Effect of Anti-Adhesive Barrier Use on Laryngotracheal Movement After Total Thyroidectomy: An Electrophysiological Study

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Received: 23 July 2011 / Accepted: 19 October 2011 / Published online: 5 November 2011
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Abstract Impairment of laryngotracheal movement is a possible complication after total thyroidectomy. Here, we aimed to investigate the frequency and extent of impairment of laryngotracheal movement after total thyroidectomy and the effect of anti-adhesive barrier hyaluronic acid-carboxymethylcellulose membrane positioning between strap muscles and laryngotracheal complex on deglutition. The study design is prospective clinical study. Istanbul Training and Research Hospital, Laboratory of Electrophysiology, Istanbul Training and Research Hospital. The patients who underwent total thyroidectomy were selected and dichotomized according to use of seprafilm. Each group consisted of 8 female patients. All patients were assessed clinically and electrophysiologically in the pre/postop

period. Electrophysiological investigations included cricopharyngeal muscle (CPM) electromyography (EMG), submental EMG, single bolus analysis [foreburst, reburst, swallowing (pause) patterns], laryngotracheal movement analysis and results were compared between two groups. CPM EMG was normal in both groups. Duration of submental muscle activity during dry and 15 cc water swallowing was similar between two groups ($P = 0.751$). Pause duration was shorter in group with seprafilm ($P < 0.01$). Dysphagia limit was 15 cc in both groups. The fore/rebound bursts duration, the time of laryngeal elevation, closure and suspension were similar ($P = 0.954$). We concluded that use of seprafilm between larynx and strap muscles during total thyroidectomy does not have any adverse effects on swallowing. Anti-adhesive barrier can be used safely during thyroid surgery.

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Keywords Swallowing · Anti-adhesive barrier ·
Laryngotracheal movement · Thyroidectomy

Introduction

Swallowing has 3 phases: oral, pharyngeal and esophageal phases. The former two are voluntary whereas the last phase is involuntary. Swallowing includes sequential muscle activity as a function of time and localizations of muscles. During the act of swallowing, velopharyngeal isthmus should get closed to protect nasal, laryngeal and tracheal airways and laryngeal elevation is the vital component of this airway protection [1–3] Following the movement of tongue which pushes the bolus into the pharynx, suprahyoid and submental muscles contract leading to direct upward movement of tongue and hyoid bone and indirect upward movement of larynx since it has connections to hyoid bone. This indirect movement

provides closure of laryngeal vestibule and antero-posterior displacement of larynx under the tongue.

In an animal model, Yigit et al. showed that the use of anti-adhesive barriers, hyaluronic acid-carboxymethylcellulose membrane (seprafilm) and oxidized regenerated cellulose (interceed), inhibited development of scar tissue after thyroidectomy [4].

Based on the above-mentioned findings, we aimed to investigate the effect of anti-adhesive barrier use on laryngeal elevation and cricopharyngeal muscle (CPM) in total thyroidectomy procedure by analysing CPM electromyography (EMG); dynamic/kinesiographical investigations of swallowing, dysphagia limit (DL) and piecemeal deglutition as well as laryngeal movement.

Patients and Method

This was a prospective study which included patients who underwent primary total thyroidectomy for benign multinodular goitre. The study was approved by the Institutional Ethics Committee of Istanbul Training and Research Hospital and all patients provided informed consent. Patients were dichotomized into two groups: the first group (group 1) included 8 female patients who underwent thyroidectomy procedure in which an anti-adhesive barrier was not used and the second group (group 2) also consisted of 8 female patients in whom 7×7 cm seprafilm was positioned in between laryngotracheal unit and strap muscles during the procedure (Fig. 1).

Patients with possible malignant thyroid disease suggested by preoperative fine needle aspiration biopsy, with massive enlarging gland especially extending through upper and/or lower pole, with previous history of neck operation for any reason, radiotherapy or trauma, with

hoarseness, and who could not swallow 15 ml water at once which was assessed preoperatively by single bolus analysis according to previously published methods [5–7] were excluded.

Informed consent was obtained from all patients and the study was approved by the local ethics committee.

Thyroidectomy Procedure Thyroidectomy procedure was performed by the same surgical team which consisted of one experienced ENT specialist and one last year resident (O.Y., Z.A., V.S., E.A.S.). Initially, thyroid gland was exposed after detaching skin and dividing strap muscles by a midline incision. Upon precise identification of RLN and parathyroid glands, lateral part of thyroid lobe was excised. Superior thyroid artery and vein were ligated as close as thyroid capsule to prevent any injury to the SLN. However, further dissection was not performed when SLN was not recognized.

Clinical Assessment All patients were assessed pre- and postoperatively by detailed interview and clinical examination. Interview also included presence of dysphagia and hoarseness. Patients were questioned for the presence of throat obstacle, pharyngeal annoyance and cough during bolus transit, sensation of foreign body in the pharynx preoperatively and postoperatively. Postoperative assessments were repeated at first and third months follow-up. All patients underwent laryngostroboscopy by an experienced ENT surgeon (Z.A., V.S., I.K.) preoperatively and postoperatively at the 1st and 3rd months.

Electrophysiological Assessment Electrophysiological studies which were done at postoperative 3rd month by a single neurologist specialized on electrophysiology (T.A.) included submental/suprahyoid muscle electromyography (SM EMG) to determine duration of oropharyngeal phase of swallowing, CPM EMG to detect functional status of upper esophageal sphincter (UES) and to evaluate swallowing dynamically and kinesiologically as well as single bolus analysis and DL test to establish oropharyngeal dysphagia. Besides, electrophysiological findings of swallowing were also confirmed by use of laryngeal sensor which directly measures upward and downward motions of larynx.

Electrophysiological investigations were performed with Neuro-MEP-Micro EMG device (Neurosoft, Russia) while patients were sitting with the head extended providing observation of neck landmarks. The head of the patient was supported by pillows in order to prevent aspiration and hypotension. For polymyographic recordings, channels were adjusted as 1. SM EMG, 2. Laryngeal sensor and 3. CFM EMG (Fig. 2). The electrophysiological methods were performed according to the methods previously described [1, 5].

The first step in the examination was SM EMG which was recorded by placing bipolar silver chloride cutaneous

Fig. 1 Intraoperative view of seprafilm

Fig. 2 Polymyographic recordings during swallowing, channels were adjusted as 1. Submental EMG activity; A–C duration provides total duration of oropharyngeal phase (*top trace*) 2. Laryngeal movement sensor; duration of interval between the two deflections which reflected upward and downward movements of larynx (0–2 duration is the time required for upward movement and closure of larynx) (*middle trace*) 3. CPM-EMG; single bolus analysis (*bottom trace*)

recording electrodes over the mylohyoid-geniohyoid-anterior digastric muscle complex [1, 5–8, 11]. The ground electrode was placed on the forehead. Analysis time and sensitivity were adjusted as 2 s/div and 200 μ V respectively. The EMG signals were band pass filtered between 100 Hz and 10 kHz). Duration of EMG activity of suprahyoid/submental muscles was measured during dry

swallow and 15 cc water swallow [Fig. 1 (channel 1)]. Each test was repeated three times at random intervals and mean duration was calculated.

Secondly, laryngeal movement sensor was placed in between thyroid and cricoid cartilages and vertical movements of larynx during swallowing (0–2 interval) were monitored and analysed. The sensor amplifier output was also band pass filtered (cut-off frequencies 0.01–20 Hz). Duration of interval between two deflections which reflected upward and downward movements of larynx was measured (the time required for upward movement and closure of larynx) [Fig. 1 (channel 2)].

Then CPM EMG was recorded using bipolar concentric needle electrodes (26 G, Technomed Europe, The Netherlands) to monitorize functions of UES. Analysis time and sensitivity were 20 ms/div and 100–200 μ V/div, respectively. Cricoid cartilage was identified by palpation and needle electrode was placed to CPM just posterior to cricoid cartilage and its position was confirmed by listening noise of high frequency tonic activity during rest from the loud-speaker and interruption of this activity by swallowing. The variables evaluated were the presence of denervation as well as amplitude, recruitment, duration of motor unit potentials (MUP), and the presence of polyphasic waveforms (Fig. 3). Furthermore, while needle electrode was positioned in CPM, we advanced with dynamic/kinesiological investigations (single bolus analysis). The filter settings and recording parameters were the same as those used for the SM EMG recording. Variables including duration of swallowing (defined as pause in the EMG activity) as well as presence

Fig. 3 The MUP of CPM EMG; high frequency tonic activity during the rest of the CPM

Fig. 4 The dynamic/kinesiographical characteristics of CPM-EMG (single bolus analysis): duration of swallowing (defined as the pause in the EMG activity), foreburst and rebound bursts during swallowing

and duration of foreburst and rebound bursts were analysed during dry swallow and 15 cc water swallow (Fig. 4). Additionally, during recording from CPM, the volume swallowed at once after administration of 15 cc water was measured and piecemeal deglutition and DL was evaluated by consecutive 15 cc water [5, 8].

Statistical Analysis Data analyses were performed using the SPSS 11.5 software statistical package. Comparisons between groups in which seprafilam was positioned or not were made by *t* test when distributed homogeneously and by Mann–Whitney U when distributed heterogeneously for quantitative data and by χ^2 test for qualitative data. Data were presented as mean $\pm$ standard deviation (95% confidence interval). Statistical significance was defined as ≤ 0.05 .

Results

Clinical Assessments Mean age of group 1 and group 2 were 45.37 ± 9.94 and 40.75 ± 13.44 years, respectively ($P = 0.447$). All patients had throat obstacle resulting from pain at first month follow-up whereas none of patients in the two groups had sensation of foreign body and had throat obstacle at third months follow-up. However, none of them had dysphagia or hoarseness at third month follow-up. Postoperative laryngostroboscopy findings and vocal cord movements were normal in all patients.

Electrophysiological Assessments Mean duration of SM EMG activity was msec 1019.25 ± 52.03 ms in group 1 whereas it was 1004.62 ± 21.54 ms in group 2 ($P = 0.751$).

The time required for upward movement and closure of larynx was also similar between the two groups, 0–2 interval was 485.75 ± 14.43 ms in group 1 compared to 485.38 ± 11.02 ms in group 2 ($P = 0.954$).

CPM EMG demonstrated normal MUPs in both groups without any fibrillation potentials. Duration of swallowing measured as the duration of the pause of high frequency

tonic activity during CPM recording was 0.50 ± 0.02 s in group 1 and 0.44 ± 0.02 s in group 2 ($P = 0.001$).

Basic electrophysiological characteristics of swallowing in CPM recordings were similar between the two groups. Foreburst and rebound bursts were obtained in all patients. In the postoperative first month 6 patients in group 1 and 7 patients in group 2 had piece-meal deglutition pattern with 15 cc water swallowing. However, in the postoperative 3rd month DL was above 15 cc in both groups and piecemeal deglutition was not observed in any patients by dry swallowing and 15 cc water swallowing tests (Table 1).

Discussion

Importance of laryngotracheal unit after thyroidectomy attracted attention due to studies reporting hoarseness after thyroidectomy in which there did not exist any injury to nerves [9, 10]. Hoarseness was suggested to be associated with laryngotracheal fixation secondary to impaired vertical laryngeal movement or temporary malfunction of the strap muscles after surgery [9]. Laryngotracheal elevation plays an important role in the formation of sound and pharyngeal phase of swallowing. As far as we know there is not any research evaluating motion of laryngotracheal unit and swallowing electrophysiologically after thyroidectomy.

A series of electrophysiological methods were suggested to investigate sequential muscular movements of pharynx and larynx during swallowing. Submental/suprahoid muscle activities measured by SM EMG enlightens beginning of the first phase of swallowing since mylohyoid, anterior digastric and geniohyoid muscles contract successively in the oropharyngeal phase of swallowing and muscular activity of those muscles can be gathered in SM EMG. As those muscles are active during the whole phase, total duration of these activities also provides total duration of oropharyngeal phase [1, 5]. There were no differences regarding the activity of SM EMG in our study. Interruption of high frequency tonic activity recorded from CPM reflects

Table 1 Swallowing related electrophysiologic findings of the patients

	Group 1 <i>n</i> = 8	Group 2 <i>n</i> = 8	<i>P</i>
Age	45.37 ± 9.94	40.75 ± 13.44	0.447
SM-EMG activity duration (msec)	1019.25 ± 52.03	1004.62 ± 21.54	0.751
LS (0–2) interval (msec)	485.75 ± 14.43	485.38 ± 11.02	0.954
CPM-EMG pause duration (sec)	0.50 ± 0.02	0.44 ± 0.02	0.001
CPM-EMG-MUP's	Normal	Normal	
Foreburst activity	All	All	
Rebound burst activity	All	All	
DL	>15 cc	>15 cc	
Piecemeal deglutition (with dry swallowing)	None	None	
Piecemeal deglutition (with 15 cc water swallowing)	None	None	

Group 1 without seprafilm group; Group 2 with seprafilm group

SM-EMG Submental and suprahyoid muscle electromyography, *LS* (0–2) *interval* laryngeal sensor, 0–2 interval (the time, required for upward movement and closure of larynx), *CPM pause* cricopharyngeal muscle electromyography pause duration (duration of swallowing), *CPM-EMG-MUP* cricopharyngeal muscle electromyography motor unit potentials, *DL* dysphagia limit

the passage of bolus through the UES. Normally, during rest CPM has high frequency tonic activity and during swallowing this activity interrupts for 400–500 ms [12] which can be measured objectively by EMG. This pause of activity begins with upward movement of larynx simultaneously and ends just before the downward movement of larynx and rebound increase of CPM activity provides closure of sphincter. Consequently, pharyngeal phase of swallowing terminates [1, 6] and bolus advances in the esophagus. Those activities can be recorded after the administration of single bolus (15 cc water) and is called the single bolus analysis which measures tonic activity of CPM during rest and interruption of this activity during swallowing [5–8, 12]. In our study, duration of pause (interruption of EMG activity during swallowing) was shorter in group 2 compared to the group 1 ($P = 0.01$), however, it was within the normal range in both groups. Besides, dry swallow and 15 cc water swallow were normal and foreburst and rebound burst were observed in both groups (Table 1).

Thyroid and cricoid cartilages move vertically during swallowing and those movements can be monitored by a piezoelectric movement sensor which is placed in between those cartilages. Upward movement of larynx leads to the first deflection (0) and downward movement leads to a second deflection (2) in the opposite direction. The interval between those two deflections (0–2) gives the duration of pharyngeal phase which includes the time for the elevation, closure and suspension of larynx [Fig. 1 (channel 2)] [12, 13]. Those variables were not different between the two groups in our study.

DL is based on a physiological method which is called piecemeal deglutition. Normally, 20 cc water can be swallowed at once; however, patients with dysphagia can not swallow and require swallowing the same amount at 2

or more times [5]. It has been reported that a normal single swallow of water for an adult averages about 17 cc varying from 14 cc for women to 21 cc for men [14]. DL method is a specific and sensitive test to show oropharyngeal dysphagia objectively [11, 12]. In our study, we used 15 cc since it was previously reported as lower limit of normal range in women. Preoperatively, all patients swallowed 15 cc at once.

Although the pathophysiology underlying adhesions is not clear, it is frequently encountered in abdominal operations where it is suggested to be related to peritoneal injury, ischemia and presence of foreign bodies. Additionally, if two sides of the injury get in contact, fibrinogenesis and fibrinolysis are activated, and distortion of the dynamic balance between these two processes leads to adhesion formation. Seprafilm is frequently used in abdominal operations to prevent postoperative abdominal adhesions [15] and it was reported to be highly effective in a meta-analysis which analysed 8 studies and 4,203 patients. Moreover, this barrier dissolves spontaneously and does not need any further surgical procedure for removal [16].

In the literature, there exists only one animal study using seprafilm in thyroidectomy procedures. Yigit et al. positioned seprafilm and interceded in between trachea and strap muscles during subtotal thyroidectomy and compared the formation of adhesion to control group [4] and showed that adhesion developed in a lesser rate in the condition that adhesive barrier used. Pathological findings suggestive of foreign body reaction like granuloma, histiocyte, giant cell, chronic inflammation, polymorphonuclear leukocyte, and fibroblasts were minimal in the group which anti-adhesive barrier used. Subsequently, they concluded that seprafilm and interceded inhibited fibrosis and adhesion.

In thyroid surgery, adhesions are ascribed to emptied thyroid bed and consequent direct contact of larynx and trachea with strap muscles resulting in formation of scar tissue between laryngotracheal unit, strap muscles and subcutaneous soft tissue. In our study, seprafilm was placed between larynx and strap muscles to prevent fibrosis; however, there were no kinesiological differences of vertical laryngeal movements in groups with and without seprafilm.

In thyroid surgery, protection of external laryngeal structures is emphasized in some studies. The most important of those structures are strap muscles which are sternohyoid and sternothyroid muscles. They may be damaged by the lateral retraction or incision during thyroid surgery or by wound contracture of surrounding structures after the surgery. Hong et al. also reported that the contraction of the sternohyoid and sternothyroid muscles caused the laryngotracheal downward movement resulting in high volume of air in the subglottic air space, which corresponded to increase in subglottic pressure [9]. Generally, in thyroidectomy, strap muscles are retracted laterally unless thyroid tissue is not enlarged. However, if the thyroid tissue is enlarged to prevent adequate vision strap muscles may be needed to be incised. In this case, if the muscles are not too thin, they are recommended to be sutured [10]. Incision of strap muscles increases the risk of fibrosis. In our patients, strap muscles remained intact and vision is provided by lateral retraction of muscles and we think that care for integrity of tissues prevented the development of fibrosis. Lombardi et al. also reported that the incidence and the severity of early voice and swallowing symptoms following thyroidectomy were significantly reduced in patients who underwent video assisted thyroidectomy compared to conventional surgery [17]. In another study Lombardini et al. reported that dysphagia/throat obstacle after thyroidectomy may result from injury of small fibers of RLN which innervate CPM and providing normal laryngeal innervation dysphagia/throat obstacle recovered totally within 3 months after thyroidectomy [18]. Clinicians generally tend to relate swallowing problems to oro-pharyngeal intubation and neglect those symptoms since they are usually evaluated subjectively. However, injury to CPM or swallowing problems can be objectively assessed by EMG. In various studies incidence of dysphagia at 3rd month ranges between 5 and 30% and it may be seen beyond the 3 months [18, 19]. Although we did not confirm any neural injury at 3rd month in our study, this may originate from the small number of patients in our study which is a limitation. Therefore, we think that CPM EMG after thyroidectomy provides objective assessment and is mandatory to prevent overlooking those important complications. Another limitation of our study was not to apply electrophysiological tests before thyroidectomy

procedure. It's hard to apply invasive electrophysiological studies successfully by conventional methods in those patients who have such a massive thyroidal enlargement that may cause topographic anatomical changes of the related neck region.

In thyroidectomy operations with SLN injury, muscular injury was also reported. Cricothyroid muscle forms the posteromedial border of the upper pole of the thyroid gland and superior thyroid vessels. This muscle may be torn by forcible anterior retraction of the upper pole by a finger pressed underneath the lateral side, which may damage the delicate cricothyroid or cricoarytenoid joints [9]. In our study, we did not encounter any findings suggestive of injury to this nerve and muscle. CPM is also localized just posterior to CTM and is under the risk of lateral retraction and catheterisation during thyroid surgery.

Since seprafilm does not lead to foreign body sensation, impairment of swallowing as seen in our study and can be obtained easily with a low cost, it may be used in high risk patients in whom strap muscles are traumatized or incised. However, for biological relevance, seprafilm should be used in larger groups.

Conclusion

In summary, our study showed that there were no electrophysiological differences regarding swallowing in groups with or without seprafilm after total thyroidectomy procedure.

Therefore, we concluded that the causes of laryngeal elevation impairment are multiple and not only related to fibrosis between the larynx, trachea and strap muscles.

Anti-adhesive barrier does not have any adverse effects and does not result in foreign body sensation and can be used safely during thyroid surgery. Patients should be informed about the probability of swallowing alteration preoperatively and patients should be followed by electrophysiological test postoperatively.

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