# Argon Laser and Gherini-Causse

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Endo-Otoprobe TM in Otologic Surgery

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## Abstract

The authors describe the various surgical indications and techniques of the argon laser and Gherini-Causse Endo-OtoprobeTM in otologic surgery, from otosclerosis to chronic otitis. The advantages are numerous, permitting the surgeon to vaporize or coagulate tissue with optimal effect, avoiding excessive mobilization of the ossicular chain and diminishing the risk ofdamage to the facial nerve and inner ear structures.

## History

Since approximately 212 B.C., when Archimedes focused sunbeams using a set of mirrors to burn the Roman Navy besieging Syracuse, the problems posed by the interaction of matter and light radiation have fired the imagination of man. It required many centuries of increasingly refined research into this problem - that of the interaction of light and matter - to finally realize the first laser source. In 1960, thanks to Prof. Maiman and his team, the first laser flashed for a few milliseconds from a ruby crystal source. If medicine, throughout its various specialities, became rapidly interested in laser, it was not until 1968 that the importance of the medical laser was to be fully realized. In 1975, the emergence of fiberoptics simplified laser beam transmission and made equipment more efficient and reliable. In otology, Escuderol in 1979 was the first to describe the use of a laser in seven cases of tympanoplasty. In 1980, Perkiàs' performed laser surgery in 11 cases of otosclerosis, introducing the rosette technique to the stapes footplate. At last, in 1983, McGee 3 demonstrated the use of laser to coagulate stapedial and promontorial vessels and in surgery for chronic otitis.

## Interactions Betwe/?en Radiatîon and Living

## Tissue

The interaction between laser energy and tissue depends upon the properties of the specific type of laser and upon the specific characteristics of the tissue. The nature of these interactions is complex. Among the mechanisms which bring to bear, thermal effects and electromechanical effects are particularly important.

**Thermal Effect**

The principal effect of lasers currently used in therapy results from the tissue's absorption of the energy transmitted by the laser beam and its local degradation in heat. This thermal effect depends upon the wavelength of the light emitted and the tissue surface treated (power density). Depending upon the extent of the thermal effect, one observes coagulation, carbonization or vaporization of the cells.

The thermal effect also depends upon the depth of the tissue affected by the radiation, on the thermal conductivity of the tissue and on its local vascularity, from which arises the notion of interactive volume. Interactive volume brings into play the elements of surface density of energy and depth. All these elements must be considered according to the effect required. The vaporization of tissue requires rapid thermal elevation on the target with a low degree of penetration. The hemostatic effect requires thermal elevation to a temperature just above that whieh is required to coagulate proteins, but below that

which will carbonize. To achieve the same hemostatic effect, the argon laser requires four to five times less power than that required by the NdYAG laser. Moreover, the penetration of the NdYAG laser is greater than that of the argon; therefore, the latter ensures more efficient coagulat/?ion in superficial tissue, while the former is more efficient for deeper coagulation. Local thermal diffusion must also be taken into consideration because of its effect upon the area surrounding the target.

The greatest energy transfer takes place during the first 10 milliseconds of exposure. The duration of laser fire must therefore be of this order; any prolongation serves only to produce calories, the majority of which will diffuse into the surrounding tissue. This thermal diffusion will also be influenced by the firing frequency rate. In the case of an excessively rapid rate, the cooling of the tissues will be insufficient, with possible damaging consequences. It is therefore essential to opt for short repeated firing, with a delay of a few seconds between each.

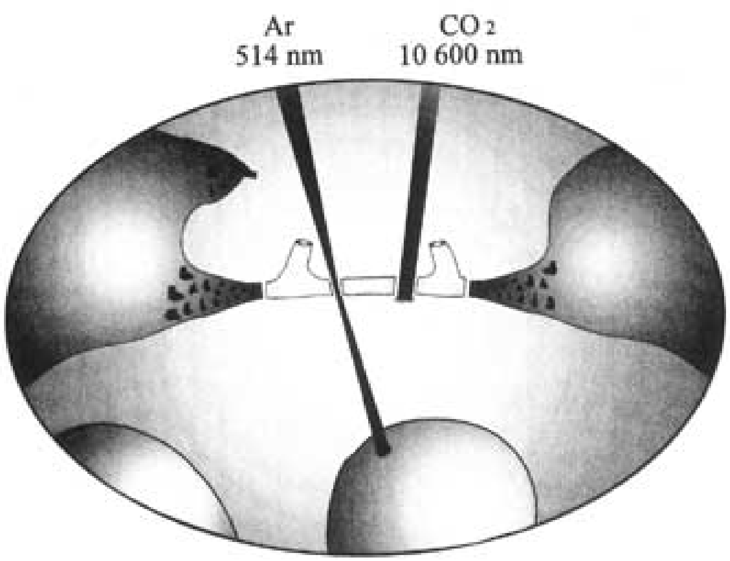


**Figure 1.** Argon beam (blue-green) delivered by a micromanipulator. In contrast to the CO 2 laser, the argon beam is not absorbed by perilymph but by dark red pigments, risking perforation of the saccule. **Electromechanical Effects**

These effects arise from the electric field accompanying the laser beam. Owing to spatial coherence, all the photons comprising the beam will be focused on a very small area. This increases significantly the electromagnetic field values. Laser fire may therefore cause changes in the area crossed, inducing notable alterations in molecular structures (ionization, binding ruptures, etc.). These electromechanical phenomena must be bome in mind, especially since they can be transmitted by bone conduction, causing distant lesions.

**Argon Laser**

At the Causse Clinic, we use the argon laser, introduced in Europe by H.G.M., which may be used in a single or continuous pulse mode and is capable of delivering up to 6W. The maj ority of the time we require a power range of 1.2 -2W, depending upon the situations encountered and the surgical stage. The argon laser delivers a visible bluegreen beam of which the two principal wavelengths are 488 and 514 nm. This characteristic of visibility offers an ideal range of use in otologie microsurgery.

Owing to its short wave length, the beam can be readily transported by fiberoptics. We use the Gherini-Causse Endo-OtoprobeTM. This perTnits a high degree of accuracy in treatment, particularly important in stapes surgery. Two effects of laser energy on the tissues must be taken into consideration before using the argon laser: its absorption, which varies according to the color of the tissue, and its thermal diffusion.

**Tissue Absorption**

The argon energy is absorbed particularly by dark red pigments like that of blood. Absorption by perilymph, whieh is similar in composition to water, is poor. At the level of the stapes footplate only part of the energy is absorbed, and the remaining energy traverses the perilymph and may be absorbed by red blood cells inside the saccule and utricle.

**Thermal Diffusion**

Because of its short wavelength, the argon laser will penetrate tissues more deeply and with greater therinal diffusion than lasers with longer wavelengths, such as the C02 laser. While the argon laser has ideal optic properties for precision, one should nevertheless be aware of these two tissue characteristies during its use (Figu/?re 1). Gantz et a14 report three cases of saccule perforation in a series of eight stapedectomies perforTned in cats. More recently, Silverstein' has reported several cases of vertigo and sensorineural hearing loss in a clinical study using the argon laser in revision surgery (stapedectomy and stapedotomy). Vollrath and Schreiner, 1,7 and Riceil have clearly demonstrated the risk of heating the labyrinth fluids with the argon laser in stapedectomy. It is with the aim of diminishing the tissular effect and the accompanying risk to the inner ear structures that we normally use the Gherini-Causse Endo-OtoprobeTm designed by Stuart Gherini, Jean-Bernard Causse and Kar Hom.

The probe consists of a 200g diameter fiberoptic filament made of quartz-silica. By virtue of its light weight,

it is as easily manipulated as any other microsurgical instrument. With it, one achieves a spot size approximately 200g in diameter. In contrast to the micromanipulator situated on the microscope, the beam transmitted via the probe diverges extremely rapidly, with an angle of divergence of 13' rather than 3'. The cross-sectional diameter of the beam enlarges rapidly. The power density of the beam becomes practically zero at a point 2mm beyond the distal tip of the fiberoptic (Figure 2). Depending upon the distance between the tip of the fiberoptic and the target, the effects will differ: when the fiberoptic is in actual contact with the target, one achieves vaporization and, hence, a sectioning effect. Slightly withdrawing the tip of the fiberoptic from the target has a coagulating effect. At a distance of 2 mm the power density is very low. Therefore, maintaining a safe distance of 2mm or more from the facial nerve is sufficient for the risk of damage to become minimal at lo/?w power settings. Maintaining a distance of 0.5mm from the footplate and selecting a pulse duration of 0.2 seconds at a power of 1.2W for coagulation prevents perforation of the footplate and reduces the risk of damage to inner ear structures.

In addition, because the bony tissue is an excellent heat conductor, it is prudent to wait a few seconds between pulses to avoid heating the perilymph. This probe offers great precision, permitting actual contact with areas to be treated, which are, at times, extremely difficult to access (notably the anterior crus of the stapes). In cases of minor aplasia, malformation or fibrosis rendering the anatomy more complex, the fiberoptic probe is an indispensable aid.

Many researchers have investigated the effects of the argon laser on the labyrinth fluids and have shown risks of a rise in temperature - which may at times be significant - as a result of firing carried out with the micromanipulator. Lesinski',` studied the effects of argon laser, as applied via micromanipulator, on models of vestibules. With the aid of a thermo-couple placed in the vestibule at a distance of 2mm below the footplate, he measured the rise in temperature of the labyrinth fluids. During laser fire of 2W, the rise in temperature was minimal (4'); it was far more significant, however, in the absence of the stapes. Sim?arly, Gherini et al" studied the same effects using a similar model, but with a fiberoptic otoprobe. They demonstrated the advantages of fiberoptics as compared to the micromanipulator, in that there was no significant rise in temperature at the level of the labyrinth in cases of stapedotomy or stapedectomy (direct application of the probe to the labyrinth fluids). In addition, in a clinical study of 2,200 cases of stapes surg/?ery for otosclerosis, including cases of both primary and revision surgery, there was not a single case of damage to the facial nerve or sensorineural hearing loss described.

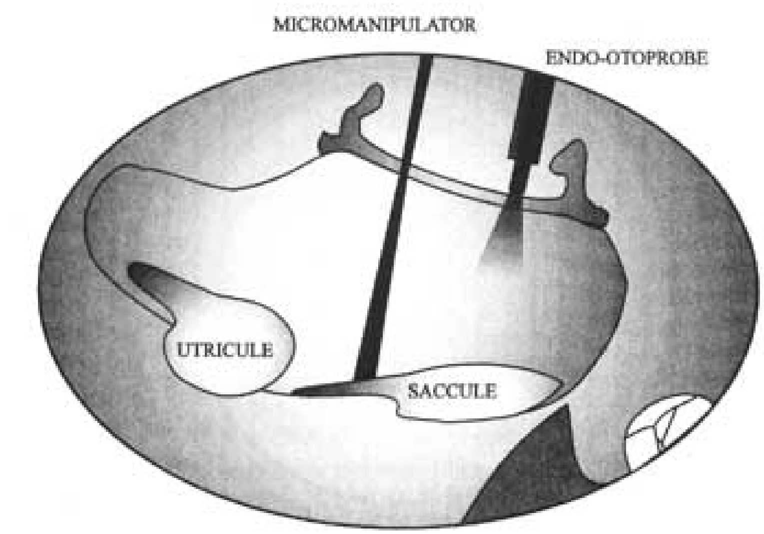


**Figure 2.** The difference between the power density of the EndoOtoprobe Tm and the micromanipulator. Because of the EndoOtoprobe's greater divergence angle (Il 3% the power density of the beam decreases rapidly and the risk of damage to distal structures is reduced.

The difference in power density depends on the mode of delivery of the laser energy. A micromanipulator situated on the operating microscope projects the beam with a narrow angle of convergence/divergence, whereas the probe has a beam with an angle of divergence of about 13'. The diameter of the spot increases rapidly with distance from the tip of the probe, and the power density diminishes with corresponding speed.

Power density is defined as:

$$\frac{\text{Power (Watts)}}{\text{Area applied (cm2')}}$$

We use the argon laser to perform stapedotomy with vein graft interposition following the JeanBemard Causse technique. 13,14,15 The use of the laser is particularly important in cases with a partially fixed footplate or agenesia of the annular ligament, which both give rise to the phenomenon of the small air-bone gap.

### Surgical Indications for the Argon Laser and Gherini-Causse Endo-Otoprobellm

Stapes surgery remains the main indication for the use of the argon laser. The great advantages and satisfaction with perfonnance are encouraging practitioners to widen the field of application, allowing surgeons a higfi degree of accuracy using a niinimally invasive technique. The KTP 532 laser coupled with a fiberoptic otoprobe, advocated by Martin and Prades, 12 has similar characteristics. The aim
of this paper is to present several situations encountered in otologic surgery in which the argon laser has been a particularly effective instrument. As with any surgical instrument a fiberoptic argon laser handpiece is only a tool. It is the surgeon's experience which remains the primary determining factor in surgical success.

## Otosclerosis

### Primary Otosclerosis

We use the argon laser to perform stapedotomy with vein graft interposition following the JeanBemard Causse technique. 13,14,15 The use of the laser is particularly important in cases with a partially fixed footplate or agenesia of the annular ligament, which both give rise to the phenomenon of the small air-bone gap. Here, verification of the mobility of the stapes, using a microinstrument gently applied to its head, is an important surgical step. If the lateral mobility is maintained, only the driving movement may be diminished.

The crura are first vaporized (Figure 3A) with the posterior crus followed by the anterior. Normally two to three laser spots suffice. The anterior crus is not usually visible, and the curve of the probe enables the surgeon to palpate the anterior crus before vaporizing it, using a setting of 2W for 0.5 seconds. It may be necessary to finish sectioning the crura using the Causse Skeeter Oto-toolTM or the diamond microdrill. The laser then facilitates preparation for stapedotomy following the technique described by Perkins .2 A superficial layer of footplate bone is weakened by laser spots of 200g at 1.2W for 0.2 seconds, at a distance of lnim from the footplate (Figures 3B and 3C). This procedure is performed on the posterior third of the footplate. The resulting rosette determines the position of the stapedotomy. The remaining layer of bone is abraded with the microdrill using a 0.7mm burr. A stapedotomy of 0.8mm is thereby achieved (Figures 3D and 3E).

Thanks to die accuracy of the argon laser, each of these stages is performed with a high degree of secuiity for the inner ear structures, avoiding excessive manipulation of the stapes. To prevent fracture of the footplate when abrading, the burr must be applied to the footplate without pressure. Usually, the otosclerotie ear has hypervascularization at the level of the promontory and oval fossa. Throughout surgery the argon laser enables photocoagulation of the nùcrovessels, diminishing considerably the risk of bleeding into the labyrinth once stapedotomy is completed.

A large, persistent stapedial artery, which may, in some cases, be found traversing the oval window (Figure 4), is impossible to avoid, given its volume, even with a posterior stapedotomy. DiBartolomeo" in 1980 was the first to use the argon laser to coagulate a persistent stapedial artery. Usually, unless the volume of the artery is too great, it is possible to coagulate the vessel holding the probe lmm from the artery (1.2W for 0.2 seconds). It is very rare to encounter a stapedial artery of such dimensions that using the laser will be ineffective or dangerous. Some cases of sensorineural hearing loss and even facial paralysis have been reported in such circumstances. In these cases, it is preferable to employ other surgical techniques, such as drilling down the lip of the promontory, to avoid the vessel entirely.

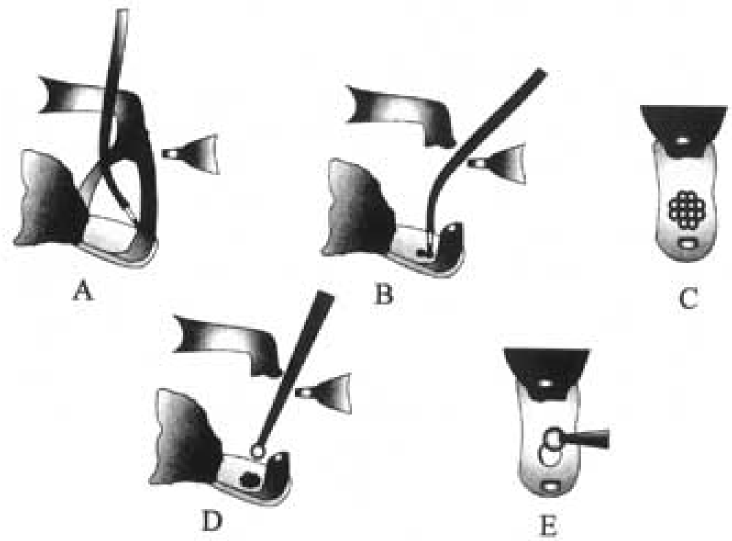


**Figure 3**. Use of Argon laser and Gherini-Causse Endo-OtoprobeTM in otosclerosis surgery : A. Vaporization of the posterior crus of the stapes (2 Watts - 0.5 seconds). B. Vaporization of the footplate on its posteriorthird (Il Watt- 0.2 seconds). C. Rosette laser spots determine the position of the future stapedotomy. DandE. 0.8mm stapedotomy with Skeeter Oto-tool.TM

Even in cases of classic otosclerosis, anatomical conditions may make surgery extremely difficult, notably in cases of an overhanging fallopian canal or exposed facial nerve, or when the oval window is very narrow with a bulky posterior crus of the stapes obscuring the stapes footplate. In each of these situations, surgical security is considerably enhanced by the use of the Gherini-Causse Endo-OtoprobeTM. We use the argon laser routinely in surgery for otosclerosis. In accord with numerous studies found in the literature,',',' 1,17-211 the results are extremely satisfying in terms of functional results and in avoiding surgical side effects (vertigo, instability, sensorineural hearing loss).

## The Limitations of Arcion Laser in Surciery for Otosclerosis

The limitations are primarily in cases of a thickened (biscuit) footplate. In this condition, weakening of the superficial layer by the argon laser is ineffective. Instead, the footplate is directly drilled using the Skeeter Ototool.TM This is done with the lightest possible touch because, paradoxically, such footplates are only partially fixed and are susceptible to becoming embedded (floating) with the smallest degree of excessive pressure.

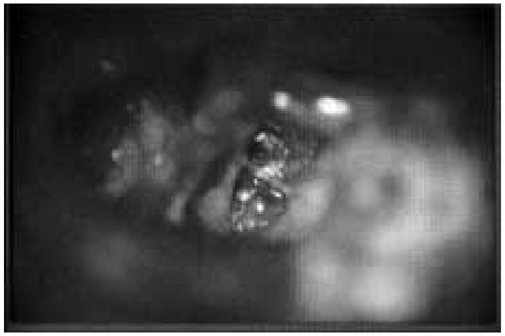

**Figure 4. Large stapedial artery crossing the oval fossa and hampering the approach to the footplate (left ear).**

**Figure 5. Deep intralabyrinthine penetration of the piston; the risk is fibrous adhesion of the piston to the saccule (left ear).**

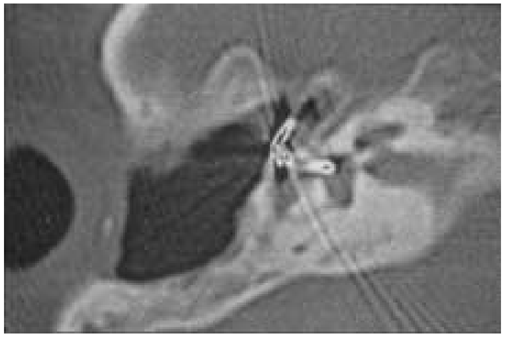

**Figure 6. Tomodensitometry showing the intralabyrinthine location of the shaft of the prosthesis.**

In revision stapes surgery the dominant problem is fibrosis, which is often extensive, around the oval window or throughout the whole of the middle ear. In addition, normal anatomical relations may be modified. The facial nerve is often obscured and dissection of fibrous tissue with a microhook may cause copious bleeding.

The type of primary stapes surgery may not be known. In cases in which the primary surgery was total stapedectomy, the risk of bleeding into the labyrinth is grave. The argon laser makes it possible to progressively vaporize the fibrous tissue while simultaneously coagulating the capillaries. The complete absence of bleeding is truly remarkable.

In order to avoid damage to the facial nerve, the tympanic portion of whieh may be exposed, dissection of the fibrosis begins at some distance from the nerve, along the promontory. To commence, a power setting of 2W at an exposure time of 0.5 seconds is used. The adhesions between the promontory and ineus, or between the incus and the tympanic membrane, are vaporized. The long process of the incus mustbe completely freed, taking great care to avoid the incus itself during firing so that its blood supply is not compromised and there is no risk of necrosis. Upon approaching the region of the facial nerve, the power and exposure time are diminished: 1.2W and 0.2 seconds respectively. The nerve is progressively freed along the length of the second portion. At the level of the oval window fibrosis is often extensive. All bleeding must be avoided here.

The region of the footplate must be freed in its entirety before disengaging the prosthesis placed in the initial surgery. The power and exposure time remain at 1.2W and 0.2 seconds, and the tip of the probe remains at a distance of lmm from the area treated. The tip of the prosthesis must be completely freed (Figure 5). This is absolutely essential in cases where the previous prosthesis is of a material other than Teflon (Figure 6). Depending upon the material used, adhesions between the extreme tip of the prosthesis and the saccule may have formed. The whole of the prosthesis must therefore be visible before its withdrawal. When there is any doubt that the prosthesis has been completely freed, it must be left in place. When a stapedectomy has been carried out during previous surgery, there is enhanced risk of heating of the labyrinth fluids. Therefore, we always try to conserve the neomembrane. We then make an opening in the membrane of 0.8mm. Using the laser, we always interpose a new vein graft before positioning of the Teflon piston or total prosthesis in cases of incus necrosis (diameter of prosthesis shaft, 0.4mm).

**Figure 7. Malformation of the stapes crura which are agenic and fixed to the promotory, whereas the footplate is mobile. Sectioning the crura with argon laser will allow transmission down to a mobile footplate (left ear).**

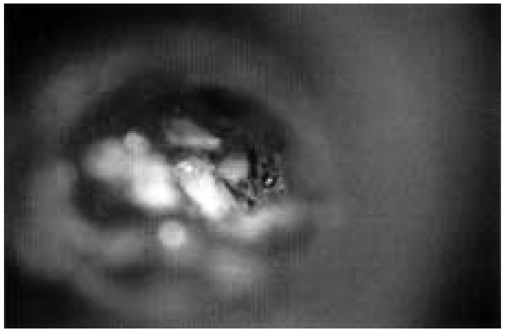

**Figure 8. Double prolapsing facial nerve necessitating a high level of surgical precision made possible bythe probe (spot seen on the posterior crus) (right ear).**

**Figure 9. Localized tympanosclerotic lesions (left ear ): anterior pole of the footplate; stapes tendon; tympanosclerotic bridge between the facial nerve and the anterior crus of the stapes.** When aplasia is associated with poor fixation of the stapes, with malformation of the lamina stapedialis of the annular ligament of the stapes footplate, the laser is equally useful as in cases of otosclerosis with poor fixation. The laser prevents excessive movement of the footplate, minimizing potential mechanical trauma to inner ear. When the crura of the stapes are malformed, with fixation of a single crus either to the promontory or to an ossified stapedial tendon, the laser is amarvelous tool for vaporization of these crura and of any bony fixation, without risk of mobilizing the footplate.

The laser is far more difficult to use in cases of a perilymphatic gusher which inhibits the effect of the beam. When this gush of perilymph under pressure appears at the first laser vaporization, it is absolutely essential to aspirate delicately but effectively very close to the opening created by the laser. Well-performed aspiration of perilymph will allow the rosette of laser vaporizations to be completed. In such a case, the stapedotomy is not completed with the diamond burr. The laser becomes the primary and essential instr-ument as the piston and vein graft plug the opening together, preventing a significant leakage of perilymph.

A prolapsing facial nerve is not a real problem because it is simple to direct the tip of the laser probe at the crura, facing away from the facial nerve. This allows vaporization and removal of the crura, thus opening the way to the footplate. In cases of an absent stapes footplate and replacement by thick bony growth, the laser is not used. In such circumstances, only the diamond burr is effective.

## Chronic Otitis

In 1979, Escuderol was the first to report use of the argon laser in tympanoplasty. He used it with a fiberoptic, creating a 'solder' effect to facilitate the adhesion of the temporalis fascia graft and the remains of the eardrum. Siinilarly, in 1980, DiBartolomeo" reported the advantage of laser in stabilizing tympanic membrane grafts using a limited number of spots around the periphery of the graft. He also cited other surgical indications: adhesions to the tympanic membrane, myringotomy with tube insertion, sculpting of the incus for transposition and freeing of a fixed chain by the vaporization of two ossicles. Many authors have since described a variety of applications of the argon laser in chronic otitis (cholesteatoma, tympanosclerosis, scar tissue, ossicular fixation) .1,20-22

For our part, we use it with great effect under three main conditions: fibrous otitis, tympanosclerosis and cholesteatoma.

Fibrous otitis. Use here conforms to the same rules as those described for otosclerosis revision surgery. It is of great value in cases of fibrosis obliterating the oval window. 'Me fibrosis may be, totally and without bleeding, freed as far as the stapes footplate. The stapes footplate then may often be found to be perfectly mobile. The risks of opening the labyrinth by splitting the footplate in an inflamed ear are therefore considerably reduced. After freeing the areas of adhesion, and in order to diminish the risk of recurrence, we usually use a strip of Silastic on the promontory.

Tympanosclerosis. When the stapes is blocked by tympanosclerotic foci, the technique is that described for otosclerosis; sectioning of the crura by laser, followed by stapedotomy of 0.8mm with vein graft interposition. Obviously, in cases complicated by perforation of the tympanic membrane, the stapes phase is perforTned after a delay of six to twelve months after myringoplasty. In certain cases, the ovaJ window is invaded by obliterating tympanosclerosis. Dissection must be carried out prudently, because the footplate, once freed, may tum out to be completely mobile. The argon laser allows vaporization of tympanosclerotic foci of the stapedius tendon or a tympanosclerotic bridge between the head of the stapes and the facial nerve, thereby restoring normal mobility of the stapes (Figure 9).

In cases of myringoplasty one may frequently find a plaque of old tympanosclerosis attached to the handle of the malleus and of sufficient thickness to immobilize the ossicular chain. Freeing of the malleus while avoiding excessive movement is achieved with four to five laser spots (2W at 0.5 seconds), actually slicing with 'perforations' along the length of the handle which must not be touched by the laser. In certain situations, the surgeon may be confronted by massive tympanosclerosis, and checking the extensions which may be adherent to the facial nerve is not possible. Whether the nerve is protected by the fallopian canal or whether it is exposed, one must avoid working along these extensions. In this situation, the argon laser enables sectioning of the extensions without fear of mobilizing the plaques when one has insufficient knowledge of the effects on the noble structures - these being the facial nerve, the membrane of the round window and the ossicular chain.

Cholesteatoma. The argon laser is highly effective in cases of invasion of the stapedial arch by cholesteatoma. Bearing in mind the completely normal mobility of the stapes, minimal dissection may be impossible or dangerous. Used at a power of 1W and a duration of 0.2 seconds, the laser enables sectioning without mobilization of the stapedial superstructure, thereby enabling excision of cholesteatoma.

## Conclusion

The argon laser and Gherini-Causse Endo-OtoprobeTM represent instruments of choice in certain situations, on the condition that some simple guidelines are respected. Far from being limited solely to stapes surgery, these tools have found a place in numerous areas of ear surgery to which they bring a level of security and precision that is indispensable.

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