How I Do It: The Role of Flexible Hand-held 2 μ -Thulium Laser Fiber in Microsurgical Removal of Acoustic Neuromas

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Abstract

Aims We performed a retrospective nonrandomized study to analyze the results of microsurgery of acoustic neuromas (AN) using 2 μ -thulium flexible hand-held laser fiber (Revolix jr).

Methods From September 2010 to September 2015, 89 patients suffering from AN have been operated on with microsurgical technique via retrosigmoid approach. In 37 cases, tumor resection was performed with the assistance of 2 μ -thulium flexible hand-held laser fiber (L-group). Eight cases operated on with the assistance of CO₂ hand-held flexible laser fiber were excluded from this study. A total of 44 patients, operated on without laser assistance during the same period, were used as comparison group (C-group) (matched pair technique). Facial nerve function was assessed with the House–Brackmann (HB) scale preoperatively, and 1 week and 6 months postoperatively.

Results Overall time from incision to skin suture changed in relation to size of tumor (165–575 minutes) and was not affected by the use of laser. In 7 out of 81 cases, a preoperative facial nerve palsy HB2 and in 1 case, HB4 (permanent) were observed. In the remaining 80 cases, at 6-month follow-up, facial nerve preservation rate (HB1) was 92.5%. Hearing preservation rate (AAO-HNS A/B classes) was 68.2% (26 out of 36). Adopting a 0 to 3 scale, the mean surgeon satisfaction rate of usefulness of laser fiber was 2.7.

Conclusion The use of 2 μ -thulium hand-held flexible laser fiber in AN microsurgery seems to be safe and subjectively facilitates tumor resection especially in “difficult” conditions (e.g., highly vascularized and hard tumors). In this limited retrospective trial, the good functional outcome following conventional microsurgery had not further improved, nor the surgical time reduced by laser. Focusing its use on “difficult” (large and vascularized) cases may lead to different results in future.

Keywords

- ▶ acoustic neuroma
- ▶ facial nerve preservation
- ▶ hearing preservation
- ▶ retrosigmoid approach
- ▶ 2 μ -thulium laser
- ▶ vestibular schwannoma

Introduction

The therapy of acoustic neuromas (AN) changed during the years, from lifesaving to preservation of function and quality of life. In particular, in the last two decades, the neurosurgical approach through retrosigmoid (RS) approach showed to be

safe and efficacious for all sizes: intracanalicular without or with cerebellopontine angle extension, without and with contact and compression to brain stem.^{1,2} Nowadays, preservation of facial nerve and hearing functions are the most relevant objectives in microsurgical treatment of these tumors, especially for AN with maximum diameter of 2 cm or

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less.^{3,4} In complex tumors, sometimes, it is difficult to respect these aims, for example, in cases with (1) strong adherence of tumor to facial nerve, cochlear nerve, and brain stem; (2) hard consistence; and (3) high vascularization, with continuous bleeding during excision.⁴

Lasers proved to be well-established instruments in different surgical fields for more than 40 years.^{5–8} Laser surgery, in general, showed various advantages, such as reduction of mechanical trauma and intraoperative bleeding. A major advance in making lasers more useful in neurosurgical practice came with introduction of continuous-wave lasers with flexible hand-held fiber.⁷ This type of laser energy avoids the explosive effects of pulsed-wave lasers and allows accurate cutting and vaporization by using focused beams, without the need to handle or retract tissues.⁹ In 2005, the development of flexible CO₂ laser fiber^{6,7,10–13} transformed it in a hand-held tool. The new devices offer the possibility of guiding the laser beam by small and variable handpieces devices for direct microsurgical use.^{7,14–16}

Recently, 2 μ -thulium laser showed to be a promising device in the surgery of intracranial meningiomas,¹⁴ especially for debulking, shrinking, and coagulating the mass and its basal implant.

The laser vaporization and cutting of AN offer the possibility of removing large parts of tumor without direct manipulations of the mass itself, reducing the mechanical trauma to adherent nerves and brain stem. In addition, laser proved to be more precise and less damaging the surrounding tissues than conventional bipolar cauterization.^{14,16,17}

First reports on brain tumors^{5,7,14,15,17–22} and on AN operated on by middle fossa approach²³ and our own experience with 2 μ -thulium hand-held laser fiber have been the rationale for applying this surgical tool in “keyhole” RS removal of AN. Direct tumor laser ablation reduced mechanical manipulation of tumor itself, bipolar coagulation, and ultrasonic aspiration, limited direct cutting with microscissors, with potentially better surgical results, especially in “complex” ANs.

Materials and Methods

Patients Data

A total of 37 consecutive patients with AN were enrolled in the study (L-group). Inclusion criteria were clinical and magnetic resonance imaging (MRI) diagnosis of AN and age of 18 years or older. Hearing preservation was attempted if functional hearing was AAO-HNS class A or B²⁴ in the affected side.

In L-group, all patients were operated on by microsurgical technique combined with assistance of 2 μ -thulium flexible hand-held laser fiber (Revolix jr), by RS approach, between July 2012 and September 2015.

The L-group was compared with a matched C-group of 44 patients operated on by the same approach, with microsurgical technique, without laser assistance between September 2010 and June 2012. After this date, all AN having maximum diameter of 1 cm or less have been operated on without laser assistance and included in the C-group. Demographic data were collected and patients were asked about the symptoms of hearing loss, tinnitus, vertigo, and other related neurological symptoms.

Determination of Tumor Size

Each patient received an MRI scan not exceeding 1 month before admission. Tumor was measured in three spatial dimensions (on axial and coronal MRI section planes) and tumor size was estimated considering its major diameter, including the part of tumor extending into the internal auditory canal.

Facial Nerve Function

Facial nerve function was assessed preoperatively (clinically and with electromyography [EMG]), 1 week and 6 months postoperatively using House–Brackmann²⁵ (HB) classification (1: normal; 6: total paralysis).

Audiological Data

In patients selected for hearing preservation (AAO-HNS class A or B),²⁴ audiological exams were performed preoperatively as well as 1 week and 6 months postoperatively by pure tone audiometry, auditory brain stem response (ABR), and monosyllabic speech audiograms.

Surgeon's Evaluation of Hand-held Laser Usefulness

The surgeon satisfaction rate of usefulness of hand-held flexible laser was evaluated adopting a 0 to 3 subjective rating scale (0 = not useful; 1 = moderately useful; 2 = useful; 3 = very useful).

Intraoperative Procedures

Monitoring of Facial and Cochlear Nerves

In all cases, facial nerve monitoring was used during all surgical procedure (Nimbus i-Care 100; IntraOperative Neurophysiological monitoring, Newmedic division of Hemodia), with electrodes inserted in orbicularis oris and orbicularis oculi muscles. The nerve stimulation was performed with monopolar (on surface of tumor) or bipolar (close to the nerve) stimulator, starting from 2 mAmp or more (on the capsule for nerve course localization) to 0.3 to 0.05 mmAmp (directly on the nerve for confirmation of function). As well as locating the course of facial nerve, intraoperative monitoring helped in driving the use of laser fiber.

Each patients selected for hearing preservation received an ABR audiometry (Nicolet Viking III; Viasys HealthCare) the day before surgery. In the last 12 cases, we used ABR neuro-monitoring evoked with CE-Chirp stimuli (Interacoustics Eclipse EP15 ABR system).²⁶ In both L- and C-groups, there were 36 patients AAO-HNS class A or B, with reproducible responses that allowed a continuous intraoperative ABR monitoring of cochlear nerve.

Retrosigmoid Approach

All operations were performed by RS approach. Continuous lumbar drain was placed in larger tumors (maximum diameter greater than 3 cm) and was left in place for 3 to 4 days, for cerebellar detention during surgery and postoperative wound closure.

Skin incision consists of a slightly curved 5 to 6 cm line behind the ear, ~1 cm posteriorly to mastoid. Free pericranial flap is harvested for dural closure. The RS-retromastoid lateral

occipital bone is exposed including superior and inferior nuchal lines.^{4,16} About 3 cm² craniotomy exposing sigmoid and transverse sinuses and the angle in between are performed. The RS dura is opened in a semicircular shape, followed by lateral medullary cistern arachnoid opening for cerebellar detention by cerebrospinal fluid (CSF) aspiration. After cutting the dura covering the roof of internal auditory canal (using laser fiber in L-group), the opening of canal is performed with 4 mm extra-coarse diamond burr or with Sonopet Ultrasonic Aspirator (Stryker) with dedicated bone tips. When adequate detention of cerebellar hemisphere is obtained, the tumor surface is exposed, with or without retraction, and possible position of facial nerve detected by using the stimulator.

According to the Fukushima's technique,^{4,16} a V-cut is usually performed on the dorsal surface of tumor with laser fiber (L-group) or with microscissors (C-group) and debulking of tumor obtained with microscissors, microcurettes, bipolar forceps, Sonopet Ultrasonic Aspirator (59 cases, usually with maximum diameter higher than 2 cm), and hand-held laser (L-group) for vaporizing and cutting. With standard microsurgical instruments (sharp dissectors, sickle knife, McElveen knife, straight and curved microscissors, ring, and cup curettes), the tumor is separated from brain stem and cranial nerves during continuous facial and—in selected cases—cochlear nerve monitoring.

In cases with strong adhesion to brain stem and/or facial nerve, a millimetric fragment of tumor capsule is left.

Accurate hemostasis and tight dura closure using pericranial graft, hemostatics, and sealants are performed, and a fitted titanium net or the bone operculum is placed on the craniectomy with miniscrews.

Flexible 2 μ -Thulium Laser System

In L-group (37 cases), the capsule incision and tumor debulking have been performed with hand-held 2 μ -thulium flexible laser fiber (Revolix jr; Lisa laser). The range of power setting was 1 to 14 W. Standard 0.9% saline solution irrigation has been used for cooling the fiber (which is not hindered in its function by the presence of water). The fiber is used for cutting, vaporizing, and coagulating the capsule and the intracapsular mass, in combination with bipolar forceps, microscissors, and Sonopet Ultrasonic Aspirator. Following tumor debulking, the remaining tumor capsule is removed with standard microsurgical tools.

Determination of Tumor Removal and Procedure Time

The amount of tumor removed has been assessed by surgeon's opinion and by postoperative contrast-enhanced MRI performed within 1 week after surgery. The removal has been classified as total (100%), nearly total (99%: millimetric residual frequently not detectable by MRI), subtotal (90%), and partial (less than 90%).

Total operation time has been defined as the period lasting from skin incision until the end of skin suture.

Statistical Analysis

Each patient of L-group was matched to a patient of the C-group. After matching, a paired sample *t*-test was performed.

For categorical analysis, chi-square test was used to calculate differences in facial nerve and hearing preservation rates.

Results

Demographic and Clinical Data

Demographic, clinical, and MRI data were substantially comparable in the two groups, with the exception of mean maximum tumor size (including the extension into the internal auditory canal): 2.0 cm in C-group and 2.7 cm in L-group (*p* = NS). The mean maximum diameter of the entire cohort was 2.4 cm.

In L-group, 17 females and 20 males were included. Mean age was 50.2 years, and mean duration from first symptoms (hearing loss, tinnitus, vertigo, and hemifacial numbness) until operation was 16.5 months; in 8 cases, AN had one or more cysts inside. According to Samii's grading classification,³⁶ the tumor belonged to grade II in 14 cases, grade III in 17, and grade IV in 6; no patient in grade I. In six patients, preoperative clinical or EMG evidence of facial nerve impairment was observed (in one long-lasting HB4). A serviceable preoperative hearing (AAO-HNS A and B classes) was present in 14 patients.

In C-group, 19 females and 25 males were included. Mean age was 48.4 years, and mean duration from first symptoms until operation was 20.7 months; 5 were cystic. The tumor was grade I in 8 cases, grade II in 22, grade III in 11, and grade IV in 3. A clinical or EMG facial involvement was detected preoperatively in 3 cases and preoperative hearing was serviceable in 22 cases.

Tumor Removal and Operation Time

Total tumor removal was possible in 20 cases of L-group and in 29 of C-group. In accordance with patient's will, neither facial nor cochlear nerve (in cases of serviceable hearing) was sacrificed to obtain entire tumor resection. In relation to this consideration, a nearly total or subtotal (99–90%) resection was performed in 12 cases of L-group (total + nearly total + subtotal: 32 cases; 86.5%) and in 12 of C-group (total + nearly total + subtotal: 41 cases; 93.2%).

In five cases of L-group and in three of C-group, partial removal was only possible because of tenacious adherences of the capsule of tumor to brain stem and to facial nerve; in all these cases, AN had a maximum diameter of more than 4 cm. The remnants were located into the conduct, or along the facial nerve course or adherent to brain stem.

Mean operation time changed in relation to size of tumor and ranged from 165 to 575 minutes (mean, 325); it was 344 minute (standard deviation [SD], 45.6) in L-group and 315 minutes (SD, 56.4) in C-group, with no statistical difference.

Mortality and major permanent morbidity were zero. In three patients, transient abducens nerve (sixth cranial nerve) palsy was observed and recovered within 6 months. In two patients with large AN (3.5 and 4.5 cm maximum diameters, respectively) swallowing disorders recovered completely within 3 months. In five patients (two from L-group and three from C-group), CSF leak from the surgical wound was observed and was resolved in all but one with 5 to 6 days

continuous lumbar drain. In one case, a surgical revision with dural repair was necessary. In three patients, transient rhinoliquorrea started from 3 to 7 days after surgery and was successfully treated with continuous lumbar drain and prophylactic antibiotics.

Facial Nerve Function

► **Table 1** summarizes the facial nerve results.

All patients were considered as HB1 preoperatively, except five patients in L-group and three in C-group who had a newly diagnosed HB2 to HB4 (long-lasting) facial palsy or, in two cases, a preoperative involvement of facial nerve on EMG.

At minimum 6-month postoperative follow-up, 33 patients of L-group had HB1 facial function and 4, a dysfunction ranging from HB2 to HB4 (1 of them with definitive preoperative deficit). In 14 cases, the facial function was HB1 immediately after surgery; in these cases, the mean maximum diameter was 2.2 cm (vs. 3.3 cm of cases with transient deficit; $p < 0.03$). On considering 36 patients (1 excluded because of preexisting long-lasting facial deficit), the day after surgery a normal face was observed in 38.9% of patients and 6 months later in 91.7%.

At the same interval of follow-up, 41 patients of C-group (93.2%) had HB1 facial nerve function and 3 had a paresis ranging from HB2 to HB4. In 27 cases (61.4%), normal function of facial nerve was observed immediately after surgery. In these cases, the mean diameter of AN was 1.7 versus 2.0 cm of cases with transient HB2 to HB3 facial palsy and recovered within 6 months ($p < 0.05$). When patients returned to normal face mobility, severe and permanent contractures were never observed.

In conclusion, on considering the whole series, 92.5% of patients had HB1 facial function at 6-month postoperative follow-up; differences between the two groups (91.7 vs. 93.2%) are not statistically relevant ($p = \text{NS}$) and seem to be related to smaller diameter of C-group.

Hearing Results

Preoperative hearing status was comparable in both cohorts.

Fourteen patients of L-group had serviceable preoperative hearing (AAO-HNS A and B classes). After operation, 11 of them presented hearing competence as before operation or slightly reduced (78.6%). In C-group, 15 out of 22 patients had preserved hearing (68.2%).

On considering the whole series, hearing preservation was possible in 72.2% of entire cohort. The different preservation rate between the two groups is not statistically significant ($p = \text{NS}$).

Surgeon's Satisfaction Rates

Mean surgeon satisfaction rate of usefulness of hand-held laser fiber was 2.7 (ranging from 0 to 3).

In particular, the use of hand-held flexible laser fiber was safe. It subjectively facilitates tumor resection especially in "difficult" conditions (e.g., highly vascularized and hard tumors), avoiding traction and continuous suction, even if the good functional outcome following conventional microsurgery had not further improved nor the surgical time reduced.

Discussion

The treatment of AN gradually changed over the years. Introduction of MRI into routine diagnostics of hearing disturbances showed increasing numbers of AN being detected at early stage. It is still an open question if small tumors really need to be treated or not (wait and see); anyway, irreversible hearing loss has to be expected in more than 50% of patients during their life.^{9,27-33}

According to the clinical experience and literature, the most common options are surgical excision, radiosurgery (Gamma Knife and CyberKnife),^{34,35} and "wait and scan" with serial clinical and MRI controls. In accordance with outstanding experienced neurosurgeons,^{3,4,16,36} we consider microsurgery as first treatment of AN and radiosurgery in patients with growing recurrent tumors not suitable for resurgery because of compromised general conditions. In patients older than 65 years with small AN (under 2 cm of maximum diameter) and hearing lost, wait and control the possible growth of tumor with serial MRI seems to be the most reasonable option. In cases with large tumors or with small tumors with serviceable hearing, we usually recommend surgery.

Life-threatening complications related to surgical treatment of AN are rare and preservation of functions is the goal.^{3,4,36} Anyway, patients with larger tumors compressing and displacing brain stem are more challenging and other possible postoperative side effects have to be considered, such as trigeminal, abducens, and lower cranial nerves

Table 1 Postoperative facial nerve function

	MMD (cm)	Postoperative HB1	Immediately HB1 and MMD	6-mo follow-up and MMD	<i>p</i> -Value
L-group (36 cases) ^a	2.7	91.7	38.9% and 2.2 cm	52.8% and 3.3 cm	< 0.03
C-group (44 cases)	2.0	93.5	61.4% and 1.6 cm	32.1% and 2.0 cm	< 0.05
Entire series	2.4	92.5	51.2 and 2.0 cm	41.3 and 2.6 cm	NS

Abbreviations: HB1, House-Brackmann 1; MMD, mean maximum diameter.

Note: A total of 81 cases of vestibular schwannomas were operated on with (L-group) and without (C-group) 2 μ -thulium flexible hand-held laser fiber assistance.

^aOne case was excluded because of long-lasting HB4 preoperatively.

deficits. In our series, neither major complications nor permanent deficits have been observed; in eight patients, minor transient complications were related to CSF circulation (wound fistulas and rhinoliquorrea), in all but one case resolved conservatively.

Intraoperative cochlear and facial nerve monitoring have improved the preservation rates of facial and cochlear nerve functions, if patients had serviceable preoperative hearing (AAO-HNS A and B classes). In our series, we obtained quite good results both for facial nerve outcome and hearing preservation.

Laser-assisted AN surgery has been described in several studies, mostly using a RS and/or translabyrinthine approach,^{13,37,38} and in the literature, there is no completely uniform opinion on an additional advantage of this special noncontact tool. Discussion of the value of hand-held laser assistance in AN surgery for facial nerve outcome has been heterogeneous to date: Cerullo and Mkrdichian¹³ and Eiras et al³⁷ demonstrated some advantages with its use in patients with larger tumors. Nissen et al³⁹ reported a normal facial function in 90% in tumors smaller than 1.5 cm. On the contrary, Zaouche et al³⁸ described a slightly worse outcome in AN operated on with laser fiber.

In our series, at minimum 6-month follow up, HB1 facial nerve function was observed in 92.5% of cases: 91.7% of L-group (mean maximum diameter of 2.7 cm) and 93.5% of patients of C-group (mean maximum diameter of 2.0 cm). As regarding hearing function, it was preserved in 68.4% of our patients with serviceable preoperative hearing (AAO-HNS A and B classes), 68.7% in L-group and 68.2% in C-group ($p = \text{NS}$).

Analyzing in detail our series, the day after surgery a normal face was observed in 37.5% of L-group patients and 6 months after operation in 90%. In C-group, 64.3% of cases had a normal facial function immediately after surgery, rising to 90.5% after 6 months. The temporary worse result of immediately postoperative facial function observed in L-group seems to be in relation to size of AN: in patients of L-group with immediate normal face, mean maximum diameter was 2.3 versus 3.0 cm of cases with transient HB2 to HB3 facial palsy recovered within 6 months ($p < 0.05$). This explanation is also more convincing if we consider the smaller dimensions of tumors of C-group (mean maximum diameter: 2.0 cm): in particular, 27 cases with immediately normal function had a mean maximum diameter of 1.7 cm (vs. 2.9 cm of cases with transient palsy) ($p < 0.05$).

Temporary facial palsy is usually related to necessary microsurgical dissection during separation of tumor from the nerve. The intensity of mechanical manipulations depends on the conditions of facial nerve and on the adherence of the tumor shell to the nerve itself and, consequently, on tumor dimensions. Our long-term rate facial results were similar in both groups and comparable to other reports.^{1,4,29,36,38,40–42} Therefore, the use of laser in proximity of facial nerve seems to be safe, especially if surgeon has a direct view of the facial nerve.

The same findings apply for the necessary manipulations of the cochlear nerve. Results of hearing preservation in AN surgery have also improved over the past decades, especially

in treatment of smaller tumors. In our series, the recent use of intraoperative ABRs with CE-Chirp stimulus²⁶ improved intraoperative monitoring of hearing, with quick brain stem evoked responses after stimuli. For attempting hearing preservation, we selected patients belonging to classes A and B of the AAO-HNS classification.^{4,24,33,43,44} In both L- and C-groups, the preservation was possible in more than two-thirds of cases (78.6 and 68.2%, respectively). Notwithstanding the evidence that a hearing preservation is much more feasible if tumor maximum diameter does not exceed 2.0 cm.^{3,4,45,46} We cannot confirm this trend in our limited series.

Eiras et al³⁷ compared resection time with or without laser fiber in giant AN operated by RS approach and reported that laser resection takes longer as well. On the contrary, in our series, the operation time was not influenced by hand-held laser assistance. Total operation time was 165 to 575 minutes (mean, 325) and it was very similar in both groups: 344 minutes (SD, 45.6) in L-group and 315 minutes (SD, 56.4) in C-group, with no statistical difference. Vascularization of the tumor as well as its adherence to the facial and cochlear nerves may lead to prolonged resection time, either by more hemostatic procedures or, what seems to be the most important factor, by repeated interruptions during tumor removal due to worsening of intraoperative facial and ABR responses, which necessitate recovery periods for the nerves without any further microsurgical manipulations.

In our limited series, the use of a hand-held flexible laser fiber was safe. The rate of usefulness evaluated by the mean surgeon satisfaction rate was 2.7 on 3 (scale ranging from 0 to 3). In some cases, the use of the 2 μ -thulium laser fiber was considered very helpful and, subjectively, facilitated tumor excision especially in “difficult” conditions (e.g., highly vascularized and hard tumors), avoiding tractions and continuous suction with ultrasonic aspirator. Anyway, on the basis of our retrospective analysis, the good functional outcome following conventional microsurgery showed to be not further improved nor the surgical time reduced by the laser fiber. On the basis of our preliminary experience, it looks like that focusing the use of 2 μ -thulium flexible hand-held laser fiber on large and vascularized AN may lead to better results in future.

Conclusion

In our limited retrospective series, 2 μ -thulium flexible hand-held laser fiber in AN operated on by “keyhole” RS approach proved to be safe, but had not significant influence on postoperative facial nerve function, hearing preservation rate, or surgical time. On the contrary, according to surgeon impression, in highly vascularized tumors, the necessary reduction of tumor volume before microsurgical dissection of facial and cochlear nerve appears to be easier with 2 μ -thulium laser fiber in association with ultrasonic aspirator and microsurgical dedicated instruments.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any

financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or nonfinancial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this article.

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