

Stapedotomija z argonskim laserjem

Argon laser stapedotomy

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Izvleček

Namen: Namen raziskave je bil predstaviti rezultate operacij otoskleroze z argonskim laserjem.

Metode: V zadnjem letu in pol je bila stapedotomija z argonskim laserjem izvedena pri 47 bolnikih. Pri vseh je bil poseg izveden v splošni anesteziji s transkanalnim pristopom, preoperativno in pooperativno je bil narejen tudi audiogram. Po operaciji smo izračunali spremembo kostnega prevajanja, kostno-zračne razlike in povprečno pooperativno kostno-zračno razliko.

Rezultati: Povprečno pooperativno izboljšanje kostnega prevajanja je znašalo 4,4 dB, povprečno izboljšanje kostno-zračne razlike 22,3 dB, povprečna pooperativna kostno-zračna razlika pa je znašala 9,6 dB.

Zaključek: Stapedotomija z argonskim laserjem je varna operacija, ki omogoča t.i. operiranje brez dotika struktur. Pooperativni rezultati sluha so zadovoljivi in stabilni, bolniki pa imajo pooperativno malo stranskih pojavov v smislu nestabilnosti in slabosti.

Abstract

Purpose: Presentation of our results of otosclerosis procedures undertaken with the argon laser.

Methods: Argon laser stapedotomy was carried out in 47 patients in the last 18 months at our center. The procedure was conducted under general anesthesia using a transcanal approach. Pure-tone audiogram was done pre- and postoperatively. After each procedure, overclosure, closure of the air-bone gap and the average postoperative air-bone gap were calculated.

Results: Average overclosure in all patients was 4.4 dB; average closure of the air-bone gap was 22.3 dB and average air-bone gap was 9.6 dB.

Conclusion: Argon laser stapedotomy is a safe procedure that enables surgery without touching middle ear structures. Postoperative hearing results were satisfactory and stable; patients also had few problems with nausea and vertigo.

INTRODUCTION

Otosclerosis is a localized disease of bone derived from the otic capsule. It is characterized by alternating phases of the resorption and formation of bone. The otosclerotic process is characterized by abnormal bone remodeling. This results in replacement of otic capsule bone with hypercellular woven bone, which may undergo further remodeling to ultimately reach a “mosaic” sclerotic appearance. The commonest site is the fissula ante fenestram, which lies anterior of the stapes footplate. Otosclerotic foci may also appear in other sites, even in the region of the round window and cochlea (1).

Shea (2) undertook the first stapedectomy in 1956, removing the whole stapes and replacing it with an artificial prosthesis. The defect in the oval window was covered by a vein graft. This technique showed better results when compared with stapes mobilisation techniques, and it soon began to be widely used. Subsequently, a stapedotomy technique was developed whereby a small fenestra was created in the footplate. The small fenestra technique now in wide use. It provides good closure of the air–bone gap with minimal risk of perilymphatic fistula or inner ear trauma and the resultant dizziness and hearing loss. Both techniques have very good hearing results – stapedotomy should have better results at 4,000 Hz (3). Complications after stapedotomy can be sensorineural hearing loss, vertigo due to perilymphatic fistula or excessively long prosthesis and reparative granulomas.

In 1965, Stahle and Högberg (4) used a ruby laser on the labyrinths of pigeons. They demonstrated primary thermal ablation of portions of the labyrinth. In 1967, Sataloff applied a NdYag laser in situ on human otosclerotic stapes, but discovered that there was very poor energy absorption due to the lack of color on the footplate. He also noted the risk of facial nerve injury through inadvertent exposure of the nerve to laser energy. Such a risk was particularly great with lasers that emitted invisible wavelengths.

The first experimental use of the argon laser was carried out in 1972 when fenestration in the horizontal

and posterior semicircular canals in monkeys was created. No significant reduction in hearing and vestibular function was noted within a fibrous reaction at the irradiation site.

The argon laser was first employed in otology in 1979 by Escudero et al. (5). They used a microscope-mounted argon laser that served to “spot-weld” the tympanic membrane graft in place for seven tympanoplasty cases. In the same year, Palva introduced the argon laser for otosclerosis surgery (6). He made small fenestrations of the footplate and observed that hearing results were slightly better than in patients with mechanical fenestration.

In 1980 in the USA, Perkins became the first to undertake small fenestra stapedotomies with an argon laser (7). A fiberoptic cable delivered the laser energy to a microscope-mounted micromanipulator. He had already noted that direct exposure to lasers through an open vestibule should be avoided because water does not absorb the argon wavelength at 488 nm. Removal of the stapes superstructure was also accomplished with a laser. The footplate was irradiated for several minutes to minimize thermal effects on the labyrinth. All of his 11 cases were successful and indicated no sensorineural hearing loss. In the same year, DiBartolomeo and Ellis, in addition to tympanoplasties and myringotomies, used an argon laser in 10 stapedotomies. In one of their cases, they divided the stapedial artery. Their series was free of sensorineural hearing loss.

Since then, the argon laser has been used in some otologic centers (8, 9, 10) and hearing results have been reported to be equal or even better than in stapedotomies undertaken with a skeeter drill. We introduced this technique to our department 2 years ago. We present the results of our surgery and compare them with the work of other authors.

MATERIALS AND METHODS

From October 2009 to February 2011, we operated on 47 otosclerosis patients (32 women and 15 men; mean



Figure 1: Vaporization of the posterior stapedial crus.



Figure 2: Creating a rosette in the stapes footplate.



Figure 3: Removal of char and rough edges. The vestibulum of the inner ear is now opened.

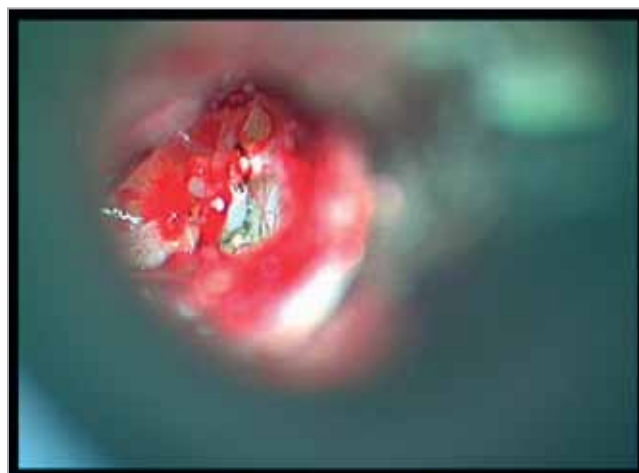


Figure 4: Placing the stapes piston.

age, 47 years). The diagnosis of stapes fixation was set after pure tone audiogram as well as tympanogram and stapedius reflex investigations.

It was the first procedure in all patients. An argon laser with an otoscope was utilized in all cases. The posterior stapedial crus and stapedial muscle were vaporized with a laser power setting of 2 W and pulse duration of 0.2 s (Figure 1). The anterior crus was often fractured or, in some cases, vaporized with those settings. The laser power was then reduced to 1.2 W and the pulse duration lowered to 0.1 s for use on the footplate. Just 2–3 bursts from the laser were shot onto the footplate to create a rosette (Figure 2). The

char was then removed and the fenestra widened with a perforator (Figure 3). We employed a Fish prosthesis, which was introduced in the stapedotomy hole and fixed to the long process of the incus (Figure 4).

Pure tone audiogram was carried out pre- and post-operatively (3 months after surgery) in all cases. After each procedure, overclosure, closure of the air-bone gap and the average postoperative value of the air-bone gap were calculated.

According to the Committee on Hearing and Equilibrium Guidelines for the Evaluation of Results of Treatment of Conductive Hearing Loss, mean thresholds

at frequencies 0.5, 1, 2 and 3 kHz were used to form a four-tone pure-tone average (11). Overclosure in stapes surgery refers to an apparent improvement in bone conduction hearing due to the Carhart phenomenon. An audiometric finding characteristic of otosclerosis is an increase in bone conduction threshold with a peak at 2,000 Hz known as Carhart's notch. Although the notch occurs at 2,000 Hz, a reduction in bone conduction sensitivity is seen at 500–4,000 Hz which is, on average, 5 dB at 500 Hz, 10 dB at 1000 Hz, 15 dB at 2000 Hz, and 5 dB at 4,000 Hz. Carhart attributed this phenomenon to "mechanical factors associated with stapedia fixation." The Carhart notch is not a true indication of "cochlear reserve" and this apparent bone conduction loss may be corrected by surgical intervention (12).

The preoperative minus the postoperative high pure-tone bone conduction average at 1, 2 and 4 kHz is a measure of overclosure or operative damage to hearing. The number of decibels of closure of the air-bone gap was determined as the preoperative value minus the postoperative value of the air-bone gap. This is a continuous variable from negative values (a larger gap after treatment) to positive values (a smaller gap). The air-bone gap is the difference between bone conduction and air conduction.

RESULTS

Hearing results are shown in Tables 1 and 2. Improvement in bone conduction was achieved in 85% of patients who underwent argon laser stapedotomy.

Table 1. Hearing improvement after argon laser stapedotomy

	N	Minimum (dB)	Maximum (dB)	Mean (dB)	Standard deviation (dB)
Overclosure (1, 2, 4 kHz)	47	-7	15	4.40	5.051
Closure of the air-bone gap (0.5, 1, 2, 3 kHz)	47	9	41	22.31	8.600
Air-bone gap (0.5, 1, 2, 3 kHz)	47	3	18	9.63	4.037

Postoperatively, 3 patients left the hospital on the second day because of nausea and vertigo. All the others left 1 day after surgery without nausea with minimal or absent vertigo (which is normal after opening of the inner ear).

DISCUSSION

The use of the argon laser in our institution has shown it to be a safe effective instrument. Its employment did not alter the operating time. The laser reduced mechanical trauma to the vestibule, provided more precision and shortened stays in hospital. These features were attributable to decreased labyrinthine irritation.

In the beginning of laser use in otology, a controversy arose about the optimal laser type and what its purpose should be. DiBartolomeo compared argon and CO₂ lasers and stressed the significant advantage of the argon laser because it had a visible beam and a smaller spot size. However, in subsequent investigations, Gantz and others found that the argon laser perforated the sacculus in 3 out of 8 stapedotomies. They concluded that further research was needed to confront the potential problem of variable absorption of energy on the footplate. In the mid-1980s, the potassium titanyl phosphate (KTP) laser appeared. It displayed similar effects to the proximate wavelength of the argon laser. The wavelength of the argon laser is between 488 nm and 514 nm; that of the KTP laser is 532 nm. These wavelengths are in the visible portion of the electromagnetic energy system. The aiming

Table 2. Average air-bone gap (0.5, 1, 2, 3 kHz) after surgery (N=47)

Air-bone gap (dB)	No. of patients (%)
<10	29 (62%)
10–15	14 (30%)
15–20	4 (8%)

beam and the firing beam are identical. The CO₂ laser has a wavelength of 10,600 nm, which is invisible.

In an experimental study using a paraffin model, Lesinski and Palmer (13, 14) compared the argon, CO₂ and KTP lasers by measuring the temperature in the vestibule. They increased the temperature to 175°C with a micro-manipulator argon laser applied directly into the opened vestibule. The spot size was 50 microns. This finding suggested that argon-laser procedures should be employed with great caution, and that such procedures are not recommended for revision surgery.

The argon laser micromanipulator is expensive, relatively delicate, and adds additional weight and bulk to the microscope. It has been replaced by a fiberoptic handpiece called an "endo-otoprobe" (15). The use of a micromanipulator increased the working distance by several centimetres. It also required the surgeon to hold his/her dominant hand in an awkward position, away from the surgical field. The handheld fiberoptic system was shaped like a Rosen needle and was made up of a 20-micron optical fiber in a 24-G needle handpiece. A rapid loss of power occurred within several millimeters from the tip of the optical fiber. The authors stated surgical techniques and settings which are still in use.

In subsequent years, studies demonstrated the safety of the fiberoptic argon laser (16, 17, 18). A fiberoptic probe eliminated the need for clear line-of-sight firing, reduced the risk of missing the target as a result of patient movement and, furthermore, the feeling of the instrument was similar to many others used in otologic surgery. Even a mobile footplate can be fenestrated with the laser. The anterior crus is not adequately visualized to permit a complete argon laser crurotomy, but it can be palpated in most cases. A thick footplate limits laser use in favour of the micro drill because it is difficult to accomplish extensive ablation of bone with an argon laser.

The endo-otoprobe system does not deliver coherent light, so the rays diverge at the probe tip. Therefore, the power density of the laser falls off rapidly from the tip of the instrument. In the first 0.5 mm from the glass tip, the laser effectively evaporates tissue. From

0.5 mm to 1 mm, the beam can be used to coagulate, but it is not powerful enough to vaporize. Beyond 1 mm there is too little energy to coagulate or ablate tissue. The argon laser passes through clear water unimpeded. Accordingly, it should not be fired into an opened vestibule because pigmented tissues reside in the saccular macula directly in line-of-sight within the vestibule. However, the divergent-beam characteristics in the fiberoptic probe make saccular injury unlikely.

The safety of the fiberoptic laser was studied by Gherini et al. (17). Their laboratory-based studies differed from those of Lesinski in the size and color of the thermocouple used, the spot size, and the method of delivering argon laser energy. In laser delivery with a fiberoptic system, the angle of divergence is much larger and the diameter of the spot increases rapidly with increasing distance from the fiberoptic tip. The power density of a fiberoptic system 2 mm in depth to the footplate was 2.85% of the micromanipulator power density. Laser injury to the facial nerve should be avoided by aspirating the hot (80°C) laser plume and allowing time for cooling between pulses. By using a defocused beam (low power density and large spot size), photocoagulation of the capillaries may be accomplished and stapedotomy done in a bloodless field. Energy absorption is initially weak on the white stapes bone and becomes more effective if carbonization has occurred. Altogether, they operated on >2200 cases of otosclerosis without sensorineural hearing loss or facial nerve injury.

Our hearing results showed considerable improvement in all our patients. Eighty-five percent of patients also exhibited improved bone conduction, suggesting a very safe surgical procedure. Perez reported mean overclosure at 1 and 2 kHz as well as at 7.5 and 8.3 dB. Average overclosure in the present study was 4.4 dB with the 4 KHz frequency included (where hearing gain is usually the lowest). A probable reason for such good results was the non-invasive entrance into the vestibule of the inner ear. Significant overclosure results were also supported by tests which showed that overheating of the inner ear vestibule did not occur with the argon laser. This also explained the very low prevalence of severe postoperative nausea or vertigo.

Table 3. Hearing results with argon laser stapedotomy ascertained by other authors

Air-bone gap (dB)	Rauch et al. 0.5, 1, 2, kHz N=39	Hodgson et al. 0.5, 1, 2, 4 kHz N=135	Raut 0.5, 1, 2, 4 kHz N=135
<10	31 (79.4%)	54 (87%)	104 (77.04%)
<20	4 (10.3%)	5 (8%)	27 (20%)
>20	4 (10.3%)	3 (5%)	4 (2.96%)

Comparison of our results with other recent studies investigating the air-bone gap demonstrates similar outcomes (Table 3). The frequencies do not match completely because some authors did not follow the Guidelines for the Evaluation of Results of Treatment of Conductive Hearing Loss set by the Committee on Hearing and Equilibrium. The greatest average air-

bone gap was 18 dB and 92% of our patients had an air-bone gap <15 dB.

We can conclude that the use of the argon laser represents a significant improvement in stapes surgery (especially in subjects with difficult anatomy). It is a refinement of the stapedotomy procedure.

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