation results before surgery and follow-up at first and second month after surgery.

CMS is a scale developed specifically for evaluating shoulder function. It consists of 14 main headings that evaluate pain, daily activity restrictions, range of motion, and strength parameters, with a maximum score of 100. The pain and daily activity restrictions are evaluated subjectively, while range of motion and strength are evaluated based on objective measurements. In this scoring system, a greater score indicates better shoulder function.

GARS is a subjective scale evaluating daily activity restrictions covering various different daily activities including, but not limited to, shoulder function. On this scale, daily activity restrictions are classified under 18 headings, and each item is scored between 1 and 5 according to the severity of the experienced disability. The points range between 18 (minimum daily activity restriction) and 90 (maximum daily activity restriction) on this scale. Contrary to the CMS, higher scores indicate a worsening situation and increased daily activity restriction.

**Statistical Analysis**

Analysis of the data was performed using the SPSS 20.0 software by a blinded public health specialist who was blinded to the assessment and treatment of the patients. The Wilcoxon signed-rank test was used for statistical comparisons within the groups, while mixed split ANOVA statistical analysis was used for comparisons between groups. Continuous variables were expressed medians in combination with quartiles and percentiles. Level of significance was set at $P < .05$.

**Results**

Table 1 shows the threshold and amplitude values determined with IONM when the SAN was first identified and at the end of surgery. The EMG investigation performed 1 month after surgery revealed normal EMG results in 1 (5%) shoulder, mild neurogenic involvement in 6 shoulders (30%), partial axonal degeneration in 10 shoulders (50%), and total axonal degeneration in 3 shoulders (15%). The median SAN latency identified by EMG was 3 ms (range, 1.86-4.02 ms, 25th to 75th percentiles). There was no statistically significant difference in shoulder function between the first and second postoperative months in comparison of shoulders with (n = 13) and without (n = 7) axonal degeneration on EMG ($p > .05$).

Clinical evaluation of shoulder function (CMS) at the first and second months postoperatively showed statistically significant deterioration of shoulder function when compared with the preoperative period. The subgroups with and without significant IONM changes (Table 2). Comparison between groups revealed less shoulder function deterioration in the group without significant IONM changes ($p < .05$) (Figure 4 A-B).

**Table 1. The Amplitude and Threshold Values Determined with Intraoperative Neuromonitoring (Expressed as Median and Range Interquartile).**

<table>
<thead>
<tr>
<th></th>
<th>Initial Amplitude (mV)</th>
<th>Postdissection Amplitude (mV)</th>
<th>Initial Threshold (mA)</th>
<th>Postdissection Threshold (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All shoulders (n = 20)</td>
<td>1044 (521-1789)</td>
<td>459 (107-735)</td>
<td>0.15 (0.15-0.25)</td>
<td>0.40 (0.15-1.72)</td>
</tr>
<tr>
<td>The group with amplitude change (n = 8)</td>
<td>1600 (627-2850)</td>
<td>95 (0-723)</td>
<td>0.15 (0.15-0.25)</td>
<td>1.40 (0.31-2.00)</td>
</tr>
<tr>
<td>The group without amplitude change (n = 12)</td>
<td>732 (277-1372)</td>
<td>571 (259-735)</td>
<td>0.15 (0.11-0.27)</td>
<td>0.22 (0.15-0.40)</td>
</tr>
<tr>
<td>The group with threshold difference (n = 9)</td>
<td>694 (531-1829)</td>
<td>87 (0-427)</td>
<td>0.15 (0.15-0.27)</td>
<td>2 (0.65-2)</td>
</tr>
<tr>
<td>The group without threshold difference (n = 11)</td>
<td>1251 (442-1793)</td>
<td>600 (384-836)</td>
<td>0.15 (0.10-0.25)</td>
<td>0.15 (0.15-0.30)</td>
</tr>
</tbody>
</table>

Abbreviations: n, number of shoulders; mV, millivolts; mA, milliampere.
The clinical evaluations performed with activity restriction scores (GARS) indicated that the whole group, including the subgroup with significant IONM changes, had statistically significant activity deteriorations at both the first and second month postoperative evaluations \((P < 0.05)\). In the subgroup without significant IONM changes, statistically significant deterioration \((P < 0.05)\) of activity scores observed after the first postoperative month diminished at the end of the second month, and statistical significance disappeared because of the continuing recovery \((P > 0.05)\) \((\text{Table 3})\).

### Discussion

Shoulder function impairments following neck dissections have been addressed in various investigations. Leipzig et al.\(^3\) performed a prospective study on 109 patients and reported shoulder dysfunction in 30% of the patients when the SAN, the SCM muscle, and the internal jugular vein were all preserved; in 50% of the patients when the SAN was preserved alone; and in 60% of the patients who had a radical neck dissection (RND). Other investigations reported similar results, and it has been shown that postoperative shoulder functions were better for SAN-sparing neck dissections when compared to RND.\(^2,3,8,10\) However, the rates of shoulder dysfunction are conflicting when different types of SAN-sparing neck dissections are taken into consideration. Some studies suggested that SAN damage was greater in MRND when compared to SND.\(^3,8,10\) The reason was suggested to be the longer course of SAN dissection in the posterior triangle of the neck. On the contrary, studies reporting greater SAN damage in SND when compared to MRND claim that cutting the SCM muscle during an early stage of the operation and freeing the nerve from neighboring structures causes less traction on the nerve. Greater traction exerted on the SAN when dissecting the lymphatics surrounding the internal jugular vein, especially during level IIb dissection, is proposed to be the cause of increased nerve damage during SND.\(^9\) The purpose of limiting our study to patients with the SCM muscle preserved and at

<table>
<thead>
<tr>
<th>Table 2. The Comparison of Preoperative, Postoperative First and Second Month Shoulder Functions (Expressed as Median and Range Interquartile).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant Murley Score</strong></td>
</tr>
<tr>
<td>All shoulders (n = 20)</td>
</tr>
<tr>
<td>The group with amplitude change (n = 8)</td>
</tr>
<tr>
<td>The group without amplitude change (n = 12)</td>
</tr>
<tr>
<td>The group with threshold difference (n = 9)</td>
</tr>
<tr>
<td>The group without threshold difference (n = 11)</td>
</tr>
</tbody>
</table>

Abbreviations: Preop, preoperative; postop, postoperative; n, number of shoulders.

\(^a\)Boldface \(P\) values are statistically significant.

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least level IIa and IIb dissection was to investigate the predictive value of IONM for postoperative shoulder function in this unique group of patients, who are generally accepted as having the greatest amount of SCM muscle and SAN traction.

Several studies have investigated SAN functions using EMG.5,8-11 Erisen et al8 reported similar electrophysiological findings in both SAN-sparing and non-sparing neck dissections, but shoulder function was clinically better after SAN-sparing neck dissections. Tsuji et al11 reported normal EMG findings in 5.7%, mild neurogenic involvement in 10%, partial axonal degeneration in 25.7%, and total axonal degeneration in 58.6% of 70 SAN-sparing SND performed on 54 patients. Cappiello et al5 reported normal EMG findings in 80% of the patients when level V was not dissected, while EMG findings were normal in only 15% of the patients when level V dissection was performed. The results of this study support the hypothesis that dissection of level V causes more frequent SAN involvement. Karaman et al18 reported normal EMG findings in 19 (86.5%), partial axonal degeneration in 2 (9%), and total axonal degeneration in 1 (4.5%) of 22 patients who had functional neck dissection (FBD). Cheng et al10 reported normal EMG findings in all 7 patients who had SND and reported that none of them developed shoulder dysfunction. In our study, we performed EMG at 20 neck sites of 17 patients and found normal EMG findings in 5%, mild neurogenic involvement in 30%, partial axonal degeneration in 50%, and total axonal degeneration in 15% of shoulders at 1 month after surgery. Our findings are in accordance with those of Erisen et al8 and Tsuji et al,11 who reported that EMG changes were common in SAN-sparing neck dissections. However, our data disagree with the findings of Cappiello et al5 and Karaman et al,18 who observed either less or no EMG change after SND and FND.

Although IONM use in lower cranial nerves is relatively new, and the prognostic criteria on this issue have not yet been clarified, various studies have investigated the prognostic criteria of electrophysiological tests for facial nerve function.14,19,20 Grosheva et al19 described patients with ≥75% amplitude loss on electroneurography (ENG) as the poor prognostic group for facial paralysis. In a similar study, Chow et al14 stated that patients with facial palsy having an amplitude loss less than 72.63% had a good prognosis with return of facial function to Brackmann grade 2. In our study, we determined an IONM amplitude loss <72% to be insignificant amplitude loss (good prognostic criteria) and an IONM amplitude loss ≥72% to be significant amplitude loss (poor prognostic criteria).

Witt et al12,13 performed 2 studies on SAN IONM and postoperative shoulder function. There was no relationship between the absence/presence of a significant threshold difference and postoperative shoulder function. However, shoulder syndrome did not develop in 89% of patients without an electrophysiological threshold increase. In both studies ≥0.4 mA was determined as the cutoff value for significance in threshold increase. However, Lalwani et al,21 analyzing facial nerve functions after acoustic neurinoma surgery, reported that patients with a threshold increase ≥0.2 mA in IONM had worse facial nerve function 1 year after the surgery. In our study, we determined that a threshold shift of 0.25 mA better defined the cutoff point for significant threshold increment, representing the limit for good and poor prognostic criteria.

Clinical shoulder function evaluations performed 1 and 2 months postoperatively showed significant deterioration in all patients compared to preoperative values, including both groups with and without significant IONM changes. Our results are in accordance with investigations of shoulder function deterioration in the early postoperative period after SAN- and SCM-sparing neck dissections, supporting the hypothesis that traction of the SAN and the SCM muscle is responsible for neural dysfunction in those patients.9,10 As level IIb was dissected in all our patients, it is also possible to interpret our findings similarly to those of investigations stressing level IIb dissection as the major reason for shoulder dysfunction.22

The total number of shoulders with significant threshold change of 9 of 20 (45%) in our study is higher than 3 of 22 (14%) reported by Witt et al.13 This may be the result of the varying values accepted as a significant threshold change of 9 of 20 (45%) in our study is higher than 3 of 22 (14%) reported by Witt et al.13 This may be the result of the varying values accepted as a significant threshold

### Table 3. The Comparison of Preoperative and Postoperative First and Second Month Activity Restriction Scores (Expressed as Median and Range Interquartile).

<table>
<thead>
<tr>
<th>Groningen Activity</th>
<th>Preop First Month</th>
<th>Postop First Month</th>
<th>Postop Second Month</th>
<th>Preop/Postop First Month P Valuea</th>
<th>Preop/Postop Second Month P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients (n = 17)</td>
<td>18 (18-18)</td>
<td>22 (21-24)</td>
<td>22 (21-25)</td>
<td>.001</td>
<td>.003</td>
</tr>
<tr>
<td>The group with amplitude change (n = 5)</td>
<td>18 (18-18)</td>
<td>23 (21-34)</td>
<td>23 (21-24)</td>
<td>.011</td>
<td>.011</td>
</tr>
<tr>
<td>The group without amplitude change (n = 12)</td>
<td>18 (18-18)</td>
<td>21 (20-24)</td>
<td>22 (20-25)</td>
<td>.034</td>
<td>.073</td>
</tr>
<tr>
<td>The group with threshold difference (n = 7)</td>
<td>18 (18-18)</td>
<td>23 (21-30)</td>
<td>23 (21-25)</td>
<td>.007</td>
<td>.007</td>
</tr>
<tr>
<td>The group without threshold difference (n = 10)</td>
<td>18 (18-18)</td>
<td>21 (20-23)</td>
<td>21 (20-25)</td>
<td>.040</td>
<td>.107</td>
</tr>
</tbody>
</table>

Abbreviations: Preop, preoperative; postop, postoperative; n, number of patients.

*Boldface P values are statistically significant.
difference: 0.25 mA in our study, and 0.4 mA by Witt et al.\textsuperscript{13} As postoperative shoulder dysfunction was also present in the early postoperative period of our patients without IONM changes, this part of our results is in accordance with these studies, which found shoulder function deterioration in the early postoperative period even though no significant changes were seen in IONM.\textsuperscript{12,13} However, our findings differ from the point that shoulder function deterioration was less in the insignificant IONM changes group than patients with significant IONM changes.

The evaluations of activity restriction (GARS) showed that deteriorations were present in the groups with either significant or insignificant IONM changes at 1 month after surgery. Although they persisted after the second postoperative month in the group with significant IONM changes, there was a recovery trend in the group with insignificant IONM changes, as reflected by the loss of statistical significance after the second month.

**Conclusion**

Shoulder functions deteriorate after neck dissections even though the SAN is anatomically preserved. Our results suggest the predictive role of IONM, showing which patients may be separated into good prognosis (insignificant IONM change) and poor prognosis (significant IONM change) groups. Patients showing good prognostic findings in IONM have less deterioration of shoulder function compared to patients with poor prognostic findings, and their activity restriction scores begin to improve earlier.

Considering that shoulder function may improve 6 to 12 months after SAN-sparing operations, studies with a longer follow-up period are required to investigate the predictive role of IONM in the long term.\textsuperscript{23}

**Acknowledgment**

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**Author Contributions**

**Yucel Birinci**, design, acquisition and interpretation of data, drafting the article, final approval; **Arzu Genc**, design, acquisition and interpretation of data, drafting and critically revising the article, final approval; **Mustafa Cenk Cecvit**, acquisition and interpretation of data, critically revising the article, final approval; **Taner Kemal Erdag**, acquisition and interpretation of data, critically revising the article, final approval; **Enis Alpin Guneri**, acquisition and interpretation of data, critically revising the article, final approval; **Ibrahim Oztura**, design, acquisition of data, critically revising the article, final approval; **Ahmet Evlice**, design, acquisition data, critically revising the article, final approval; **Ahmet Omer Ikiz**, conception and design, acquisition and interpretation of data, drafting and critically revising the article, final approval.

**Disclosures**

**Competing interests:** None.

**Sponsorships:** None.

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