Eur Arch Otorhinolaryngol (2014) 271:1693–1699
DOI 10.1007/s00405-013-2668-9

HEAD AND NECK

Risk factors for internal carotid artery injury in adults during simple nasopharyngeal surgeries

Ching-Feng Lien · Hsu-Huei Weng · Ching-Feng Liu · Bor-Shyh Lin · Tai-Ching Wu · Yung-Song Lin

Received: 4 June 2013 / Accepted: 16 August 2013 / Published online: 28 August 2013

Abstract The purpose of this study attempted to analyze the potential risk factors for internal carotid artery injury during simple nasopharyngeal surgeries with or without an endoscopic aid. One hundred and seventy magnetic resonance imaging scans (340 halves) of the brain were retrospectively reviewed and studied. Anatomic variations of carotid arteries were classified, and various distances from the internal carotid arteries to the nasopharyngeal subsites were directly measured on the scans. The mean distances between the internal carotid arteries and nasopharyngeal subsites were significantly shortened in patients with nasopharyngeal internal carotid artery aberrancy, female gender, and lower body weight. The distance to the posterior nasopharyngeal wall was also shortened with age. However, the severity of nasopharyngeal carotid artery variations (kinking and coiling) did not reflect the shortening of mean distances to nasopharyngeal subsites. In conclusion, from multiple linear regression analysis, we found that the risk of an internal carotid artery injury during simple nasopharyngeal surgeries with or without an endoscopic aid is greatest in adult patients with nasopharyngeal carotid artery aberrancy, followed by female gender, lower body weight, and increasing age.

Keywords Aberrant internal carotid artery · Eustachian tuboplasty · Adenoidectomy · Simple nasopharyngeal surgery · Carotid artery hemorrhage

Introduction

Although endoscopic surgery has many advantages, complications such as vascular injuries with massive hemorrhage are particularly difficult to be managed [1–4]. In addition to experience and skills, patient characteristics and vascular anomalies are associated with vascular injuries. The internal carotid artery (ICA) injury is the most feared and devastating complication of endoscopic surgery.

C.-F. Lien
Department of Otolaryngology, E-DA Hospital and I-Shou University, Kaohsiung, Taiwan
e-mail: lien980206@yahoo.com.tw

H.-H. Weng
Department of Diagnostic Radiology, Chang Gung Memorial Hospital at Chiayi and Chang Gung University College of Medicine, Taoyuan, Taiwan
e-mail: hweng@post.harvard.edu

C.-F. Liu (✉) · Y.-S. Lin
Department of Otolaryngology, Chi Mei Medical Center, No. 901, Zhonghua Rd., Yongkang Dist., Tainan 710, Taiwan
e-mail: wtcen@hotmail.com

Y.-S. Lin
e-mail: kingear.lin@msa.hinet.net

C.-F. Liu
Department of Biological Science and Technology, National Chiao Tung University, Hsinchu, Taiwan

B.-S. Lin
Institute of Imaging and Biomedical Photonics, National Chiao Tung University, Tainan, Taiwan
e-mail: borshyhlin@gmail.com

T.-C. Wu
Department of Diagnostic Radiology, Chi Mei Medical Center, Tainan, Taiwan
e-mail: taichingwu@yahoo.com.tw

Anatomic relationship is one of the risk factors for an ICA injury during endoscopic nasopharynx and skull base surgery [1, 5]. During simple nasopharyngeal surgeries, an ICA injury is often ascribed to carotid artery aberrancy, which was considered in the past to stem from the sudden shortening of the distance between the vessel and nasopharyngeal wall [5–11]. From the literature, most studies on ICA aberrations were used to clarify the associations with cerebrovascular disease [12–14], and most data on the distance between the ICA and pharyngeal wall were analyzed for applications in oropharyngeal surgeries [15]. However, the concrete effect of nasopharyngeal carotid artery aberrancy on the distances between the vessel and nasopharyngeal subsites has not been reported and scant information on the distance between the carotid artery and nasopharyngeal wall is available to the clinical practice of simple nasopharyngeal surgeries [5, 11, 16].

Eustachian tuboplasty has been a common endoscopic surgery using techniques of laser, microdebrider, or ballon dilation for improving the function of the eustachian tube (ET) in recent years [17–20]. During eustachian tuboplasty, serious complications have occurred by not appreciating the proximity of the ICA to the ET [5, 6]. In addition, an ICA injury may be risked either directly by laser or indirectly by thermal injury when using the laser technique [5, 21]. During adenoidectomies, catastrophic hemorrhaging caused by an ICA injury has also been reported [7, 8, 22]. From the literature, ICA injuries can be further prevented by a thorough review of the preoperative computer tomographic (CT) scans to clearly understand the anatomic relationship during endoscopic nasopharynx and skull base surgery [1, 5, 10]. However, it is difficult to arrange either CT or magnetic resonance (MR) scans preoperatively for simple endoscopic nasopharyngeal surgeries because the expense for both examinations is too high to be afforded by many patients or covered by national health insurance. Therefore, understanding the risk factors for an ICA injury is as important as preoperative CT (or MR) scans when performing simple nasopharyngeal surgeries.

The purpose of this study attempted to reduce the risk of the ICA injury via analyzing the risk factors of ICA injuries during simple nasopharyngeal surgeries by measuring the shortening of mean distances to represent the risk of the ICA injury in adults. The potential risk factors analyzed in this study include nasopharyngeal ICA aberrations, aberrant types (severity), age, gender, body weight, and side (right or left).

Materials and methods

This is a retrospective study, with approval by the institutional review board. Patients with MR brain scans and MR angiograms (MRAs) were selected from routine adult health examinations between February and September 2011. A total of 178 consecutive patients were reviewed. The images were reviewed by an otolaryngologist, and a head and neck radiologist. To achieve the same numbers of male and female subjects, all 85 women were included, and up to 85 men were consecutively collected according to the timeframe. Scans with a motion artifact (3 scans) and scans that did not include the level of the eustachian tube (incomplete imaging, 5 scans) were excluded from analysis. A total of 170 MR brain scans (340 halves) were obtained for analysis, and the demographic data are shown in Table 1. All scans were obtained using a 1.5-Tesla scanner (GE Medical Systems, Milwaukee, WI, USA). The MR images consisted of axial T1 and T2 weighted images, post-contrast T1 weighted images, and MRAs. The standard three-dimensional time-of-flight MRA protocol for ICA was as follows: repetition time, 6 ms; echo time, 2 ms; flip angle, 45°; field of view, 30 × 30 cm. A picture archiving and communication system (INFINITT Healthcare, Seoul, Korea) was used to evaluate images. Measurements were taken on both sides for independent analysis. The courses of nasopharyngeal ICAs were examined and classified for an aberrant pathway according to the criteria of Paulsen et al. [13] with slight modifications. The courses of nasopharyngeal ICAs were classified as (1) straight without curvature if the deviation from the vertical was <15°, (2) curving or tortuosity if the deviation was >15° and <90° S or C-shaped elongation, (3) kinking if deviation was between 90° and 180°, and (4) coiling if a loop of 360° was visible. In the present study, ICA variations were classified by evaluating the medial deviation of the nasopharyngeal ICA on the coronal view of three-dimensional time-of-flight MRAs. The transverse plane was used to measure the distance between the ICA and nasopharyngeal wall. The anterosuperior torus tubarius (TT) was used as a marker, and all parameters were measured on this marker plane, including the distances from the anterior margin of the TT, the opening of the Rosenmuller's fossa (RF), and the posterior nasopharyngeal wall (PW), to the

Table 1 Demographic data

No. of patients included (halves)	170 (340)
Age (range), years[a]	53.2 ± 10.4 (27–81)
Age groups	No. of ICAs (%)
Under 40 years	34 (10.0 %)
41–50 years	102 (30.0 %)
51–60 years	128 (37.6 %)
Over 61 years	76 (22.4 %)
Gender	
Male:female	170:170
Side	
Right:left	170:170

[a] Mean ± standard deviation

Fig. 1 Axial contrast-enhanced T1 weighted MRI showing the distances from the ICA to the anterosuperior torus tubarius 'TT' '*solid line*', orifice of Rosenmuller's fossa 'RF' '*dashed line*', and posterior nasopharyngeal wall 'PW' '*solid line*'. *ICA* internal carotid artery, *arrow* indicates the eustachian tube orifice, *arrowhead* indicates the Rosenmuller's fossa, *dashed arrow* indicates the torus tubarius

closest margin of the ICA (Fig. 1). Nasopharyngeal ICA aberrations were distinguished from oropharyngeal aberrations by analyzing the coronal and transverse sections. A medial curving of the left ICA at the nasopharynx level (Fig. 2a), a kinking of the left ICA (Fig. 2b), and a coiling of the left ICA (Fig. 3a) were demonstrated. With the aid of the crosshairs on these axial and coronal images for the localization, the intricate course of the ICA aberration could be clarified in detail (Fig. 3a–c).

The numeric variables are presented as total numbers, percentages, mean values, and standard deviation. Analysis of variance or unpaired student *t* test was performed between the continuous data and the mean distance to the nasopharyngeal wall. Univariate analysis was performed between the potential predictors (aberrancy, age, gender, body weight, side) and the mean distance to the nasopharyngeal wall. Multivariate analysis using a multiple linear regression model was then performed, including significant variables on univariate analysis, to identify factors linked with the different outcomes. All statistical analyses were performed using Stata version 12.1 statistical software (StataCorp LP, College Station, Texas, USA). A value of $p < 0.05$ was considered statistically significant. Moreover, $p < 0.1$ was relaxed to be significant in multivariate models.

Results

The 170 subjects included in this study ranged from 27 to 81 years old (mean 53.2 years). Of the medial deviations,

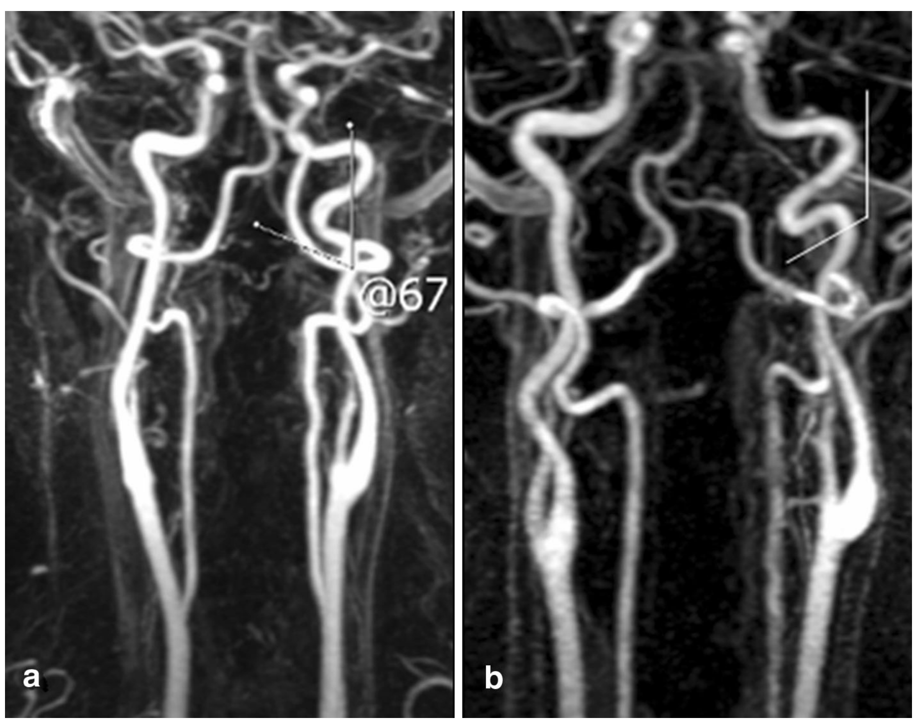

Fig. 2 Frontal projection images from the neck magnetic resonance angiogram revealing the aberrant ICAs at the nasopharynx level. **a** Curving (the angular degree measured with the inner protractor on a computer workstation and @67 shown to indicate 67°), **b** Kinking

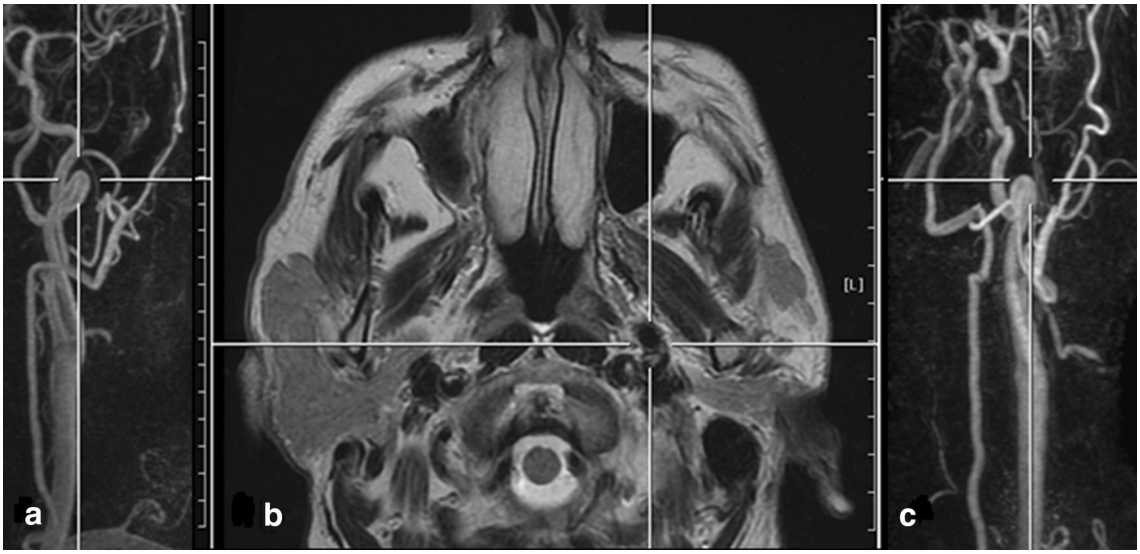

Fig. 3 **a** The left-sided coiled ICA shown. **b** The axial section revealing the horizontal run. The cross hairs in the coronal and axial views aiding differentiation. **c** The oblique view shown to help distinguish vessels

Table 2 Aberrant nasopharyngeal ICAs and the associated carotid artery measurements

	No. of ICAs (%)	MD to TT (mm)	MD to RF (mm)	MD to PW (mm)
Non-aberrant	299 (87.9 %)			
Aberrant	41 (12.1 %)			
Type				
Tortuous	36 (10.6)	19.7 ± 3.1	16.1 ± 3.6	16.9 ± 3.6
Kinked	3 (0.9)	20.0 ± 1.7	16.3 ± 2.1	17.7 ± 2.5
Coiled	2 (0.6)	21.0 ± 0	18.0 ± 1.4	18.5 ± 0.7

ICAs internal carotid arteries, *MD* mean distance, *PW* posterior nasopharyngeal wall, *RF* orifice of Rosenmuller's fossa, *TT* torus tubarius

nasopharyngeal ICA variations were detected in 41 (12.1 %) halves. Of the 41 (12.1 %) ICA variations in the nasopharynx, curving (tortuosity), kinking, and coiling were found in 36 (10.6 %) halves, 3 (0.9 %) halves, and 2 (0.6 %) halves, respectively. The severity of nasopharyngeal ICA aberrations (kinking and coiling) does not reflect the shortening of mean distances to nasopharyngeal subsites (Table 2). With increasing age, the mean distances from the vessel to nasopharyngeal subsites showed significant difference ($p < 0.05$). The mean distances from the ICA to nasopharyngeal subsites (TT, RF, PW) in men, in patients without nasopharyngeal ICA aberrancy, and in patients with higher body weight are significantly longer than those in women, in patients with aberrancy, and in patients with lower body weight, respectively (Table 3). Furthermore, the distance to the PW was also shortened with increasing age (Table 4).

Discussion

In the present study, the mean distances in the aberrant group were found to be significantly shorter than those in the non-aberrant group. From the literature, severe complications due to an ICA injury during simple nasopharyngeal surgeries with or without an endoscopic aid have been reported and were mainly attributed to the proximity of the ICA to the nasopharyngeal subsites [5, 6] and aberrant carotid arteries [7–9], which is consistent with our result. We think that because most ICA aberrations are medial deviations, the aberrations shorten the distance between the ICA and the nasopharyngeal wall (RF, TT, PW). It was also found that the severity (kinking and coiling) of nasopharyngeal ICA aberrations did not shorten the mean distances between the ICA and nasopharyngeal wall, which is consistent with another report [11]. However, because only five severe aberrations (three kinking, two coiling) were detected, the mean values could not be compared objectively.

In this study, by univariate linear regression analysis, the mean distances from the ICA to nasopharyngeal subsites were significantly associated with nasopharyngeal ICA aberrancy, age, gender, and body weight. However, by multiple linear regression analysis, the mean distances to nasopharyngeal subsites were significantly shortened in patients with nasopharyngeal ICA aberrancy, female gender, and lower body weight. It should be noted that the distance to PW was also shortened with increasing age. Deutsch et al. [15] undertook MRI studies in children with no anomalies of ICAs and reported that the distance from the ICA to the TT increases with age, which is inconsistent

Table 3 Analysis of the associated factors with mean distances to nasopharyngeal Subsites

Factors (no. of ICAs)	TT	*p* value	RF	*p* value	PW	*p* value
Aberrancy						
Yes (41)	19.8 ± 2.9	<0.001	16.2 ± 3.4	<0.001	17.1 ± 3.4	<0.001
No (299)	23.3 ± 3.0		20.1 ± 3.4		20.9 ± 3.4	
Age groups, years						
≦40 (34)	22.9 ± 2.6	0.007	20.3 ± 3.0	0.016	21.3 ± 2.9	0.008
41–50 (102)	23.3 ± 2.9		20.0 ± 3.5		20.9 ± 3.5	
51–60 (128)	23.2 ± 3.3		19.7 ± 3.6		20.6 ± 3.6	
≧61 (76)	21.8 ± 3.5		18.5 ± 3.7		19.3 ± 3.8	
Gender						
Male (170)	24.2 ± 3.0	<0.001	21.6 ± 3.0	<0.001	22.4 ± 3.1	<0.001
Female (170)	21.5 ± 2.9		17.6 ± 3.0		18.5 ± 3.0	
Body weight (kg)[a]						
≧65.2 (162)	23.8 ± 3.0	<0.001	21.3 ± 3.0	<0.001	22.1 ± 3.1	<0.001
<65.2 (178)	22.0 ± 3.2		18.0 ± 3.4		19.0 ± 3.4	
Side						
Right (170)	22.8 ± 3.2	0.893	19.8 ± 3.4	0.329	20.7 ± 3.4	0.150
Left (170)	22.9 ± 3.3		19.4 ± 3.8		20.2 ± 3.8	

[a] Body weight (mean 65.2 kg)

Table 4 Multiple linear regression model to predict the factors associated with mean distances to nasopharyngeal subsites

Variable	Regression coefficient	95 % confidence interval	*p* value
TT			
Aberrancy	−3.47	−4.35 to −2.58	<0.001
Gender	−1.9	−2.62 to −1.21	<0.001
Body weight	+0.05	+0.02 to +0.07	0.001
RF			
Aberrancy	−3.91	−4.75 to −3.08	<0.001
Gender	−2.49	−3.16 to −1.82	<0.001
Body weight	+0.10	+0.07 to +0.13	<0.001
PW			
Aberrancy	−3.85	−4.70 to −3.00	<0.001
Gender	−2.50	−3.18 to −1.81	<0.001
Body weight	+0.09	+0.06 to +0.12	<0.001
Age	−0.03	−0.05 to −0.00	0.054

with our result. Older patients in the age range between 27 and 81 years have lower muscle mass (levator veli palatini muscle) but increased fatty tissue between the ICA and TT, so the distance to the TT is not as lengthened as that in young age patients. Bergin et al. [5] undertook CT studies according to the classification by Weibel and Fields and reported that the predicted minimum safe distance for all patients was different for male and female subjects, and also varied with age, which is similar to our findings. From the anatomic point of view, more fatty tissue is located from the ICA to the TT and RF than from the ICA to the PW. However, more muscle (longus capitis muscle) is located from the ICA to the PW than from the ICA to the TT (levator veli palatini muscle) and RF. Patients with advanced age are considered to have lower muscle mass and increased fatty tissue [23], causing more shortening of the distance to PW than shortening of the distances to RF and TT, so the mean distances to TT and to RF are not significantly shortened with increasing age on the model of multiple linear regression. Furthermore, patients with body weight higher than average have more connective tissue (fat, muscle) than those with lower body weight, causing longer mean distances to nasopharyngeal wall (TT, RF, PW). It was presumed that women have less muscle mass (levator veli palatini muscle, longus capitis muscle) than men and therefore have shorter mean distances (TT, RF, PW) than men. From the literature, ICA aberrancy was found in almost 36 % of the population [5]. However, nasopharyngeal ICA aberrancy was found in about 12 % of the population in our series. The difference of the incidence of ICA aberrancy was presumably from an ethnic difference (between New Zealand Caucasians and Taiwan Han Chinese) and a different criterion for the classification. From the report, the minimal critical distance from the ICA to the TT was also analyzed for applications in eustachian tuboplasty without aberrant severity and body weight included, but predictions based on age, sex, and carotid aberrancy did not explain all the variability of distance. In contrast, we analyzed more factors than Bergin et al., to predict the factors associated with mean distances to nasopharyngeal subsites, and found the variability of distance could be explained by ICA aberrancy, gender, body weight, and age. Although many factors affect the distance between the ICA and nasopharyngeal wall, ICA aberrancy is considered to be critical in determining the distance because of the largest absolute value of regression coefficient among age, gender, body weight, and aberrancy. In the literature, most of the studies were aimed at estimating the distance between the ICA and oropharyngeal wall for clinical applications in oropharyngeal surgeries, and only a few studies provided partial information on the distance between the ICA and nasopharyngeal subsites by analyzing the CT and/or MR scans according to the classification by Weibel and Fields [5, 11]. In contrast, by analyzing the MR brain scans and MRAs according to the criteria by Paulsen et al. [13], we estimated the distances between the ICA and nasopharyngeal subsites to provide simpler and clearer associations between various variables (nasopharyngeal ICA aberrancy, age, gender, body weight) and distances to nasopharyngeal subsites for risk assessments. The results also provide relative effect of various variables on the distances to nasopharyngeal subsites.

Some patients have close distances between the ICA and nasopharyngeal subsites, but because of the high price, it is difficult to arrange either CT or MR scans preoperatively to evaluate the critical distances when performing these simple nasopharyngeal surgeries. Without the preoperative anatomic evaluation by either CT or MR scanning, the relationship between the ICA and nasopharyngeal subsites may be speculated by ICA aberrancy, gender, body weight, and age. Therefore, in addition to experience and skills, severe complications due to an ICA injury may be prevented by further understanding the risk factors for the ICA injury instead of arranging preoperative CT and MR scans during simple nasopharyngeal surgeries.

The limitations of this study are that first, only the distances at the level of the anterosuperior torus are measured to represent the level of the nasopharynx, which leads to deviations from omitting other values at higher levels of the nasopharynx; secondly, the effect of aberrant types (severity) on the distance to the nasopharyngeal wall cannot be objectively analyzed because of insufficient numbers of severe aberrant ICAs.

Conclusions

Simple nasopharyngeal surgeries with or without an endoscopic aid performed by otolaryngologists include eustachian tuboplasty, adenoidectomies, nasopharyngeal biopsies, and so on. Severe complications caused by an ICA injury during these surgeries are infrequent but fatal. In this study, from the univariate linear regression analysis, it was found that the mean distance between the ICA and nasopharyngeal wall is significantly affected by the presence of nasopharyngeal ICA aberrancy, age, gender, and body weight. In addition, from multiple linear regression analysis, it was found that the risk of an ICA injury during simple nasopharyngeal surgeries may increase foremost in adult patients with nasopharyngeal ICA aberrancy, followed by female gender, lower body weight, and increasing age.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Solares CA, Ong YK, Carrau RL, Fernandez-Miranda J, Prevedello DM, Snyderman CH, Kassam AB (2010) Prevention and management of vascular injuries in endoscopic surgery of the sinonasal tract and skull base. Otolaryngol Clin North Am 43:817–825
2. Weidenbecher M, Huk WJ, Iro H (2005) Internal carotid artery injury during functional endoscopic sinus surgery and its management. Eur Arch Otorhinolaryngol 262:640–645
3. Koitschev A, Simon C, Lowenheim H, Naeqele T, Ernemann U (2006) Management and outcome after internal carotid artery laceration during surgery of the paranasal sinuses. Acta Otolaryngol 126:730–738
4. Isenberg SF, Scott JA (1994) Management of massive hemorrhage during endoscopic sinus surgery. Otolaryngol Head Neck Surg 111:134–136
5. Bergin M, Bird P, Cowan I, Pearson JF (2010) Exploring the critical distance and position relationships between the eustachian tube and the internal carotid artery. Otol Neurotol 31:1511–1515
6. O'Connor A, Shea J (1981) Autophony and the patulous Eustachian tube. Laryngoscope 91:1427–1435
7. Windfuhr JP, Schloendorff G, Sesterhenn AM, Prescher A, Kremer B (2009) A devastating outcome after adenoidectomy and tonsillectomy: ideas for improved prevention and management. Otolaryngol Head Neck Surg 140:191–196
8. Mckenzie W, Woolf CI (1959) Carotid abnormalities and adenoid surgery. J Laryngol 73:596–602
9. Osguthorpe JD, Adkins WY, Putney FJ, Hungerford GD (1981) Internal carotid artery as source of tonsillectomy and adenoidectomy hemorrhage. Otolaryngol Head Neck Surg 89:758–762
10. Ozgur Z (2007) A study of the course of the internal carotid artery in the parapharyngeal space and its clinical importance. Eur Arch Otorhinolaryngol 264:1483–1489
11. Pfeiffer J, Ridder GJ (2008) A clinical classification system for aberrant internal carotid arteries. Laryngoscope 118:1931–1936
12. Weibel J, Fields WS (1965) Tortuosity, coiling, and kinking of the internal carotid artery. I. Etiology and radiographic anatomy. Neurology 15:7–18
13. Paulsen F, Tillmann B, Christofides C, Richter W, Koebke J (2000) Curving and looping of the internal carotid artery in relation to the pharynx: frequency, embryology and clinical implications. J Anat 197:373–381
14. Metz H, Murray-Leslie RM, Bannister RG, Bull JW, Marshall J (1961) Kinking of the internal carotid artery. Lancet 1:424–426
15. Deutsch MD, Kriss VM, Willging JP (1995) Distance between the tonsillar fossa and internal carotid artery in children. Arch Otolaryngol Head Neck Surg 121:1410–1412

16. Wen YH, Wen WP, Chen HX, Li J, Zeng YH, Xu G (2010) Endoscopic nasopharyngectomy for salvage in nasopharyngeal carcinoma: a novel anatomic orientation. Laryngoscope 120: 1298–1302
17. Kujawski OB, Poe DS (2004) Laser Eustachian tuboplasty. Otol Neurotol 25:1–8
18. Poe DS, Grimmer JF, Metson R (2007) Laser Eustachian tuboplasty: two-year results. Laryngoscope 117:231–237
19. Metson R, Pletcher SD, Poe DS (2007) Microdebrider Eustachian tuboplasty: a preliminary report. Otolaryngol Head Neck Surg 136:422–427
20. Jurkiewicz D, Bien D, Szczygielski K, Kantor I (2013) Clinical evaluation of ballon dilation Eustachian tuboplasty in the Eustachian tube dysfunction. Eur Arch Otorhinolaryngol 270:1157–1160
21. Shapshay SM (1987) Laser applications in the trachea and bronchi: a comparative study of the soft tissue effects using contact and noncontact delivery systems. Laryngoscope 97:1–26
22. Pratt LW (1970) Tonsillectomy and adenoidectomy: mortality and morbidity. Trans Am Acad Ophthalmol Otolaryngol 74:1146–1154
23. Ito H, Ohshima A, Ohto N, Ogasawara M, Tsuzuki M, Takao K, Hijii C, Tanaka H, Nishioka K (2001) Relation between body composition and age in healthy Japanese subjects. Eur J Clin Nutr 55:462–470