



Facial canal dehiscence in patients with cholesteatoma: concordance between intraoperative inspection, computed tomography and neurophysiological findings

Francisco Arias-Marzán¹ · Gemma de Lucas-Carmona¹ · Esteban Reinaldo Pacheco Coronel¹ · Pedro Javier Perez Lorensu² · Alejandro Jiménez-Sosa³ · Blas Pérez-Piñero¹

Received: 19 November 2018 / Accepted: 28 March 2019 / Published online: 6 April 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

Abstract

Objectives To assess the diagnostic capacity of intraoperative neurophysiological monitoring with respect to “gold standard” microscopic findings of facial canal dehiscence in middle ear cholesteatoma surgery.

Study design, patients and setting We carried out a retrospective cohort study of 57 surgical interventions for cholesteatoma between 2008 and 2013 at Hospital Universitario de Canarias, Spain.

Diagnostic interventions Each patient underwent preoperative computed tomography (CT), intraoperative neurophysiological monitoring and intraoperative inspection of the facial nerve during microsurgery. Diagnostic concordance on the presence/absence of facial canal dehiscence was assessed in 54 surgical interventions.

Main outcome Presence of facial canal dehiscence.

Results Of 57 interventions, 39 were primary surgeries; 11 (28.2%) showed facial canal dehiscence. and 18 were revision surgeries; 6 (33.3%) showed facial canal dehiscence. The facial nerve was not damaged in any patient. Facial canal dehiscence was observed in 17 (29.82%) interventions. We used intraoperative microscopic findings as the gold standard. Neurophysiological study showed a sensitivity of 94.1, specificity 97.3, positive predictive value (PPV) 57.8 and negative predictive value of 97.2. CT showed a sensitivity of 64.7, specificity 78.4, PPV 57.8 and negative predictive value of 82.

Conclusions Our neurophysiological study showed greater sensitivity and higher PPV than CT for the detection of facial canal dehiscence. We found no relationship between disease progression time and the presence of facial canal dehiscence.

Keywords Cholesteatoma surgery · Facial canal dehiscence · Neurophysiological monitoring

Introduction

Dehiscence of the facial canal leaves the facial nerve exposed in this portion of the middle ear. It is probably one of the most important causes of facial nerve injury

during middle ear surgery [1]; the facial nerve may protrude into the cavity of the middle ear and may sometimes be observed outside the canal [2].

During middle ear or mastoid surgery, the facial nerve is vulnerable because of its proximity to the cochlea, oval

✉ Esteban Reinaldo Pacheco Coronel
epaccor@gobiernodecanarias.org;
estebanpachecocoronel@hotmail.com

Francisco Arias-Marzán
fmarzan73@yahoo.es

Gemma de Lucas-Carmona
gemmaelucas@yahoo.es

Pedro Javier Perez Lorensu
Perezlorensu@yahoo.es

Alejandro Jiménez-Sosa
ajimenezsosa@gmail.com

Blas Pérez-Piñero
bperez@ull.edu.es

¹ ENT Service, Hospital Universitario de Canarias, Ctra. Ofra S/N La Cuesta, 38320 La Laguna, Santa Cruz de Tenerife, Spain

² Intraoperative Neuromonitoring Unit, Hospital Universitario de Canarias, Ctra. Ofra S/N La Cuesta, 38320 La Laguna, Santa Cruz de Tenerife, Spain

³ Research Unit, Hospital Universitario de Canarias, Ctra. Ofra S/N La Cuesta, 38320 La Laguna, Santa Cruz de Tenerife, Spain

window, lateral semicircular canal, and vestibule. Facial nerve dehiscence can occur due to multiple circumstances, even associated with cholesteatoma, and is, therefore, a risk factor, because without its bony coating, it can be damaged during surgical maneuvers [3]. In addition, the risk of damage has been described to increase with reoperation for revision (increases the percentage of dehiscence) [4]. There may even be anatomical variations of the facial nerve in its otic segment with bifid or even cystic formations [5].

The aim of the present study was to assess the utility of routine facial nerve neurophysiological monitoring using low-intensity electrical stimulation during middle ear cholesteatoma surgery, to alert the surgeon of possible injury and reduce the risk of causing irreversible damage. A secondary aim was to describe the frequency of facial canal dehiscence in patients with cholesteatoma, at primary or revision surgery, its location and the influence of patient age and disease evolution time on the development of facial canal dehiscence.

Materials and methods

Design and patients

We carried out a retrospective cohort study of 57 surgical interventions for cholesteatoma performed between January 2008 and December 2013 at Hospital Universitario de Canarias, Spain. Inclusion criteria were clinical and histopathological diagnoses of cholesteatoma, preoperative CT scan, and intraoperative neurophysiological monitoring to detect facial canal dehiscence.

We recorded patient age, gender and any previous middle ear surgery. The diagnostic techniques used to detect facial canal dehiscence were preoperative CT scan, intraoperative neurophysiological monitoring and intraoperative visualization of the facial nerve.

Procedure

For each patient meeting the inclusion criteria, we recorded clinical and demographic variables. Before surgery, temporal bone CT scan without contrast was performed with 1-mm horizontal and coronal slices using a Toshiba Aquilion 64 scanner. We scanned the three main segments of the facial canal: the labyrinth, the tympanic and the mastoidal segments.

Coronal sections allowed circumferential assessment of the tympanic and the mastoid segments. With horizontal slices, we explored the lateral wall of the facial canal

in its tympanic portion. CT scans were evaluated by the same two operators using the same criterion for facial canal dehiscence, namely interruption of the tympanic and mastoid segments of the facial canal evident in both coronal and horizontal planes.

Intraoperative neurophysiological facial nerve monitoring

Since the initial studies, it is recommended not to infiltrate with local anesthetic because it can temporarily block the facial nerve motor responses [5]. We use partial nondepolarizing neuromuscular blocking agents remifentanyl and propofol and stimulation thresholds and amplitudes were recorded at each train-of-four (TOF) nerve stimulation level [6].

The characteristics of intraoperative monitoring in this type of surgery were similar to those previously reported: needles are placed in the facial muscles to obtain the EMG response, both electrically evoked and spontaneously by direct maneuvers on the nerve (the stimulator electrode settings at 8 Hz and 100 μ s in duration) [4].

Similar papers [4] have described that if the threshold of stimulation of the facial nerve is less than 1 V, the facial nerve is electrophysiologically dehiscent [3], and should be considered at risk [7]. The same group studied the data and converted from milliamperes to volts using an empirically determined impedance of 1.3 kV (thus, 1 V is similar to 0.77 mA). Other groups consider upper limits of thresholds at 0.29 mA in the tympanic segment and 0.41 mA in the mastoid. Stimulation intensities greater than 1 mA would indicate 1 mm of bone protection [5].

In addition to the stimulation, continuous EMG monitoring in free sweep allows us to assess possible compressions or lacerations of the nerve while removing the mucosa or tumor [4].

In fact, there are commercial devices that allow electrical stimulation while the bone is milled [8].

All patients underwent intraoperative facial nerve monitoring using Cadwell Cascade Elite equipment (Cadwell Labs, USA). Pairs of subdermal monopolar needles (Ambu 12 \times 0.40 mm) were inserted in frontal, nasal, orbicular, ocular and chin muscles. Electrical stimulation of 100 ms duration was performed with a single-phase monopolar electrode (Medtronic), and a subdermal needle in adjacent musculature was used as a reference.

Electrical dehiscence was considered to be present if electrical stimulation with intensities lower than 0.7 mA caused a motor response greater than 50 μ V amplitude [3]. The same neurophysiologist specialized in intraoperative neurophysiological monitoring was present at all surgical

interventions, indicating any facial nerve stimulation and thresholds.

Surgery and CT

During surgery, dehiscence of the facial canal was considered to be present when it was microscopically observed during surgery and the facial nerve without bone cover was visually verified.

Both CT and neurophysiological monitoring were considered as diagnostic tests to predict the existence of dehiscence. In all patients, the histopathological samples, taken and sent after surgery, were diagnosed as cholesteatoma.

Concordance between diagnostic techniques was calculated for 54 interventions because 3 patients underwent surgery more than twice in 1 ear.

Statistical analysis

Quantitative variables are expressed as means and standard deviation (SD), and categorical variables as absolute frequencies and percentages.

Regarding the presence of facial dehiscence and patient age, the sample was divided into two age groups (≥ 16 and < 16 years), and the proportion of dehiscence in each group was compared.

Proportions were compared with Jonckheere–Terpstra test

The concordance between preoperative CT, intraoperative neurophysiological and the “gold standard” microscopic findings was assessed using Cohen’s kappa coefficient with 95% confidence intervals (CI).

Two-by-two comparisons of concordance coefficients were performed using STATISTICA v. 7.0 (Stat Soft, OK). The remaining analyses were performed using SPSS v. 17.0 (Chicago, IL). Differences with a p value lower than 0.05 were considered statistically significant.

The following rule [9] was used to categorize the degree of concordance (Table 1).

Results

We analyzed the surgical characteristics of 57 interventions in 50 patients aged 41 ± 20 years, of which 36 (66.7%) were men. Seven of these 50 patients underwent 2 surgeries, 5 due to relapse and 2 due to bilateral cholesteatoma.

Of these interventions, 39 were primary surgeries, and 18 were second or more surgeries. Facial canal dehiscence was microscopically observed in 17 (29.82%) interventions.

Table 1 Categories for kappa coefficients

Kappa coefficient	Concordance
< 0.20	Poor
0.21–0.40	Weak
0.41–0.60	Moderate
0.61–0.80	Good
0.81–1.00	Very good

Regarding the presence of dehiscence according to age group, in patients younger than 16 years, only one (14.3%) had facial canal dehiscence. Of the remaining 50 patients aged > 16 years, 16 (32%) had dehiscence ($p = 0.42$).

Table 2 shows surgery characteristics according to the presence or absence of facial canal dehiscence, age, evolution time.

We did not observed statistically significant difference between patients undergoing one or two surgical interventions ($p = 0.52$), nor between patients aged < 16 and ≥ 16 years ($p = 0.42$).

Table 3 shows the frequency distributions and concordance between the three diagnostic techniques according to the presence or absence of facial canal dehiscence, for all patients, for those undergoing only one intervention and those undergoing two interventions.

The concordance between intraoperative microscopic and neurophysiological findings ($p < 0.001$) was significantly higher than that between microscopic and CT findings; it was not significant between CT and microscopic findings or between CT and neurophysiological findings ($p = 0.60$ for both).

For the whole cohort and for the subgroup undergoing only one intervention, two-by-two comparison of concordance coefficients showed significant differences between neurophysiological and microscopic findings and between microscopic and CT findings ($p < 0.001$). No significant differences were observed between CT and neurophysiological findings or between CT and microscopic findings ($p = 0.50$).

For the subgroup undergoing revision surgery, two-by-two comparison of concordance coefficients showed no significant differences between neurophysiological–microscopic findings and CT–microscopic findings ($p = 0.26$), between neurophysiological–microscopic and neurophysiological–CT findings ($p = 0.072$) or between CT–neurophysiological and CT–microscopic findings ($p = 0.50$).

Table 3 also shows the diagnostic concordance between intraoperative observation “in situ” (microsurgery) and neurophysiological or CT findings, according to the number of surgical interventions.

Taking “in situ” inspection during microsurgery as the gold standard, intraoperative neurophysiological study

Table 2 Surgery characteristics according to the presence or absence of facial canal dehiscence, age and evolution time

	Dehiscence, <i>n</i> (%)		<i>p</i>
One surgery (<i>n</i> = 39)	11 (28)		0.76
More than one surgery (<i>n</i> = 18)	6 (33)		
Age < 16 years (<i>n</i> = 7)	1 (14.3)		0.42
Age ≥ 16 years (<i>n</i> = 50)	16 (32)		
	Dehiscence (<i>n</i> = 17)	No dehiscence (<i>n</i> = 50)	<i>p</i>
CT-to-surgery time (months)	5 ± 3	5 ± 6	0.9

Table 3 Kappa concordance with 95% confidence intervals (CI) in the whole cohort, with one or more surgeries

	Kappa (95% CI)	<i>p</i>
Overall cohort (<i>n</i> = 54)		
CT–neurophysiology	0.33 (0.067–0.592)	0.04
CT–microsurgery	0.42 (0.165–0.674)	0.002
Microsurgery–neurophysiology	0.91 (0.796–1.000)	< 0.001
Cohort with one surgery (<i>n</i> = 39)		
CT–neurophysiology	0.357 (0.051–0.662)	0.024
CT–microsurgery	0.357 (0.051–0.662)	0.024
Microsurgery–neurophysiology	0.99 (0.998–1.001)	0.001
Cohort with two surgeries (<i>n</i> = 15)		
CT–neurophysiology	0.286 (0.204–0.776)	0.26
CT–microsurgery	0.571 (0.139–0.999)	0.025
Microsurgery–neurophysiology	0.722 (0.369–0.999)	0.005

showed significantly better diagnostic capacity than preoperative CT for the detection of facial canal dehiscence in the whole cohort (with one or two interventions), but in revision surgeries the difference was not significant.

Discussion

Damage to the facial nerve during middle ear surgery is a possible complication, especially in the area of the tympanic region or in the mastoid. The tympanic segment of the facial nerve is vulnerable since it is usually dehiscent, and this incidence of dehiscence is increased in the presence of chronic otitis media and cholesteatomas [10].

Silverstein performed the first regulated studies on intraoperative neurophysiological monitoring (IOM) in middle ear surgery in 1988 [5, 11] although it was already stated at that time that this monitoring does not replace the need to have an exquisite surgical technique and exhaustive knowledge of the anatomy of the area. Back in 2002, a survey in the USA defined the validity and necessity of IOM in this type of surgeries [12], and in 2003, its validity

in cost-effectiveness was demonstrated [13] and its use is becoming more frequent [14].

In addition to surgery of the posterior fossa, the facial nerve should be monitored to prevent iatrogenic injuries [4], which is between 0.6 and 3.6% of primary interventions [11], and 4 and 10% in reinterventions [13, 15]. The dehiscence of the facial nerve in this type of pathology is considered to be close to 38% and may be anatomically bifurcated or bifid [1, 4, 7].

The presence of facial canal dehiscence in patients undergoing microsurgery for cholesteatoma implies increased surgical risk of damaging the facial nerve, with serious consequences. Taking intraoperative microscopic findings as the gold standard, we assessed the diagnostic accuracy of preoperative CT and intraoperative neurophysiological monitoring for the detection of facial canal dehiscence.

We found high concordance between neurophysiological findings and microscopic observations during microsurgery, in accordance with reports by other authors [7, 12], especially in primary as compared with revision surgeries.

Regarding preoperative CT, we found low concordance with intraoperative findings, unlike some authors who have reported high sensitivity and good concordance [16]. Our results are more consistent with those of studies with larger sample sizes [17] although they did show lower sensitivity and specificity.

We believe the reason for this discrepancy, beyond image interpretation or technique of acquisition, may be related to the anatomy of the facial nerve, which in its tympanic portion is extremely thin; this hinders interpretation of the integrity of bone coverage. In our study, the average interval between preoperative CT and surgery was 4 months which seems insufficient time for bone resorption to occur, although we have not found previous studies on this aspect.

Regarding safety, no patient suffered facial paresis or paralysis; in previous reports, this ranges from 0.6 to 3.6% [18]. In our study, less than a third of patients were diagnosed with facial canal dehiscence, with a slightly higher proportion in those undergoing revision surgery, and all were located in the tympanic segment except one, which was located in the mastoidal segment, associated with a high

jugular bulb. The predominance of tympanic segment location coincides with previously reported data [2, 19].

In our study, no lateral semicircular canal fistulas were detected. In previous studies [1, 18], an association was observed between lateral semicircular canal fistula and facial dehiscence, which was nearly fivefold more frequent in the presence of the fistula. The presence of a semicircular canal fistula detected with radiology or intraoperative microscopy should alert us to the presence of a dehiscence of the facial nerve.

With respect to patient age and the presence of facial canal dehiscence, we observed no statistically significant differences between children under 16 and adults, although other authors have reported that facial canal dehiscence is five times more frequent in adults, possibly due to prolonged disease progression and more severe lesions [18].

On comparing CT-to-surgery time between patients with versus without dehiscence, we observed no statistical difference between the two groups. The explanation may be the short CT-to-surgery time in our sample of patients, which ranged from 2 to 9 months since previous authors refer to an increase of dehiscence associated with disease progression over 5 years.

The main limitations are the retrospective design, the relatively small sample size and the fact that the study was performed in a single center.

In conclusion, neurophysiological study showed greater sensitivity and higher PPV than CT for the detection of facial canal dehiscence. CT-to-surgery time was not different between patients with and without dehiscence, and we observed no statistically significant differences according to age in our series of patients.

Conclusions

1. In our series, intraoperative neurophysiological study showed very high sensitivity (99%) for the detection of facial canal dehiscence in primary surgeries.
2. Preoperative computed tomography showed limited sensitivity (50%) for the detection of facial canal dehiscence.
3. We observed no statistically significant differences in the diagnosis of dehiscence between primary and revision surgeries.
4. We found no data to support a clear influence of disease progression time on the presence of facial canal dehiscence.
5. There was also no relationship between patient age and the presence of dehiscence in any segments of the facial canal.

6. There was no alteration of facial functionality in any of the study patients, regardless of whether they underwent primary or revision surgery.
7. During microsurgery for cholesteatoma, intraoperative neurophysiological monitoring of the facial canal provides valuable information for the operator, thus minimizing the surgical risk of facial nerve injury. It has been progressively used in our department, from 2 interventions in 2008 to 19 interventions in 2013 (almost 100% of the surgeries performed that year).

Funding This study was performed without funding.

Compliance with ethical standards

Conflict of interest Francisco Arias-Marzán declares that he has no conflict of interest; Gemma de Lucas-Carmona declares that she has no conflict of interest; Esteban Reinaldo Pacheco-Coronel declares that he has no conflict of interest; Pedro Javier Pérez Lorensu declares that he has no conflict of interest; Alejandro Jiménez-Sosa declares that he has no conflict of interest; Blas Pérez-Piñero declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Selesnick SH, Lynn-Macrae AG (2001) The incidence of facial nerve dehiscence at surgery for cholesteatoma. *Otol Neurotol* 22(2):129–132
2. Nager GT, Proctor B (1982) The facial canal: normal anatomy, variations and anomalies. II. Anatomical variations and anomalies involving the facial canal. *Ann Otol Rhinol Laryngol Suppl* 97:45–61
3. Choung YH, Park K, Cho MJ, Choung PH, Shin YR, Kahng H (2006) Systematic facial nerve monitoring in middle ear and mastoid surgeries: “surgical dehiscence” and “electrical dehiscence”. *Otolaryngol Head Neck Surg* 135(6):872–876
4. Noss RS, Lalwani AK, Yingling CD (2001) Facial nerve monitoring in middle ear and mastoid surgery. *Laryngoscope* 111(5):831–836
5. Silverstein H, Smouha EE, Jones R (1988) Routine intraoperative facial nerve monitoring during otologic surgery. *Am J Otol* 9(4):269–275
6. Choe WJ, Kim JH, Park SY, Kim J (2013) Electromyographic response of facial nerve stimulation under different levels of neuromuscular blockade during middle-ear surgery. *J Int Med Res* 41(3):762–770

7. Heman-Ackah SE, Gupta S, Lalwani AK (2013) Is facial nerve integrity monitoring of value in chronic ear surgery? *Laryngoscope* 123(1):2–3
8. Bernardeschi D, Meskine N, Otaibi NA, Ablonczy R, Kalamarides M, Grayeli AB, Sterkers O (2011) Continuous facial nerve stimulating burr for otologic surgeries. *Otol Neurotol* 32(8):1347–1351
9. Ashby D (1991) *Practical statistics for medical research*. Douglas G. Altman, Chapman and Hall, London, 1991. *Stat Med* 10(10):1635–1636. <https://doi.org/10.1002/sim.4780101015>
10. Linder T, Mulazimoglu S, El Hadi T, Darrouzet V, Ayache D, Somers T, Schmerber S, Vincent C, Mondain M, Lescanne E, Bonnard D (2017) Iatrogenic facial nerve injuries during chronic otitis media surgery: a multicentre retrospective study. *Clin Otolaryngol* 42(3):521–527
11. Silverstein H, Smouha E, Jones R (1988) Routine identification of the facial nerve using electrical stimulation during otological and neurotological surgery. *Laryngoscope* 98(7):726–730
12. Greenberg JS, Manolidis S, Stewart MG, Kahn JB (2002) Facial nerve monitoring in chronic ear surgery: US practice patterns. *Otolaryngol Head Neck Surg* 126(2):108–114
13. Wilson L, Lin E, Lalwani A (2003) Cost-effectiveness of intraoperative facial nerve monitoring in middle ear or mastoid surgery. *Laryngoscope* 113(10):1736–1745
14. Hu J, Fleck TR, Xu J, Hsu JV, Xu HX (2014) Contemporary changes with the use of facial nerve monitoring in chronic ear surgery. *Otolaryngol Head Neck Surg* 151(3):473–477
15. Ryu NG, Kim J (2016) How to avoid facial nerve injury in mastoidectomy? *J Audiol Otol* 20(2):68–72
16. Yu Z, Wang Z, Yang B, Han D, Zhang L (2011) The value of preoperative CT scan of tympanic facial nerve canal in tympanomastoid surgery. *Acta Otolaryngol* 131(7):774–778
17. Cai YR, Xu J, Chen LH, Chi FL (2009) Electromyographic monitoring of facial nerve under different levels of neuromuscular blockade during middle ear microsurgery. *Chin Med J (Engl)* 122(3):311–314
18. Magliulo G, Colicchio MG, Appiani MC (2011) Facial nerve dehiscence and cholesteatoma. *Ann Otol Rhinol Laryngol* 120(4):261–267
19. Moreano EH, Paparella MM, Zelterman D, Goycoolea MV (1994) Prevalence of facial canal dehiscence and of persistent stapedia artery in the human middle ear: a report of 1000 temporal bones. *Laryngoscope* 104(3 Pt 1):309–320

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.