The Journal of Laryngology & Otology (2016), ***130***, *219–224*.

doi:10.1017/S0022215115003394

REVIEW ARTICLE

Facial nerve management in jugular paraganglioma surgery: a literature review

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Abstract

Objective: This literature review analysed facial nerve management strategies in jugular paraganglioma surgery and discusses the tumour resection rate and the facial nerve outcome associated with each technique.

Methods: A retrospective review of PubMed and Medline articles on the surgical treatments for jugular paraganglioma was performed. Tumour resection rates and post-operative facial nerve function after non-rerouting, short anterior rerouting and long anterior rerouting approaches were evaluated for each article.

Results: A total of 15 studies involving a total of 688 patients were included. Post-operative facial nerve function was similar after non-rerouting and short anterior rerouting approaches ($p = 0.169$); however, both of these techniques had significantly better post-operative facial nerve outcomes compared with long anterior rerouting ($p < 0.001$ and $p = 0.001$, respectively). The total tumour removal rate was significantly higher for long anterior rerouting than with the non-rerouting approach ($p = 0.016$). There was no difference in total tumour removal rate between the long and short anterior rerouting approaches ($p = 0.067$) and between the short anterior rerouting and non-rerouting approaches ($p = 0.867$).

Conclusion: No strict guidelines for facial nerve management in jugular paraganglioma resection are available. Although long anterior rerouting provides the best tumour exposure along with a low morbidity rate, case-by-case selection of the surgical approach is recommended.

Key words: Facial Nerve; Facial Paralysis; Glomus Jugulare; Paraganglioma; Skull Base Neoplasms

Introduction

Jugular paragangliomas are the most common neoplasms to affect the jugular foramen.[1] Their main presenting symptoms are hearing loss and pulsatile tinnitus, although lower cranial nerve deficits may occur in up to 10 per cent of patients.[2] Facial nerve paralysis may occur in jugular paraganglioma patients as a result of direct nerve invasion.[3] Although these tumours are histologically benign, they can cause extensive local invasion of the bone, soft tissues and nerves.[4]

The ideal primary treatment for these tumours is total surgical extirpation with preservation of the lower cranial nerves and major vessels.[5,6] However, they arise in anatomically complex areas and affect critical neurovascular structures. The facial nerve is a major obstacle to tumour resection because it impedes the free manipulation of the tumour medial to it and obscures access to the jugular foramen and the intratemporal portion of the internal carotid artery (ICA).[7]

Three techniques have been described for handling the facial nerve during jugular paraganglioma surgery: non-rerouting, without facial nerve exposure; short anterior rerouting, in which only the mastoid segment of the facial nerve from the stylomastoid foramen to the second genu is anteriorly rerouted; and long anterior rerouting, in which the facial nerve is anteriorly transposed from the stylomastoid foramen to the first genu (geniculate ganglion).

This literature review discusses facial nerve management techniques in jugular paragangliomas and describes the tumour resection rate and facial nerve outcome for each technique.

Materials and methods

A retrospective review of articles retrieved from the PubMed and Medline databases on the surgical treatment of jugular paraganglioma up to February 2015 was performed. The search terms were 'tympanojugular paraganglioma', 'glomus jugulare', 'jugular

Accepted for publication 2 October 2015 First published online 16 December 2015

foramen tumours', 'rerouting of the facial nerve', 'infratemporal fossa approach', 'facial nerve management in glomus jugulare' and all combinations of these terms.

Inclusion criteria were that articles should be published in English, discuss only jugular paragangliomas (Fisch classes C and/or D), report a series of more than 10 cases, and include precise pre- and post-operative facial nerve assessment using the House–Brackmann scale and descriptions of the tumour resection rate and long-term follow up (>1 year). Articles published in a language other than English and those reporting a small case series (<10 cases), duplicate data, a glomus tympanicum series or jugular foramen tumours other than jugular paragangliomas, and with facial nerve outcome not interpreted according to the House–Brackmann scale and short-term follow up (<1 year) were excluded.

Post-operative facial nerve function, the surgical technique used to manipulate the facial nerve (non-rerouting, short anterior rerouting, long anterior rerouting), and tumour removal outcome and follow-up period were evaluated for each article. Complete tumour removal was determined by (1) intra-operative assessment at the end of surgery and (2) post-operative high-resolution computed tomography and magnetic resonance imaging, usually within three months of surgery.[8]

Statistical analysis

Pearson's chi-square test was used for pairwise comparisons of non-rerouting, short anterior rerouting and long anterior rerouting results. This method was considered to be more accurate than a simultaneous comparison of all three techniques, and was approved by the institute statistician. Statistical significance was set at a p value of less than 0.05. Confounding factors such as age, sex, race, surgeon's experience and disease severity were not controlled for because of a lack of reported information.

Results

The literature search identified 653 articles; after screening, 108 full-text articles were retrieved for a detailed review. After excluding duplicates and those not meeting the inclusion criteria, 15 studies involving 688 patients were included in this review (Table I).

Table II summarises post-operative facial nerve function after the different management techniques. Five articles reporting jugular paraganglioma management with non-rerouting of the facial nerve in a total of 150 patients met our inclusion criteria. The average tumour removal rate was 79 per cent and the rate of achieving House–Brackmann grade I–II facial nerve function was 95 per cent. Four articles reporting the use of the short anterior rerouting technique in a total of 124 patients were included. The average final facial nerve function of House–Brackmann grades I–II was 90.3 per cent. In 8 articles reporting the use of long anterior rerouting in a total of 414 patients, infratemporal fossa type A was the main approach. The total tumour resection rate and the rate of achieving House–Brackmann grades I–II facial nerve function were 87.0 per cent and 67.2 per cent, respectively.

TABLE I
LITERATURE SEARCH OF FACIAL NERVE MANAGEMENT IN JUGULAR PARAGANGLIOMA SURGERY

Articles	*n*
Total identified	653
Excluded because of title	344
Excluded because of abstract	80
Excluded because published in a language other than English	37
Included in full review	108
Excluded for containing overlapping data by the same author	12
Excluded because of insufficient data	17
Excluded for meeting the exclusion criteria	40
Total included	15

Tables III–V show detailed results according to the type of facial nerve management technique used. Post-operative facial nerve function was not significantly different after non-rerouting and short anterior rerouting ($p = 0.169$). However, non-rerouting and short anterior rerouting showed significantly better post-operative facial nerve outcomes compared with long anterior rerouting ($p < 0.001$ and $p = 0.001$, respectively). The total tumour removal rate was significantly higher after long anterior rerouting than after non-rerouting ($p = 0.016$). There was no difference in the total tumour removal rate after long anterior rerouting and short anterior rerouting ($p = 0.067$) and after short anterior rerouting and non-rerouting ($p = 0.867$). Despite excluding from the statistical analysis two articles that failed to report the gross total removal rate after short anterior rerouting, the risk of bias in this parameter is still high in comparisons involving this technique.

Discussion

Facial nerve paralysis is the most disfiguring complication of temporal bone surgery and represents a frustrating outcome for both patients and surgeons.[18] Facial nerve management and preservation of its normal function remain the most challenging issues in jugular

TABLE II
POST-OPERATIVE OUTCOMES FOR DIFFERENT FACIAL NERVE MANIPULATION TECHNIQUES

Surgical option	Articles (*n*)	Patients (*n*)	Tumour removal rate (%)	HB grade I–II (%)
Non-rerouting	5	150	79	95
Short rerouting	4	124	80*	90
Long rerouting	8	414	87	67

*Missing data. HB = House–Brackmann

https://doi.org/10.1017/S0022215115003394 Published online by Cambridge University Press

TABLE III
POST-OPERATIVE OUTCOME AFTER NON-REROUTING OF THE FACIAL NERVE*

First author	Patients (*n*)	Total tumour removal (*n* (%))	Long-term facial nerve function		Follow up (years)
			HB I–II (*n* (%))	HB III (%)	
Borba[9]	34	31 (91)	32 (95)	NA	>4
Tran Ba Huy[10]	24	18 (75)	22 (92)	NA	>1
Pensak[11]	13	9 (71)	12 (92)	NA	1.5
Llorente[12]	17	11 (64)	17 (100)	NA	5.5
Makiese[13]	62	49 (79)	59 (94)	NA	>5
Total	150	118 (79)	142 (95)	NA	

*In some cases, the facial nerve was managed without rerouting or with temporary rerouting; some cases included tumours other than glomus jugulare. HB = House–Brackmann grading system

paraganglioma surgery, especially for very large tumours with extensive internal carotid artery (ICA) involvement.

It was difficult to interpret articles on facial nerve management in jugular paraganglioma surgery. Most reported only small case series, described jugular foramen tumours with histopathological characteristics that differed from those of jugular paragangliomas, used different classification systems (modified De La Cruz, Fisch or Glasscock–Jackson system), did not analyse their results according to surgical approach or tumour stage, or did not classify facial nerve function according to the House–Brackmann grading system. A few small case series with weak statistical analyses reported factors affecting facial nerve outcome. Some studies suggested correlations between outcome and the degree of nerve injury, manipulation, tumour stage and pre-operative facial nerve status.[19,23,24] This review discusses facial nerve management strategies in jugular paraganglioma patients and presents data on the tumour resection rate and facial nerve outcome achieved with each technique:

Non-rerouting technique

The technique of leaving the facial nerve in situ during infralabyrinthine lesion resection has been described by several authors.[25–27] However, the literature search identified only a few articles describing small case series that used this approach for jugular paragangliomas. After applying the inclusion and exclusion criteria and excluding those with overlapping data, only five articles were included in this review (Table III).

In 1987, Al-Mefty *et al*. refined the infratemporal fossa approach described by Fisch *et al*. into four types (A,B,C, and D)[28,29]: in types A–C, the facial nerve is preserved within its bony canal; and in type D, the nerve is rerouted anteriorly and fixed into the parotid gland. These authors believe that the modified technique could be used to remove jugular paragangliomas of any size and extension to provide a better facial nerve outcome. Borba *et al*. reported the outcomes for 34 jugular paragangliomas that were removed using this approach.[9] Gross total tumour removal was achieved in 91 per cent of cases; in 94.7 per cent of cases, facial nerve function was House–Brackmann grade I.

Tran Ba Huy *et al*. compared outcomes for rerouting and non-rerouting surgical groups.[10] The facial nerve was rerouted anteriorly in 18 patients (9 patients each underwent long anterior rerouting and short anterior rerouting) and was left in situ in 24 patients. House–Brackmann grade I–II nerve function was achieved in 67 per cent and 91.7 per cent of the rerouted and non-rerouted groups, respectively. These authors believed that facial nerve paralysis after rerouting was caused only by interruption of the facial nerve blood supply at the stylomastoid foramen, and that the incidence of paralysis is the same after long or short anterior rerouting. They also suggested that facial nerve paralysis after the non-rerouting technique is caused by nerve dissection in the stylomastoid region or possibly by pre-operative embolisation, as suggested by Marangos and Schmacher.[30]

TABLE IV
POST-OPERATIVE OUTCOME AFTER SHORT ANTERIOR REROUTING OF THE FACIAL NERVE*

Author	Patients (*n*)	Total tumour removal (*n* (%))	Long-term facial nerve function		Follow up (years)
			HB grade I–II (*n* (%))	HB grade III (*n* (%))	
Manolidis[14]	58	47 (81)	53 (92)	NA	>4
Farrior[15]	17	NA	16 (94)	NA	>1
Spector[16]	35	27 (78)	29 (83)	NA	2
Cece[17]	14	NA	14 (100)	NA	>2
Total†	124	74 (80)	112 (90)	NA	

*In some cases, the facial nerve was managed without rerouting or with temporary rerouting. †Missing data. HB = House–Brackmann; NA = not available

https://doi.org/10.1017/S0022215115003394 Published online by Cambridge University Press

In 1997, Pensak and Jackler popularised the fallopian bridge technique for managing jugular foramen tumours and described its indications and limitations.[11] In this approach, tumour excision anterior and inferior to the nerve is accomplished after drilling through the retrofacial air cells. These authors used this technique to treat 35 jugular foramen tumours, of which 13 were jugular paragangliomas. Complete gross tumour removal and House–Brackmann grade I facial nerve function was obtained in 71 per cent and 92 per cent of patients, respectively.

Borba *et al.*, Tran Ba Huy *et al.* and Al-Mefty *et al.* considered that jugular paragangliomas of any size and extension can be removed with better facial nerve outcomes via a modified infratemporal fossa approach that leaves the facial nerve in situ.[9,10,28] In contrast, Pensak and Jackler recommended using the facial bridge technique for tumours limited to the jugular foramen without erosion of the carotid genu (Fisch class C1).[11] They consider this approach to have limited indications because it is very difficult to remove extensive jugular paragangliomas while leaving the facial nerve in situ. Although maintaining facial nerve function is an important goal in temporal bone surgery, total tumour resection is the priority. However, Russo and colleagues consider this approach to be indicated for non-vascular jugular foramen tumours that do not infiltrate the surrounding bone or ICA adventitia, such as lower cranial nerve schwannomas and meningiomas.[31]

Llorente *et al.* compared non-rerouting and long anterior rerouting of the facial nerve in 34 patients, most with jugular paragangliomas: 17 were managed by non-rerouting and 17 by long anterior rerouting.[12] In the non-rerouting group, total tumour resection was achieved in 64 per cent of patients, and House–Brackmann grade I–II function in 100 per cent. However, in the long anterior rerouting group, the outcomes were total tumour resection in 70 per cent, House–Brackmann grade I–II nerve function in 24 per cent and House–Brackmann grade III nerve function in 76 per cent. Between-group differences in facial nerve outcome were statistically significant ($p = 0.003$).

Short anterior rerouting of the facial nerve

This technique was originally described by Capps and Shapiro and Neues.[32,33] It was popularised by Glasscock and colleagues, who reported a method in which only the mastoid segment is anteriorly rerouted.[34] The indication for this technique is jugular paraganglioma with limited ICA involvement (Fisch classes C1 and some C2).[35]

Only four articles describing the use of this technique were found (Table IV). Manolidis *et al.* reported the experience of an otology group in managing skull base tumours over a 20-year period.[14] Short anterior rerouting was used in 58 patients with benign skull base tumours: most had jugular paragangliomas, and House–Brackmann grade I–II function was achieved in 92 per cent. The rarity of these benign, slow-growing tumours, the conservative 'wait-and-see' treatment strategy, delayed diagnosis and limited indications for this approach may explain why no large case series have been reported, even from tertiary otology centres.

Long anterior rerouting of the facial nerve

Development of the infratemporal fossa approach by Fisch in 1977 was a significant advance in the removal of large lesions of the jugular foramen and skull base, particularly jugular paragangliomas of all classes (C and D).[7,36] Long anterior rerouting is the cornerstone of this approach: it provides the widest infratemporal fossa exposure, with better tumour, ICA and lower cranial nerve exposure. However, long rerouting from the stylomastoid foramen to the geniculate ganglion has its own limitations and risks: it requires microsurgical expertise and additional surgical time, and often some degree of facial nerve paresis (Table V).[37]

As described by Fisch, long anterior rerouting places the facial nerve at risk of post-operative paresis by depriving it of its major extrinsic blood supply.

TABLE V
POST-OPERATIVE OUTCOME AFTER LONG ANTERIOR REROUTING OF THE FACIAL NERVE

Author	Patients (*n*)	Total tumour removal (*n* (%))	Long-term facial nerve		Follow up (years)
			HB I–II (*n* (%))	HB III (*n* (%))	
Moe[8]	52	42 (81)	46 (88)	4 (8)	3.4
Fayad[18]	46	37 (81)	43 (94)	1 (2)	>2
Green[19]	40	34 (85)	38 (95)	2 (5)	3.4
Llorente[12]	17	12 (70)	4 (24)	13 (73)	5.5
Manolidis[14]	50	43 (81)	46 (66)	6 (34)	>3
Pareschi[20]	25	24 (96)	15 (60)	8 (32)	4.9
Bacciu[21]	97	83 (86)	50 (52)	NA	4.3
Wang[22]	87	85 (98)	36 (42)	29 (34)	3.6
Total	414	360 (87)	278 (67)	63 (20)	–

*In some cases, the facial nerve was managed without rerouting or with temporary rerouting; some cases included tumours other than glomus jugulare. HB = House–Brackmann grading system

https://doi.org/10.1017/S0022215115003394 Published online by Cambridge University Press

Major trauma during nerve dissection from the soft tissue contents of the stylomastoid foramen is also possible.[36] In 1987, Brackmann modified Fisch's approach to decrease facial nerve trauma during long rerouting.[7] He recommended temporary en bloc mobilisation of the nerve with the soft tissue contents of the stylomastoid foramen. He used this technique to treat 32 jugular foramen tumours, most of which were jugular paragangliomas: at 1-year follow up, 86 per cent of patients had House–Brackmann grade I–II nerve function.[7]

Non-overlapping data were later published from the same centre (House Ear Institute, Los Angeles, California, USA): Green *et al*. reported a total tumour removal rate of 85 per cent and House–Brackmann grade I–II facial nerve function in 95 per cent of patients; and Fayad *et al*. reported a total tumour removal rate of 81 per cent and House–Brackmann grade I–II facial nerve function in 93.5 per cent of patients.[18,19] These authors believed that refining facial nerve management using an infratemporal fossa approach (i.e. facial nerve monitoring, preserving the soft tissues surrounding the facial nerve at the stylomastoid foramen and temporary rerouting of the facial nerve) improved facial nerve function in the immediate and long-term post-operative period. However, the inclusion of Fisch class B tumours and the use of a non-rerouting approach may explain the good facial nerve outcomes achieved in some of their patients.

Temporary rerouting of the facial nerve carries a considerable risk of paralysis when second stage or revision surgery is needed for tumour removal because scar tissue can make nerve identification and dissection difficult.[31] Therefore, temporary rerouting should only be performed when the surgeon is confident that the tumour has been completely excised.

Facial nerve function is maintained by a balance between its intrinsic and extrinsic blood supplies. The stylomastoid, deep petrosal and internal auditory arteries perforate the periosteum of the fallopian canal to provide the main extrinsic blood supply.[37] Rerouting the facial nerve necessitates some interruption of the extrinsic supply; thus, the nerve depends on its intrinsic blood supply for survival.[24] Variations in the extrinsic and intrinsic blood supplies between patients can lead to differences in outcome. The outcome for facial nerve function after rerouting depends mainly on the degree of nerve trauma and the ability of the intrinsic plexus to compensate for extrinsic blood supply interruption. In an experimental study on guinea pigs, facial nerve rerouting induced axon swelling, Schwann cell proliferation, myelin sheath vacuolation and cellular infiltration (similar to findings reported after facial nerve injury); these changes persisted for a considerable period.[38]

This review found that although facial nerve outcome is better in non-rerouting than in short anterior rerouting (94.7 per cent *vs* 90.3 per cent), the difference was not statistically significant ($p = 0.169$), possibly because of the limited number of patients included in our analysis. Furthermore, facial nerve outcome was significantly worse after long anterior rerouting (67.2 per cent) than after non-rerouting and short anterior rerouting ($p < 0.001$). The tumour resection rate was significantly higher after long anterior rerouting than after non-rerouting (87 per cent *vs* 78.7 per cent; $p = 0.016$); however, there was no difference in the tumour resection rate between long anterior rerouting and short anterior rerouting ($p = 0.067$) and between short anterior rerouting and non-rerouting ($p = 0.867$). These results might be explained by the small amount of data available on the tumour resection rate after short anterior rerouting.

Other previous reports support our findings. For example, Von Doersten and colleagues analysed the factors affecting facial nerve outcome in a retrospective review of 217 operations to remove benign lateral skull base tumours, of which 77 per cent were jugular paragangliomas.[24] These authors found that the pre-operative House–Brackmann score, tumour stage, type of facial nerve manipulation and surgical approach all significantly affected facial nerve outcome, with facial nerve mobilisation being the most important factor. In non-rerouting, short anterior rerouting and long anterior rerouting facial nerve management techniques, the mean House–Brackmann scores were 2.09, 1.65 and 2.74, respectively; the differences were statistically significant. In a literature review on facial nerve rerouting, Selesnick *et al*. reported House–Brackmann grade I–II function in 91 per cent of facial nerves after short anterior rerouting and in 74 per cent after long anterior rerouting.[39] They concluded that facial nerve dysfunction increases with the length of the facial nerve segment rerouted.

Bias is likely to have been introduced in the comparison of tumour resection rates among the three techniques because long anterior rerouting was mainly used for advanced stage tumours, while non-rerouting and short anterior rerouting were mainly used for smaller tumours. As tumour stage affects facial nerve outcome, the outcomes of all three techniques in treating tumours of the same stage should be compared to avoid bias.[24] Furthermore, most articles included in the present review reported the overall tumour resection rate irrespective of the technique used.

Conclusion

No strict guidelines for facial nerve management in jugular paraganglioma resection are currently available. The surgical approach should be selected to preserve facial nerve function without compromising total tumour removal. Temporary facial nerve paresis after long anterior rerouting is common, but good function (House–Brackmann grade I–III) is the usual long-term outcome. The best nerve preservation rate was achieved with non-rerouting and short anterior rerouting approaches, but these approaches can only be used for tumours with limited internal carotid

https://doi.org/10.1017/S0022215115003394 Published online by Cambridge University Press

artery involvement; in contrast, long anterior rerouting can be used for all (including advanced) tumour stages.

This review found that the infratemporal fossa approach provides the best tumour exposure along with a low morbidity rate; however, case-by-case selection of the surgical approach is recommended.

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Dr H. Odat takes responsibility for the integrity of the content of the paper
Competing interests: None declared