Jugular Foramen Paraganglioma (Glomus Jugulare): A 10-Year Single-Center Experience

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■ BACKGROUND: **Jugulotympanic paragangliomas (JTPs) are rare, hypervascular skull base tumors. Surgery and stereotactic radiosurgery (SRS) are often framed as competing options, yet outcome data from Latin American public referral centers are scarce. We evaluated a function-first surgical strategy and related tumor stage to outcomes.**

■ METHODS: **Retrospective single-center study of 24 consecutive patients with histopathologically confirmed JTP who underwent 32 resections (2016–2025), analyzed at patient and procedure level. Fisch class (A/B vs. C/D) was related to extent of resection, cranial nerve morbidity, and reoperation (Fisher's exact test, exploratory). Functional outcome (modified Rankin Scale) was assessed at 6 and 12 months; cranial nerve deficits were classified as transient or permanent.**

■ RESULTS: **Mean age was 51 years; 83% were women. Advanced (Fisch C/D) tumors comprised 79%. Preoperative embolization was used in 88%. Gross total resection was achieved in 56% of procedures. New or worsened facial nerve injury occurred after 25% of procedures (permanent in 6 of 8 affected patients), and all facial injuries occurred in Fisch C/D tumors. Eight patients (33%) required unplanned reoperation; none were planned staged. There was no perioperative mortality. Functional outcome was favorable (median modified Rankin Scale score 1 at 12 months; mRS ≤2 in 92%). After a median follow-up of 86 months, recurrence after gross total resection occurred in 4 patients and progression of residual disease in 2.**

■ CONCLUSIONS: **In a predominantly advanced, public-referral cohort, a function-first surgical strategy with SRS reserved for residual or recurrent disease achieved good functional outcomes without mortality. Surgery and SRS are complementary rather than competing modalities.**

INTRODUCTION

Paragangliomas are rare neuroendocrine neoplasms of extra-adrenal autonomic paraganglia. Those arising in the middle ear and jugular foramen (glomus tympanicum and glomus jugulare) are collectively termed jugulotympanic paragangliomas (JTPs); they are hypervascular and locally aggressive, typically arising from the jugular bulb adventitia and growing along the lower cranial nerves.[1,2]

Key words
- Glomus jugulare tumor
- Jugular foramen
- Neurosurgical procedures
- Paraganglioma
- Radiosurgery
- Treatment outcome

Abbreviations and Acronyms
CI: Confidence interval
CN: Cranial nerve
CSF: Cerebrospinal fluid
CT: Computed tomography
GTR: Gross total resection
HB: House-Brackmann (grade)
JTP: Jugulotympanic paraganglioma
MRI: Magnetic resonance imaging
mRS: modified Rankin Scale
SRS: Stereotactic radiosurgery
STR: Subtotal resection

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JTPs are exceedingly rare (incidence approximately 1 per 1.3 million per year; <1% of head and neck neoplasms), show a female predominance, and peak in the fifth to sixth decades. Recognized associations include genetic predisposition and syndromes such as neurofibromatosis type 1, von Hippel–Lindau disease, and multiple endocrine neoplasia type 2.[3-6]

Management is debated. Contemporary SRS series report tumor control of approximately 95%, often exceeding surgical gross total resection rates, which has shifted practice toward function-preserving strategies.[7-9] However, most large series originate from a few high-volume centers in North America, Europe, and Asia; outcome data from Latin American public health systems, where late referral yields a high proportion of advanced (Fisch C/D) disease, are scarce. How surgery should be positioned relative to SRS in such a population—and which factors predict morbidity—remains unclear.

We therefore report a 10-year single-center experience, with a focused aim: to evaluate a function-first, stage-tailored surgical strategy and to relate tumor stage to extent of resection, cranial nerve morbidity, and tumor control, positioning our results honestly against contemporary SRS outcomes.

METHODS

Study Design, Population, and Eligibility

A retrospective study was performed at the Hospital das Clínicas, Ribeirão Preto Medical School, University of São Paulo. All consecutive patients surgically treated for JTP between January 2016 and December 2025 were included. Inclusion required histopathologically confirmed JTP, surgical resection at our institution within the study period, and available clinical, operative, and follow-up records. Patients with other jugular foramen pathologies or incomplete records were excluded. Three patients had undergone an initial operation before this period (in 2006, 2014, and 2015) and were re-operated within it; oncologic follow-up was measured from the index operation.

Unit of Analysis

Twenty-four patients underwent 32 surgical resections. Demographic, clinical-presentation, functional-outcome, and tumor-control data are reported per patient (n = 24); extent of resection and surgical complications are reported per procedure (n = 32). Reoperations are reported separately as salvage for recurrence or salvage for residual progression; no reoperation was planned as a staged procedure.

Imaging, Classification, and Approach

Tumors were staged with high-resolution CT and contrast-enhanced MRI according to the Fisch classification, including subclassification (C1–C4; De/Di).[10,11] Because Fisch C subclasses are defined by the extent of internal carotid artery involvement and class D by dural/intracranial extension, the tumor–vascular relationship is captured by the subclassification and reported as such. A uniform presigmoid transjugular approach to the jugular foramen was used in all patients; approach-based stratification was therefore not applicable.

Surgical Technique

All procedures were performed by the senior skull base team using a function-preserving strategy in which the facial nerve and lower cranial nerves were prioritized over maximal resection.[12,13] Patients were positioned supine with the head rotated to the contralateral side and fixed in a three-point headrest, with continuous intraoperative neuromonitoring of the facial and lower cranial nerves throughout (Figure 1).

A retroauricular C-shaped incision was made and the skin flap reflected anteriorly to expose the mastoid, with the external auditory canal left intact (Figure 2). The superficial mastoid cortex was removed as a replaceable fragment and a mastoidectomy performed with skeletonization of the sigmoid sinus and jugular bulb (Figure 3). The fallopian (facial) canal was skeletonized but the facial nerve was preserved in situ without anterior transposition, working through pre- and retrofacial corridors (fallopian bridge technique) (Figure 4). The great cervical vessels and lower cranial nerves were then dissected for proximal control of the internal and external carotid arteries and the internal jugular vein, with the tumor exposed within the proximal jugular vein and external-carotid feeders coagulated and divided (Figure 5).[12,13] The sigmoid sinus was ligated and the jugular bulb opened, with intrabulbar dissection preserving its medial wall to protect cranial nerves IX–XI.[14] After extradural removal, the dura was inspected and any intradural component resected; reconstruction used autologous fat and fascia with a watertight closure to minimize cerebrospinal fluid leak.

Preoperative embolization was performed in most patients to reduce tumor vascularity, with surgery scheduled within 48 hours.[15-17] When complete resection would have required unacceptable cranial nerve morbidity—particularly of intact lower

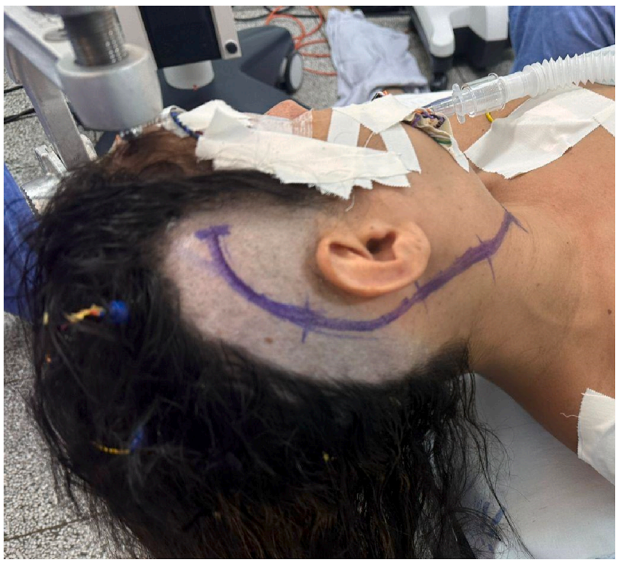

Figure 1. Patient positioned supine with the head rotated to the contralateral side and fixed in a three-point headrest; the C-shaped skin incision is marked.

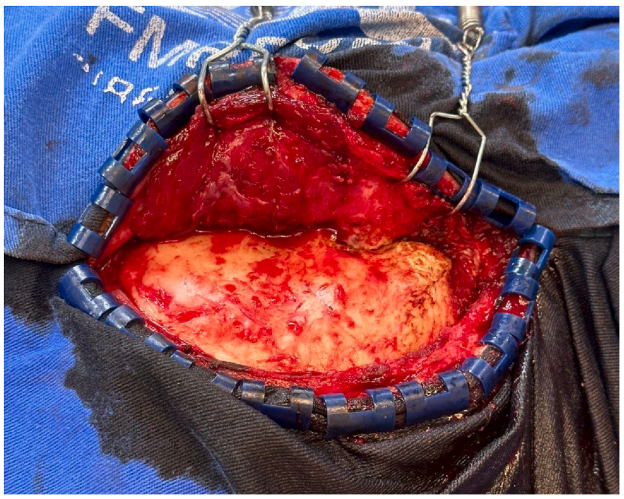

Figure 2. The skin flap has been rotated anteriorly, exposing the mastoid tip, the posterior part of the zygomatic process of the temporal bone, and the posterior margin of the (untransected) external auditory canal.

cranial nerves—a subtotal resection was performed, with the residuum followed on surveillance imaging or referred for stereotactic radiosurgery.

Outcome Definitions and Statistical Analysis

Extent of resection (gross total [GTR] vs. subtotal) was confirmed on postoperative MRI and reported per patient (index result) and per procedure. Cranial nerve outcomes were classified as new, worsened, or improved deficits and as transient or permanent; facial function used the House-Brackmann scale. Tumor control was defined as absence of residual or progressive disease on surveillance imaging; recurrence denoted regrowth after GTR and

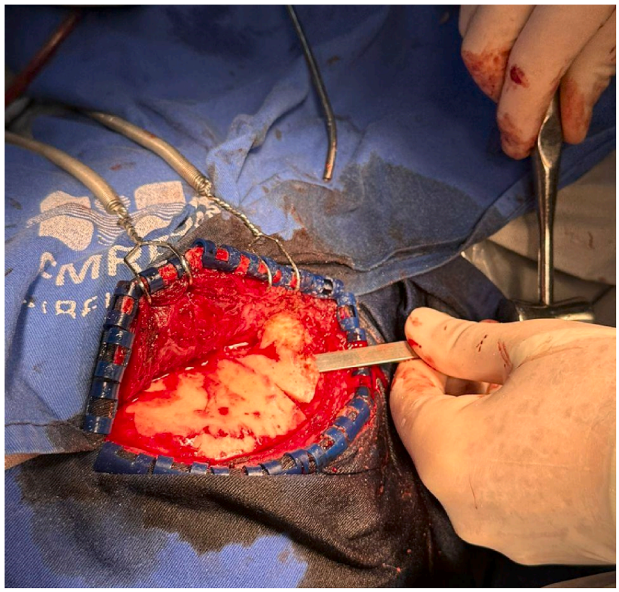

Figure 3. The superficial cortical layer of the mastoid process is removed as a free fragment, to be replaced at closure for a better cosmetic result.

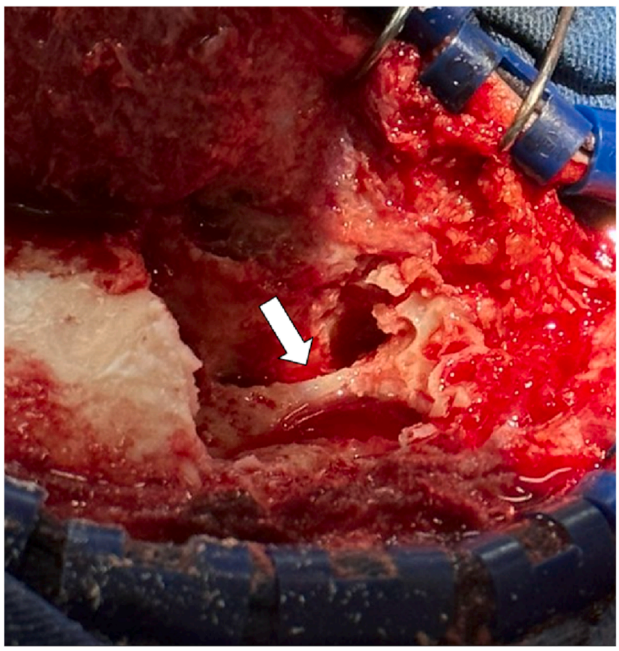

Figure 4. The facial canal (*white arrow*) has been skeletonized without fully exposing the nerve (fallopian bridge technique); in this patient, the intramastoid facial nerve was not involved by tumor, so aggressive dissection was unnecessary.

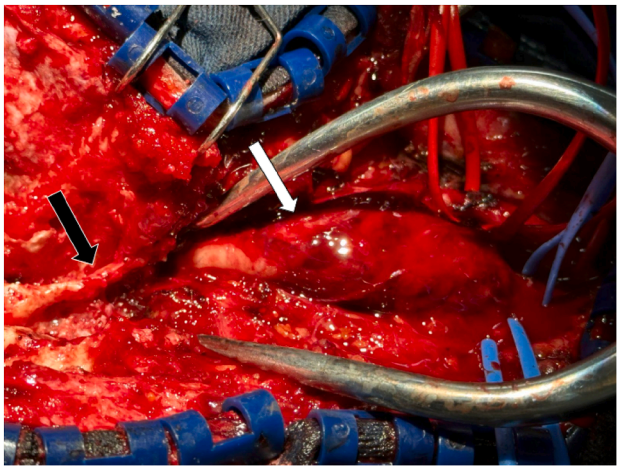

Figure 5. After mastoidectomy and cervical dissection, the internal and external carotid arteries (*red vessel loop*) are preserved; the facial nerve (*black arrow*) is partially exposed beneath a thin bony layer within the mastoid, and tumor (*white arrow*) is visible within the proximal internal jugular vein (*blue vessel loop*).

progression denoted growth of residual after subtotal resection. Reoperations were classified as delayed salvage for recurrence, delayed salvage for progression of residual disease, or same-admission completion after a procedure aborted for intraoperative hemorrhage. Imaging timepoints were standardized: an early postoperative MRI within 3 months for resection extent, and surveillance MRI at 6 and 12 months, annually until 5 years, and every 2 years thereafter, for tumor control. Oncologic follow-up was measured from the index surgery and functional outcome from the last definitive surgery. Categorical variables were summarized as counts and percentages following the journal's significant-digit guidelines. Associations of tumor stage (Fisch A/B vs. C/D) with outcomes were assessed with Fisher's exact test. Because a single surgical approach was used and only 3 patients were not embolized, comparisons by approach or embolization status were not performed. Predictors of poor outcome (new permanent cranial nerve deficit, non-GTR, or recurrence) were explored. Given the sample size and group imbalance, analyses are exploratory and hypothesis-generating. A two-sided $P < 0.05$ was considered significant; freedom from salvage reoperation was estimated by the Kaplan–Meier method; analyses used Python 3 (SciPy).

RESULTS

Demographics and Presentation

Twenty-four patients were included (mean age 51 years, range 14–71; 20 women [83%], 4 men [17%]). The most frequent symptoms were hearing loss (79%), pulsatile tinnitus (54%), and lower cranial nerve dysfunction (54%); facial palsy and dysphagia each occurred in 46%. Secretory tumors were present in 13%. Details appear in **Tables 1–3**, and complete per-patient data in **Supplementary Table S1**.

Tumor Classification and Vascular Relationship

Advanced (Fisch C/D) tumors comprised 79% (19/24). The distribution was Fisch A in 1 patient (4%), B in 4 (17%), C in 13 (54%; C1 in 5, C2 in 5, C3 in 3), and D in 6 (25%; all intradural [Di]). Carotid canal involvement was present in the 13 Fisch C tumors, and intradural extension in the 6 Fisch D tumors.

Treatment and Extent of Resection

Preoperative embolization was performed in 21 patients (88%). All patients underwent a presigmoid transjugular approach, and no procedure was planned as a staged operation. Gross total resection was achieved in 18 of 32 procedures (56%); 16 of 24 patients (67%) achieved GTR at the index operation.

Stratified Analysis and Predictors

Fisch A/B (n = 5) versus C/D (n = 19): new or worsened facial nerve injury occurred in 0/5 (0%) versus 8/19 (42%) (P = 0.13); GTR at the index operation in 4/5 (80%) versus 12/19 (63%) (P = 0.63); and reoperation in 2/5 (40%) versus 6/19 (32%) (P = 1.00). All facial nerve injuries in the cohort occurred in Fisch C/D tumors. On exploratory analysis, advanced Fisch class was the only variable associated, in trend, with facial nerve injury, although the small Fisch A/B subgroup (n = 5) precludes statistical inference.

Table 1. Demographic and Clinical Characteristics (n = 24)

Characteristic	Value, n (%) or as Noted
Age, mean (range), years	51 (14–71)
Female sex	20 (83)
Presenting features	
Hearing loss	19 (79)
Pulsatile tinnitus	13 (54)
Lower cranial nerve dysfunction	13 (54)
Facial palsy	11 (46)
Dysphagia	11 (46)
Catecholamine-secreting tumor	3 (13)
Fisch classification	
A	1 (4)
B	4 (17)
C (C1 = 5, C2 = 5, C3 = 3)	13 (54)
D (intradural, Di)	6 (25)
Advanced disease (Fisch C/D)	19 (79)
Preoperative embolization	21 (88)

Complications, Cranial Nerve Recovery, and Mortality

Per procedure (n = 32), new or worsened facial nerve injury occurred after 8 procedures (25%; affecting 8 patients, 33%); intraoperative hemorrhage, surgical-site infection, and cerebrospinal fluid leak each occurred after 4 procedures (13%). Single cases of hydrocephalus, decompressive craniectomy, and greater auricular nerve injury were recorded (3% each). A new (de novo) facial palsy occurred in 5 previously normal nerves—permanent in 3 and transient in 2—and a pre-existing palsy worsened to a permanent deficit in 3; overall, 8 procedures (25%) were associated with a new or worsened facial deficit, permanent in 6 (House-Brackmann grade 4 in 2, grade 5 in 4) and transient in 2 (recovering by approximately 6 months). Recovery of

Table 2. Surgical and Morbidity Outcomes Stratified by Fisch Class

Outcome	Fisch A/B (n = 5)	Fisch C/D (n = 19)	*P* Value
New or worsened facial nerve injury	0 (0)	8 (42)	0.13
Gross total resection at index operation	4 (80)	12 (63)	0.63
Reoperation	2 (40)	6 (32)	1.00

Values are n (%). *P* values by Fisher's exact test. Analyses are exploratory and hypothesis-generating; the Fisch A/B subgroup (n = 5) is small. All observed facial nerve injuries occurred in Fisch C/D tumors.

Table 3. Facial Nerve Outcomes in the 8 patients With a New or Worsened Facial Deficit

Patient	Preoperative facial Status	Tumor–nerve Relationship (operative Findings)	HB	Course	Management	mRS (12 mo)
2	Normal	80% intraoperative potential loss	V	Permanent	None	2
4	Normal	Anatomically intact; complete signal loss	IV	Permanent	None	3
6	Pre-existing palsy (HB IV)	Infiltrated; not identifiable	V	Permanent	None	2
7	Normal	Multiple cranial nerves (VII, IX–XII)	NR	Transient (~6 months)	None	3
13	Pre-existing palsy (HB V)	Infiltrated; anastomosis not feasible	V	Permanent	None	1
17	Pre-existing palsy (HB III)	Canalicular segment infiltrated; resected	V	Permanent	Greater auricular nerve graft	2
19	Normal	Temporal-branch injury; mostly preserved	IV	Permanent	None	1
24	Normal	Injury near geniculate ganglion	NR	Transient (6 months)	None	1

Patient numbers correspond to **Supplementary Table S1**. Operative findings are abstracted from operative reports.
HB, House-Brackmann grade; NR, not formally graded; mRS, modified Rankin Scale.

lower-cranial-nerve deficits was not a predefined endpoint of this study. There was no perioperative mortality.

Functional Outcome, Follow-up, and Tumor Control

Functional outcome was favorable: the median modified Rankin Scale score was 2 at 6 months (mRS ≤2 in 20/24, 83%) and 1 at 12 months (mRS ≤2 in 22/24, 92%). Median follow-up was 86 months (7.1 years; range 12–244). During follow-up, 8 patients underwent unplanned reoperation: 4 for recurrence after gross total resection, 2 for progression of residual disease, and 2 as same-admission completion after an aborted initial procedure (intraoperative hemorrhage). Eighteen of 24 patients (75%) remained free of recurrence or progression at last follow-up; by Kaplan–Meier analysis, freedom from salvage reoperation was 86% at 5 years (95% CI: 63–95%; median 125 months) (**Figure 6**).

DISCUSSION

In this single-center series, most patients had advanced Fisch C/D disease and a high baseline burden of cranial nerve deficits. A function-first strategy achieved favorable functional outcomes without mortality, at the cost of a moderate GTR rate and an unplanned reoperation rate (33%) consistent with advanced disease and with a strategy that accepted subtotal resection rather than risk intact cranial nerve function.

Current Challenges in the Management of Jugulotympanic Paragangliomas

Several unresolved problems frame the contemporary management of these tumors. First, their rarity precludes randomized trials, so the evidence base rests almost entirely on heterogeneous retrospective series in which apparent differences between modalities are confounded by selection.[7,18] Second, the central controversy—surgery versus stereotactic radiosurgery (SRS)—is frequently reduced to a comparison of radiographic "control" rates, a metric that conflates absence of growth with cure, derives from series with relatively short follow-up, and may overestimate durable efficacy, a concern amplified in the young patients common in late-referral populations.[9,19] Third, the clinically decisive endpoint is not control but cranial nerve morbidity: the lower cranial and facial nerves are often already infiltrated or displaced at presentation, so outcomes are best expressed with standardized functional and nerve-specific scales rather than resection rates alone. Fourth, the role of preoperative embolization—although widely used and supported by reductions in operative time and blood loss—remains incompletely defined regarding its effect on cranial nerve outcomes and the optimal agent and timing.[15,17] Finally, the genetic and secretory dimension (succinate dehydrogenase–related syndromes, catecholamine secretion, and multicentricity) requires biochemical and genetic screening that is inconsistently applied. In public health systems with delayed referral these challenges are compounded by a high proportion of advanced (Fisch C/D) disease, for which any single modality is rarely sufficient and individualized, multidisciplinary treatment is essential.

Clinical Presentation

Our presentation broadly matches the literature, with hearing loss and pulsatile tinnitus predominating; the high frequency of lower cranial nerve dysfunction reflects advanced disease at referral.[20,21] The female predominance (83%) and mean age (51 years) are consistent with reported figures, with minor differences attributable to sample size.

Tumor Stage, Embolization, and Morbidity

All facial nerve injuries in our series occurred in Fisch C/D tumors (8/19, 42%) and none in Fisch A/B tumors, identifying advanced stage as the principal driver of morbidity, although the small Fisch A/B subgroup (n = 5) precludes formal significance. Our GTR (56%) and facial nerve morbidity fall within reported ranges for advanced JTP.[11,13,14] Preoperative embolization, used in 88% of our patients, is recommended for Fisch C/D tumors considered for surgery; a recent systematic review and meta-analysis confirmed that it reduces intraoperative blood loss and operative time without increasing cranial nerve deficits.[17] Because only 3 patients were not embolized and a single approach was used, our cohort was not designed to compare embolized versus non-embolized

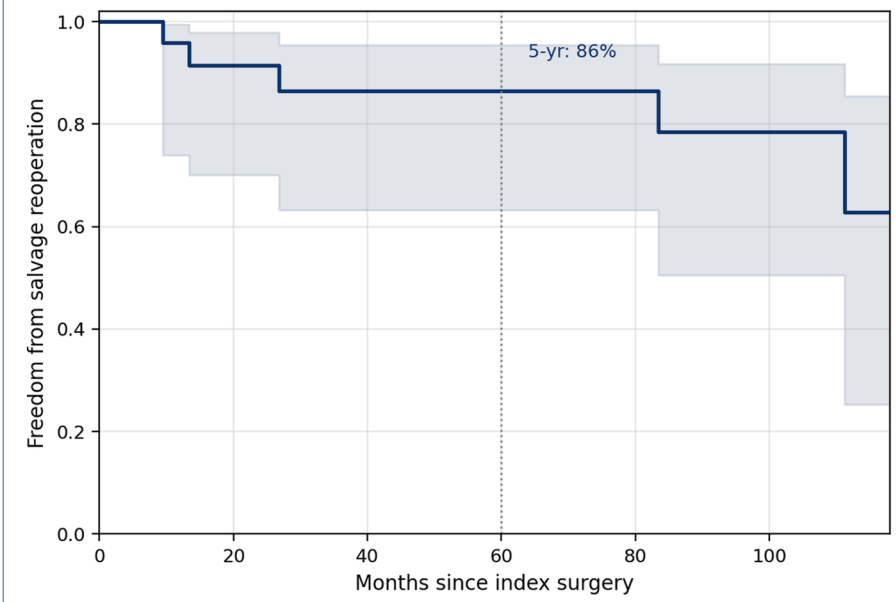

Figure 6. Kaplan–Meier estimate of freedom from salvage reoperation (for recurrence or progression), measured from the index operation. The dotted line marks 5 years; the widening confidence band at later timepoints reflects the small number of patients still at risk.

patients or alternative approaches, and these questions are better addressed by the cited synthesis.

Surgery versus Stereotactic Radiosurgery

Contemporary meta-analyses report pooled tumor control of approximately 95%–97% after SRS for glomus jugulare tumors,[7,8] exceeding the GTR rate of most surgical series. Considered in isolation, this favors SRS, but framing the modalities as competitors for radiographic control alone is misleading. First, control after SRS denotes absence of growth rather than eradication, derives from retrospective series with relatively short follow-up, and may be overestimated[19]—a concern for younger patients, present in our cohort (range: 14–71 years). Second, the most directly comparative evidence, a systematic review of 3498 patients (2215 surgical, 1283 SRS), found low long-term recurrence with both modalities (surgery 15%, SRS 7%), the principal difference being higher rates of CSF leak, dysphagia, and lower cranial nerve palsies after surgery[18]; the relevant trade-off is morbidity, not control. Third, the modalities are increasingly combined rather than opposed, with SRS reasonable for small, minimally symptomatic tumors or high-surgical-risk patients and surgery reserved for established lower cranial neuropathy or failure of radiation.[22,23]

Surgery remains preferred when eradication or tissue diagnosis is required, for large or symptomatic tumors with mass effect, for secretory tumors (13% of our cohort), and for younger patients in whom the decades-long latency and cumulative risk of SRS are concerns.[9] Our complication profile should be read against this indication profile: an embolization-assisted, facial-nerve–preserving approach deliberately prioritized function over maximal resection, reflected in favorable functional outcomes and zero mortality despite a 56% GTR. Where complete resection would exceed the morbidity of the tumor's natural history, subtotal resection with surveillance and SRS for documented residual or recurrent growth represents, in our experience, an appropriate balance.

Tumor Control and Prognosis

In our cohort, recurrence after gross total resection occurred in 4 patients and progression of residual disease in 2 (the remaining two reoperations were same-admission completions after an aborted procedure); 18 of 24 patients (75%) remained free of recurrence or progression at a median of 86 months, and Kaplan–Meier freedom from salvage reoperation was 86% at 5 years (95% CI: 63%–95%). This reoperation-free figure is not directly equivalent to the radiographic control reported after SRS, but it indicates durable local control with the added benefits of histological diagnosis and substantially longer follow-up. As in published series, more extensive resection improves local control but must be balanced against morbidity.[23-25]

Strengths and Limitations

Strengths include a consecutive cohort with standardized outcome scales and imaging timepoints, no loss to follow-up (all patients remain under clinical and radiological surveillance), and a long median follow-up of 86 months (7.1 years) that exceeds that of most contemporary SRS series. Limitations include the retrospective single-center design and modest sample size, which

limit the power of the stratified comparisons; these analyses are exploratory and hypothesis-generating. Because a single approach was used and few patients were non-embolized, approach- and embolization-based comparisons were not feasible. Referral bias toward advanced disease may limit generalizability.

CONCLUSION

In a predominantly advanced, Latin American public-referral cohort, a function-first surgical strategy—preoperative embolization, a facial-nerve–preserving presigmoid transjugular approach, and subtotal resection when total removal would exceed the morbidity of the tumor's natural history—combined with SRS reserved for residual or recurrent disease, achieved good functional outcomes (median mRS 1 at 12 months) with no perioperative mortality, despite a GTR of 56%. Surgery and SRS are complementary rather than competing modalities, and treatment should be individualized by tumor stage, carotid involvement, baseline cranial nerve function, and patient age.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Otávio da Cunha Ferreira Neto: Investigation, Visualization, Writing — original draft, Writing — review & editing. **Rodrigo Inácio Pongeluppi:** Visualization, Writing — original draft, Writing — review & editing. **Cid Soares:** Conceptualization, Resources, Software. **Fernando Cesar de Souza Filho:** Conceptualization, Data curation, Investigation, Methodology. **Ruan Krubniki Ferraz:** Conceptualization, Data curation. **Daniel Giansante Abud:** Funding acquisition, Resources, Validation, Visualization. **Eduardo Tanaka Massuda:** Conceptualization, Methodology. **Ricardo Santos de Oliveira:** Supervision, Validation, Visualization. **Benedicto Oscar Colli:** Resources, Software, Supervision, Validation, Visualization.

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