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CONTROL OF THE FUNCTIONALITY OF THE BRACHIAL PLEXUS DURING ROBOT-ASSISTED TRANSAXILLARY THYROID SURGERY

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At present, such a type of endoscopic surgery as robot-assisted transaxillary thyroidectomy has become available. In this case, traumatization of the brachial plexus is a rare but possible complication. For the control of the function of the brachial plexus during the above operation we used monitoring of somatosensory evoked potentials (SSEPs) induced by stimulation of the median nerve. Fifteen patients (14 women and one man) were included in this study. All interventions were robot-assisted transaxillary thyroidectomies using the daVinci SI Surgical System. We found that such surgery induced mild but significant increases in the latency of the cortical N20 potential, especially when the tissue was tensioned by the autostatic retractor. The latency prolongation was a valuable signal given to the surgeon, followed by repositioning or loosening of the retractor. In the examined group, no significant decreases in the amplitude of the N20 potential were observed. We conclude that SSEP monitoring during robotic thyroid surgery is an available and safe method providing valuable information on the functional integrity of somatosensory pathways during surgical maneuvers.

Keywords: robot-assisted thyroidectomy, somatosensory evoked potentials, SSEPs, brachial plexus, intraoperative monitoring, neurapraxia

INTRODUCTION

Endoscopic surgical approaches are gradually becoming more frequent and widespread. In particular, thyroid and parathyroid surgery evolved also in this direction; within the last decade, a number of endoscopic or video-assisted surgical methods were developed in this field [1]. The necessity for an endoscopic extracervical remote access approach in thyroid surgery is sustained by the esthetic criteria; the pathology is more frequent among women, while the classical approach leaves an unaesthetic incision scar at the base of the anterior region of the neck.

Postoperative results after endoscopic or video-assisted thyroid surgery are, in general, satisfactory. Nonetheless, there are several technical disadvantages involving a bidimensional image and limited degrees of freedom for the movements of endoscopic instruments. These factors exert a limiting effect on spreading of the respective endoscopic procedures.

Robotic assistance was introduced in endoscopic thyroid surgery mainly to overcome the mentioned technical limitations. Such intervention was performed and described first by Chung in 2007 [2]. The approach is transaxillary; the patient is in a dorsal lying position, with the abducted and supine upper limb on the side of intervention. Most operations using the above technique are successful, but there is a danger of traumatization of the brachial plexus. The occurrence of this complication is rather low but mentioned by most authors [3–5]; we also met a respective case in our surgical practice.

Even if the technique is mostly safe and the outcomes are comparable with the classical method [6, 7], there is an obvious necessity to avoid such complication. This explains the expedience of controlling the functionality of the brachial plexus during different stages of the intervention. Considering this, we have used intraoperative neurophysiological monitoring with recording of somatosensory evoked potentials (SSEPs) elicited by stimulation of the median nerve [8]. It should be taken into account that the respective surgical intervention needs myorelaxation, and it is impossible to use free-run electromyography or motor EPs.

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In discussing the axillary approach for robotic thyroidectomy, one modality to obtain SSEPs is to stimulate a mixed nerve (in our case, the median nerve) and to record the EPs from the respective zone of the somatosensory cortex. The SSEP components after stimulation of the median nerve are well-known, and N20 is one of the most important and consistent near-field potentials suitable for our purpose [9, 10]. We measured the latency of precisely this component.

METHODS

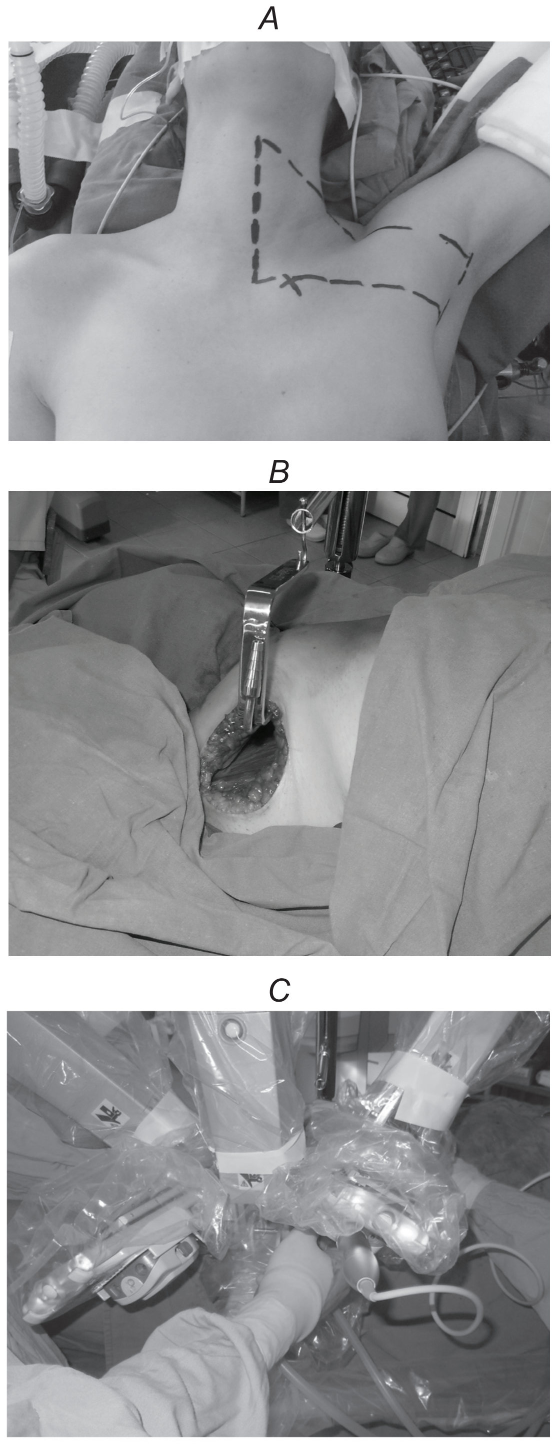
Patients. Fifteen patients with thyroid pathology were included, 14 women and one man, six with right lobectomy (40%), eight with left lobectomy (53.3%), and one with left-sided intervention, but total thyroidectomy (6.7%). The mean age was 46.27 ± ± 4.14 years. No significant comorbidity was noted, and there were no side-related differences in the EP recordings (not shown).

Operation technique. To perform the robot-assisted thyroidectomies, we have used the daVinci SI Surgical System (Intuitive Surgical). The patient was positioned on the operating table in dorsal decubitus, with slight extension of the head. The upper limb on the side of operation was held in abduction, extension, and inward rotation, on a special detail of the table, in order to obtain the shortest distance between the axilla and thyroid loggia (Chung's position [2]) (Fig. 1 A).

The approach was transaxillary, with a vertical incision parallel with the external margin of the *m. pectoralis major* (PM). Dissection continued in the fascial layer of the PM, leaving the axillary fascia unopened, up to the internal third of the clavicle, then between the sternal and clavicular insertions of the *m. sternocleidomastoideus* (STM) and under the *m. subhyoidus* (SH) in the thyroid loggia. The musculocutaneus layers were then elevated by the special autostatic retractor of Chung (CAR) (Fig. 1 B).

The robotic cart was placed contralaterally to the incision. After this, the arms of the DaVinci system were positioned in the following mode, the instruments for arms 1, 2, and the 30-deg down endoscope through the axillar incision, and the instrument for arm 3, through an 8-mm laterosternal incision, on the side of the operation (Fig. 1 B).

The robotic intervention consists of the effective exeresis of the lobe or, by case, the entire gland, dissecting first the thyroid capsule, isolating, sealing, and sectioning the vascular pedicles with the Harmonic ultrasound scissor, with isolating and preserving the recurrent laryngeal nerve, parathyroids, and their



F i g. 1. Mode of robot-assisted thyroid surgery. A) Position on the operating table; B) Chung's autostatic retractor in position, and C) docking the robot

Р и с. 1. Техніка роботизованої операції на щитоподібній залозі.

vascular supply.

SSEPs. Monitoring was performed using a Keypoint portable system. Stimulation was performed using an attachable bar stimulation electrode fixed on the skin over the carpal tunnel, in order to stimulate the median nerve. A band electrode was fixed on the forearm as the ground one.

The N20 component of the cortical SSEP was recorded with an Ag 0.5-cm cup-type electrode attached with conductive paste to the previously cleaned scalp, over the parietal region, – 2 cm behind and 20% lateral (according to the 10-20 system) to the Cz position. A reference electrode was positioned in Fz, and an additional ground electrode was placed in Cz.

A low-pass filter was set to 5 Hz, and a high pass filter, to 3 kHz. The ground impedance was below 20 kΩ, and the accepted electrode impedance was below 5 kΩ. The stimulus duration was set to 0.1 msec (negative polarity), and the stimulation frequency was 3 sec^{-1}. The intensity was varied according to the individual threshold, around 12–15 mA.

Designations. According to the above-described techniques and the requirements of monitoring, we identified important moments of the surgery when such monitoring was necessary. Pre-surgical measurements of the N20 component gave the Baseline value. Another value named Supine, when the limb was in the operating position, was also obtained. Following these, anesthesia was performed, and the following recordings were obtained. Starting from the incision and reaching the thyroid loggia, potentials were similar in their characteristics. As a consequence, we introduced only two values, when the tunnel was already constructed up to the muscle, referred to as SCM, and when the operation opened the thyroid loggia, ThyLog. After these, monitoring followed different stages of the robotic surgery; these were retractor positioning (CARin), arm positioning (ROBin), and exeresis (Op); then arms were taken out (ROBout), and the retractor also (CARout). At the end, prior to the end of the anesthesia, another potential was recorded with the arm of the patient in pronation and positioned on the table, parallel with the body (Pron). The SSEP was recorded after 5 min in the new position in order to permit the possible pathogenetic processes (compression and/or ischemia) to take place.

Post-anesthesia recordings did not differ significantly from the baseline. Patients with neurapraxia were absent among the monitored ones.

Statistical analysis. The data were collected in MS Excel sheets, and an SPSS database was created. Descriptive statistics were performed, and the Kolmogorov-Smirnov test was used for estimation of normality of the distributions. For statistical pair-by-pair comparisons between the group mean values, we used the Wilcoxon test. All statistical analyses were performed using SPSS version 17. Differences with $P < 0.05$ were considered significant.

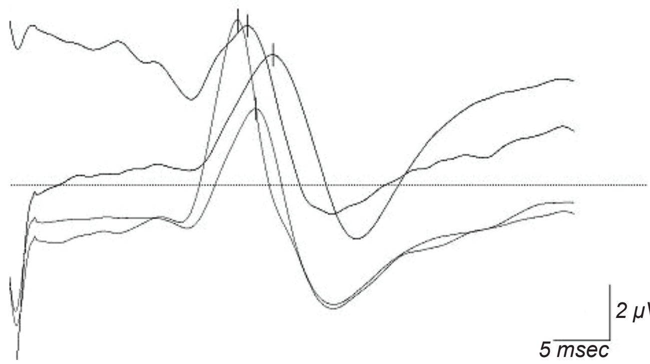
RESULTS

The SSEP waveforms obtained during intraoperative monitoring (Figure 4) are shown in Fig. 2.

The Kolmogorov-Smirnov test proved that distributions of the values for all 10 groups of the measurements could be considered normal (not shown). Taking into account that a parametric test is debatable with only 15 samples per group, we preferred to test the numerical data in a non-parametrical manner using the Wilcoxon test (Table 1).

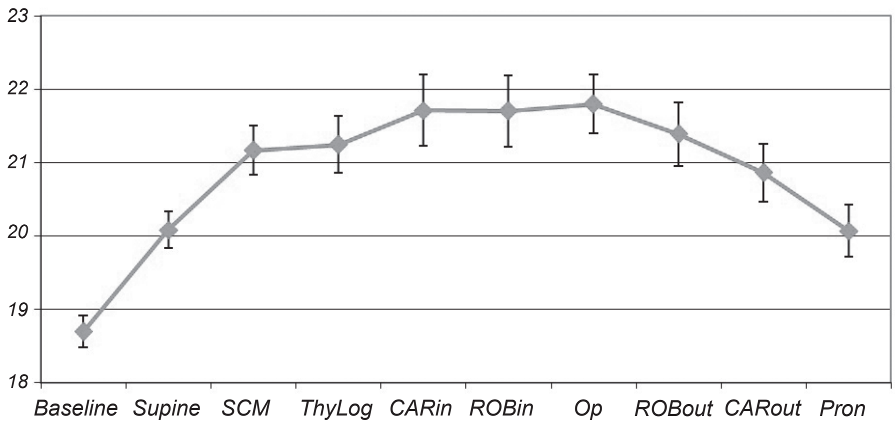
When the Baseline values were compared with Supine, highly significant differences were noticed (the latter set of values increased). The same was true also with respect to the next step, when after introduction of the anesthetic (at evaluation in SCM), a significant increase in the N20 latency was observed. Next, the potentials in ThyLog were almost identical to those in SCM.

A further significant increase in the latencies of the N20 component was observed in the next step, CARin, when the retractor was positioned and maintained in ROBin (and in Op too). The maximum increment in



F i g. 2. Examples of cortical SSEPs recorded in one of the patients.

Р и с. 2. Приклади кортикальних соматосенсорних викликаних потенціалів, відведених у одного з пацієнтів.



F i g. 3. Dynamics of the N20 latency during principal moments of the surgery. Mean values ± s.e.m. are shown. Designations of the operation stages are shown in the text.

Р и с. 3. Динаміка латентного періоду потенціалу N20 протягом основних стадій оперативного втручання.

the mean N20 latency compared to the Baseline was about 3.0 msec.

A significant decrease of the values occurred, compared with the latencies measured during the operation, when the robotic arms were out (ROBout). The same happened in the next monitoring step, when the retractor was also taken out (CARout). The next moment showed also a sequentially significant difference when compared with its previous set, lowering and pronating the hand (Pron).

As a final step, we have compared Pron values with Baseline; in this case, statistically significant differences were still present. Post-anesthesia values were not standardized but were comparable with baseline.

In the examined group, any considerable drops in the amplitude of the N20 component during all surgical manipulations were not observed.

T a b l e 1. Comparison of the latencies of the N20 component measured in different stages of the surgery.

Т а б л и ц я 1. Порівняння латентних періодів компонента N20, виміряних під час різних стадій оперативного втручання

Operation stages	Latency, msec (mean ± s.e.m.)	Comparisons	*P* (Wilcoxon)
Baseline	18.70 ± 0.22	Baseline – Supine	**0.001**
Supine	20.08 ± 0.25	Supine – SCM	**0.001**
SCM	21.17± 0.33	SCM – ThyLog	*0.552*
ThyLog	21.25 ± 0.39	ThyLog – CARin	**0.047**
CARin	21.72 ± 0.48	CARin – ROBin	*0.783*
ROBin	21.71 ± 0.48	ROBin – Op	*0.638*
Op	21.80 ± 0.40	Op – ROBout	**0.016**
ROBout	21.39 ± 0.43	ROBout – CARout	**0.001**
CARout	20.87 ± 0.39	CARout – Pron	**0.002**
Pron	20.07 ± 0.36	Pron – Baseline	**0.002**

Footnote: Cases of significant differences are shown in bold.

DISCUSSION

Operation-related lesions of the brachial plexus are constantly present, representing complications both from the point of view of postsurgical evolution and of the legal aspect. Surgical interventions are extremely various [11], and cases of plexus lesions produced, e.g., by an inappropriate position of the upper limb on the operating table during general anesthesia or by excessive tensioning of the tissue layers are quite possible [12]. Brachial plexus lesions, sometimes even bilateral, were described also for lower abdominal interventions using robotic surgery, when the patient is kept for a long time in a Trendelenburg position with the upper limbs abducted to 90 deg [13].

Brachial plexus neurapraxia after robotic thyroidectomy is rare but, nonetheless, present, and this has been reported. Kang et al. in 2009 reported one case, representing 0.2% of the interventions [14]. In a multicenter study performed on 1043 cases, Lee et al. (2001) reported three cases (approximately 0.3%) [15]. In the USA, Kandil et al. in 2012 reported one case in 100 interventions [4]. A similar complication was also mentioned by Piccoli et al. in 2015 (nine cases representing 3.06% of the interventions) [5]. Monitoring the functions of the brachial plexus was started after one complication case in our earlier operations.

The layer-oriented dissection in the surgical technique used excludes a direct lesion of the nerves and tracts of the plexus. Still, different moments of the intervention clearly influenced the SSEP pattern. One significant "jump" in the values occurred after positioning the arm in the Supine position (vs. Baseline). The subsequent significant increase in the values was due to anesthesia, an understandable and widely known effect [16] (not a subject of this study). The anesthesia-related effect on the SSEP parameters is rather important [17].

Progressive dissection in the fascial layer of the PM up to the sterno-clavicular joint, the internal third of the clavicle, and then between the sternal and clavicular heads of the SCM also influenced the potentials. Positioning the retractor further increased the latencies in a significant manner, the values being maintained during the presence of the robot and the exeresis.

A feasible explanation for these changes is possible only if several factors are taken into account. On the one hand, the long-lasting abducted position of the upper limb confers a degree of elongation and compression to the plexus on its trajectory to or from the periphery, between the clavicle and first rib [18, 19]. When the robot and retractor are taken out, the impact is significant (not reaching the Supine values), the patient being still in the supine position and under anesthesia. On the other hand, we believe that the time factor, namely duration of the dissection up to the thyroid loggia, also noticeably affects the N20 latencies. Sustained compression leads to some increase in the latencies further increased by positioning of the CAR.

During dissection, the components of the plexus are at a distance from the direct contact. The working space and progressive dissection are initially secured by the continuous use of manual retractors with various lengths. The skin, subcutaneous tissues, and muscles (SCM, SH) are tractioned towards the anterior. The brachial plexus might be involved in this tension, and the consequent slight anterior traction of the whole shoulder joint, external rotation of the arm, and narrowing of the space between the clavicle and first rib also exert some effect. The tension is transmitted also through soft tissues, both cranial and caudal to the clavicle, increasing compression of the elements of the plexus on the posterior surface of the clavicle.

The suspension of musculocutaneous structures on the CAR and robot docking further influence the latency (visible in a significant manner both at introduction and after removal). It augments the previously mentioned traction, but in a uniform manner, still resulting in compression of the nervous tissue.

The latencies are rapidly modified if additional tension is applied. The fast response of SSEPs usually signals in time the dangerous functional changes, a more than 50% amplitude drop or an increase by more than 5 msec with respect to the baseline values (the maximum change, without permanent damage, in the investigated group). Arm or retractor repositioning permitted us to continue safely the surgery, with no case of peripheral nerve or plexus injury in the row of the presented cases.

Further investigations are needed to clearly demonstrate also the intimate structural changes, which may lead to certain disturbances.

Thus, robotic thyroid surgery with close neurophysiological monitoring is a valuable and safe method, even if monitoring was restricted to only SSEPs. We believe that SSEP monitoring must be routinely performed in robotic thyroid surgery in order to prevent compressive lesioning of the components of the brachial plexus.

All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national Research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All patients gave their written informed consent prior to their inclusion in the study.

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КОНТРОЛЬ ФУНКЦІЙНОГО СТАНУ БРАХІАЛЬНОГО СПЛЕТІННЯ В ПЕРЕБІГУ РОБОТИЗОВАНОЇ ОПЕРАЦІЇ НА ЩИТОПОДІБНІЙ ЗАЛОЗІ

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Р е з ю м е

У теперішній час такий вид ендоскопічної хірургії, як роботизована трансаксилярна тиреоїдектомія, став доступним. У цих умовах травмування брахіального сплетіння є рідкісним, але можливим ускладненням. Ми використали моніторинг характеристик соматосенсорних викликаних потенціалів (ССВП) при стимуляції медіанного нерва для контролю функції вказаної структури. В дослідженні взяли участь 15 пацієнтів (14 жінок та один чоловік). Усі втручання являли собою роботизовану трансаксилярну тиреоїдектомію з використанням хірургічної системи daVinciSI. Як виявилося, така операція була пов'язана з невеликими, але вірогідними збільшеннями латентного періоду компонента N20 у кортикальному ССВП, зокрема тоді, коли тканини зазнавали розтягнення під дією автостатичного ретрактора. Збільшення латентного періоду є цінним сигналом для хірурга і повинно супроводжуватися корекцією положення або усуненням ретрактора. В обстеженій групі не спостерігалось істотних зменшень амплітуди компонента N20. Згідно зі зробленим висновком, моніторинг ССВП під час роботизованих операцій на щитоподібній залозі є цінним та безпечним методичним заходом, що дає важливу інформацію про функційну цілісність соматосенсорних шляхів у перебігу дій хірурга.

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