

## Early Post-Laser Stapedotomy Hearing Thresholds

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**Objective:** Auditory testing is not routinely performed within 4–6 weeks after stapedotomy, because hearing acuity is thought to be transiently depressed. In rare circumstances, postsurgical auditory and vestibular complaints may lead one to test hearing soon after stapedotomy. The early postoperative effects of carbon dioxide (CO<sub>2</sub>) and potassium titanyl phosphate (KTP) lasers, which now are routinely used to perform stapedotomies, have not been reported. The purpose of this report is to present normative data for auditory thresholds measured within 2 weeks of laser stapedotomy.

**Study Design:** The study design was a prospective, unblinded study.

**Setting:** The study was conducted at three academic medical centers.

**Patients:** Thirty-six subjects undergoing 38 stapedotomies for otosclerosis by 5 surgeons participated.

**Main Outcome Measures:** Behavioral audiometry was performed using standard techniques beginning before surgery and continuing through >1 year after surgery.

**Results:** The CO<sub>2</sub> laser was used in 26 stapedotomies and the KTP laser was used in 12. Nine cases were revision procedures. Bone conduction pure-tone averages and speech discrimination scores did not worsen during the early postoperative period. Bone conduction at 250 and 4,000 Hz dropped slightly within the first 2 weeks (-4.3 and -6.7 dB) but recovered thereafter. Bone conduction at 1,000 Hz actually improved within the first week after surgery (+6.2 dB,  $p = 0.021$ ). Significant improvements in air conduction thresholds (and air–bone gap) were seen at the second week and late audiometry. The results for CO<sub>2</sub> and KTP laser-treated groups were not significantly different.

**Conclusions:** Cochlear function is not significantly depressed in the early postoperative period after laser (CO<sub>2</sub> or KTP) stapedotomy. **Key Words:** Laser—Stapedotomy—Hearing—Otosclerosis.

*Am J Otol* 19:443–446, 1998.

Lasers have been touted as the least traumatic method of performing a stapedotomy, because they minimize the need for mechanical manipulation of the inner ear (1). In theory, this should improve hearing results. Higher rates of hearing improvement have been reported with laser stapedotomy than with conventional stapedectomy performed by both experienced (2) and inexperienced (3) otologic surgeons. Very high rates of successful hearing improvement have been reported for stapedotomy performed with both visible light and carbon dioxide (CO<sub>2</sub>) lasers (2–6).

Hearing results usually are not evaluated until at least 4 weeks after stapedotomy, because transient sensorineural hearing has been reported to be a common but (usually) clinically insignificant finding (7–10). As a result, little data have been published on hearing acuity in the early postoperative period (within 4 weeks of stape-

dotomy). Although laser energy can uniquely damage the inner ear, by penetrating the membranous labyrinth (11) or by heating the perilymph (12), no prior studies have examined hearing in the immediate postoperative period after laser stapedotomy.

Patients seldom have significant complications after stapedectomy; however, early postoperative audiometry may be considered necessary in these unusual circumstances. Interpretation of early post-stapedectomy audiometry is difficult without normative data. The purpose of this study is to examine the normal range of hearing in patients who recently have undergone laser stapedectomy.

### METHODS

After receiving investigational review board approval, all patients undergoing surgery for otosclerosis at the authors' respective academic medical centers from April 1994 through July 1996 were prospectively invited to participate. Subjects underwent surgical and postoperative treatment as deemed appropriate by the attending surgeon. Any subject who had revision surgery in which the oval window was *not* reopened or an unusual postoperative course (e.g., persistent cochlear or

Presented at the American Otological Society annual meeting, Scottsdale, Arizona, May 10–11, 1997.

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vestibular complaints) would have been excluded from the study.

Subjects underwent routine behavioral audiometry (pure-tone thresholds and speech discrimination) during the first 2 postoperative weeks and at routine intervals (e.g., after 6 weeks). Although a discrete period of "early" postoperative hearing has not been rigidly defined in the literature, we focused our hearing assessments on the first 2 postoperative weeks, because patients have, in our experience, been most likely to encounter difficulties (e.g., dizziness) during this period. Subjects and surgeons were blinded to the results of the early postoperative audiometric results unless clinical concerns required such information. As the need for early postoperative audiometry deviated from the normal postoperative course, any subject whose data were unblinded would have been excluded from the study.

Postoperative pure-tone thresholds, speech discrimination scores, and speech reception thresholds were analyzed for change from baseline. The pure-tone threshold was calculated as the average of 500, 1,000, 2,000, and 3,000 Hz. The nonparametric Wilcoxon signed rank test, analogous to the paired *t*-test, was used to determine whether change from baseline at each observation time after surgery was statistically significant. The nonparametric Wilcoxon rank sum test, analogous to the independent sample *t*-test, was used to compare change from baseline at each observation time between patients treated with potassium titanyl phosphate (KTP) laser and patients treated with CO<sub>2</sub> laser.

## RESULTS

Many potential subjects could not participate in the study, because the distance that they lived from our respective tertiary care facilities made serial testing inconvenient or impossible. Thirty-six subjects were enrolled and underwent early postoperative testing for this study. No patients were excluded because of postoperative complications. Hearing results were available for 38 stapedotomy procedures. Nine cases (24%) were revision procedures, and the remaining cases were primary procedures. Two revision procedures and one primary procedure involved malleus-to-oval window prostheses. All procedures were performed with small fenestra stapedotomy techniques. The CO<sub>2</sub> laser was used to perform the stapedotomy in 26 cases, and the KTP laser was used in 12 cases. None of the procedures were performed without using the laser to create a stapedotomy.

Of the 36 enrolled subjects, 24 returned for testing within the first week after surgery (mean, 2 days; median, 1 day). Twenty-one returned during the second postoperative week (mean, 9 days; median, 8 days). The first routine audiogram (i.e., >6 weeks after surgery) was performed on 36 subjects after a mean of 12 weeks (median, 8 weeks). Long-term follow-up was available for 18 subjects (mean, 732 days; median, 675 days). Patients who were and were not available for long-term follow-up were not significantly different with respect to demographic data such as age (mean, 46 years for both) or hearing outcome (mean air pure-tone average after 6 weeks, 28 dB for both).

Bone conduction pure-tone averages (Fig. 1A) and speech discrimination scores (Fig. 1B) did not worsen

appreciably during the early postoperative period. Bone conduction at 4,000 Hz dropped slightly within the first week (-7.1 dB,  $p = 0.0127$ ) but recovered thereafter. Bone conduction levels at 250 Hz were transiently, mildly, but (statistically) significantly depressed (-4.25 dB,  $p = 0.056$ ) at 2 weeks after surgery. Bone conduction at 1,000 Hz actually improved within the first week after surgery (+5.6 dB,  $p = 0.0362$ ). Bone conduction thresholds at 1,000 and 2,000 Hz improved significantly by the time of late postoperative audiometry (4 dB change and  $p < 0.05$  for each).

Air conduction thresholds at 8,000 Hz worsened significantly at the first postoperative audiometry. Return to baseline did not occur until the late audiometry, and improvement in 8,000 Hz thresholds was not achieved (Fig. 1C). Significant improvement in air conduction thresholds was seen at 250, 500, 1,000 Hz, and pure-tone average within the first 2 weeks (20.3, 18.5, 14, and 9.5 dB;  $p = 0.0006, 0.0017, 0.0091, \text{ and } 0.0245$ , respectively). Improvement in the air conduction thresholds, except for 8,000 Hz, continued through the latest hearing assessment (Fig. 1D).

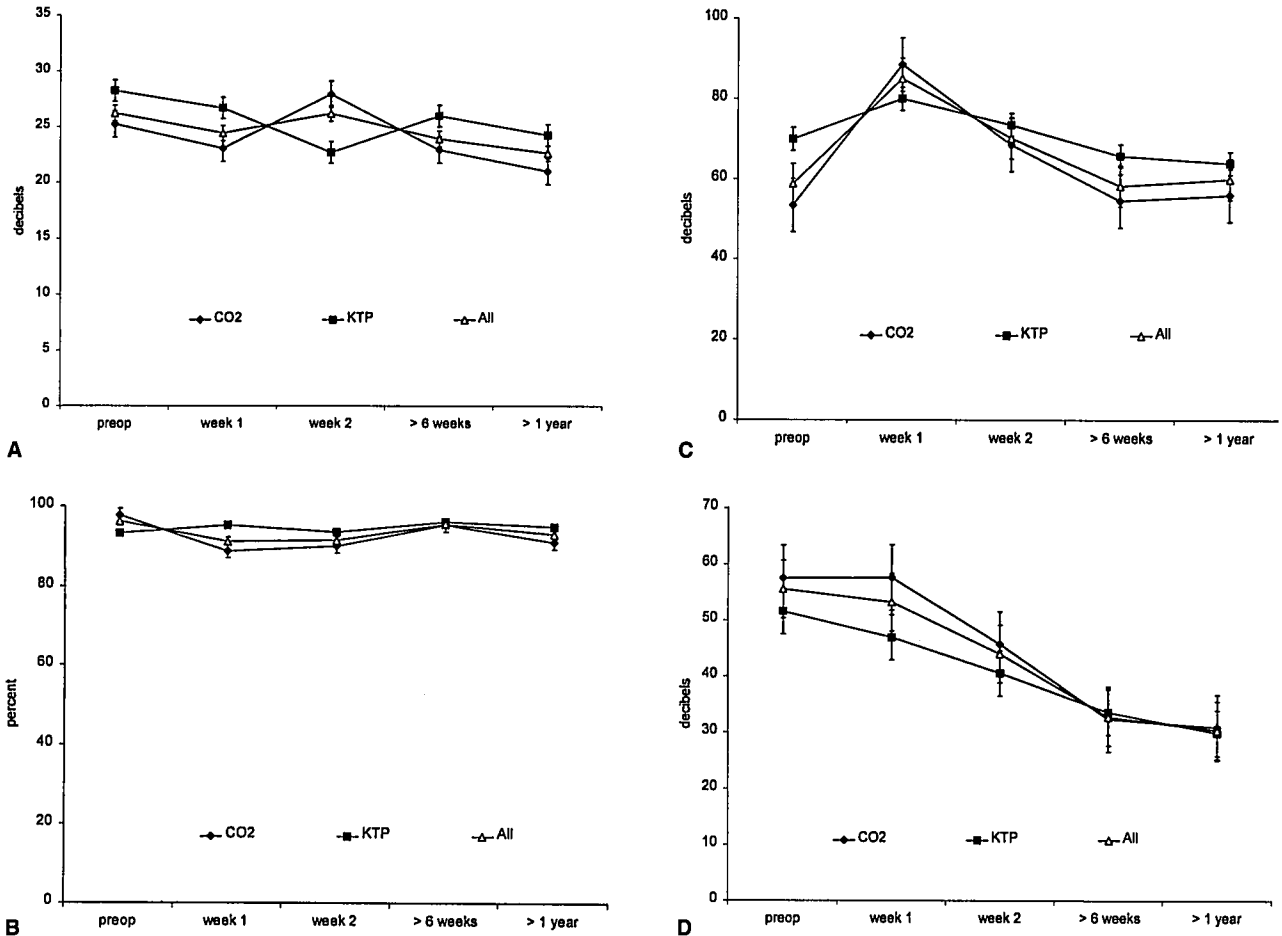
Time course for closure of the air-bone gap closely followed that of the pure-tone average air conduction thresholds. Audiometry performed after >4 weeks showed closure to within 10 dB in 67%, 15 dB in 83%, and 20 dB in 97%. The lone patient who did not close to within 20 dB had undergone a revision procedure with a malleus-to-oval window prosthesis (52.5 dB before surgery, 27.5 dB after surgery). Hearing results for primary and revision cases were not statistically different.

The results for CO<sub>2</sub> and KTP laser-treated groups were not appreciably different. More specifically, the mild, transient decline in the early 250- and 4,000-Hz bone conduction thresholds was not different for either laser. Although speech discrimination scores did not decline significantly from preoperative levels as a group, the *change* associated with the KTP laser was slightly better (3.0% improvement to 96%) than with the CO<sub>2</sub> (-2.7% drop to 95%, Fig. 1B). This difference was statistically significant ( $p = 0.0086$ ).

## DISCUSSION

Testing hearing in the early postoperative period after stapedotomy has not been performed routinely because transient sensorineural hearing losses were encountered frequently after stapedectomy using conventional techniques (7-10). The cause for such transient sensorineural loss has never been proved. Labyrinthine hydrops, vascular sludging, and direct surgical trauma were commonly considered causes for this phenomenon (10).

In 1977, Robinson and Kasden (10) reported that speech discrimination by bone conduction was maintained relative to pure-tone thresholds immediately after stapedectomy. They interpreted this as an indication that transient sensorineural losses observed after stapedectomy resulted from changes in the middle ear impedance and transformer mechanisms (e.g., edema, transudates, and bleeding)



**FIG. 1.** Bone conduction pure-tone average thresholds (A), speech discrimination scores (B), 8-kHz air conduction thresholds (C), and air conduction pure-tone average thresholds (D) measured before surgery (preop), in the first week after surgery, in the second postoperative week, at least 6 weeks after surgery, and >1 year after surgery. Results for the entire group (all) are stratified by the type of laser used to perform the stapedotomy (CO<sub>2</sub> [carbon dioxide] or KTP [potassium titanyl phosphate]). Error bars represent the standard error for each group.

rather than inner ear pathology. Colletti and Ricci (9) found that the degree of sensorineural hearing loss immediately after stapedectomy was directly proportional to the size of the oval window fenestration. This also suggested the sensorineural losses seen after stapedectomy resulted from loss of compressional and inertial components of bone conduction rather than actual injury to the inner ear.

Laser and microdrill techniques have gained widespread popularity for stapedotomy, because these techniques may cause less injury to the inner ear. However, hearing outcomes soon after surgery with these techniques have not attracted much study. Barbara and colleagues (13) and Naramura and colleagues (14) reported on the early postoperative hearing results after stapedotomy using the microdrill technique. Their investigations focused on closure of the air-bone gaps, and no data specific to cochlear function (e.g., bone conduction thresholds and speech discrimination scores) were presented.

In this study, we examined hearing in the early postoperative period after laser stapedotomy. We observed

slight, but statistically significant, transient declines in bone conduction thresholds at 250 and 4,000 Hz. The higher frequency sensorineural hearing loss is consistent with those reported previously for larger fenestra, conventional technique stapedotomies. Although these threshold changes were *statistically* significant, the magnitude was on par with test-retest variability. Hence, they would likely not concern most otologists.

We observed no decline and even noted some improvement in parameters of cochlear function after small fenestra laser stapedotomy. The improvement seen at 1,000 Hz probably resulted from a combination of minimal trauma to the inner ear and improvement in the inertial component of bone conduction. There were no differences in auditory results between patients treated with the CO<sub>2</sub> and KTP lasers. These data suggest that small fenestra stapedotomies performed with CO<sub>2</sub> and KTP lasers usually impart no significant trauma to the inner ear.

The postoperative hearing results that we observed after laser stapedotomy, using the CO<sub>2</sub> and KTP lasers,

were better than those reported for stapedectomy using conventional techniques (9,10). Hence, concerns raised over heating of the perilymph and penetration of the membranous labyrinth by laser energy in basic science studies were not found to be of clinical significance. Since the initiation of this study, Anthony (15) has reported that argon laser ablation of the otolithic viscera seldom causes sensorineural hearing loss.

By definition, our observations apply only to patients with uncomplicated postoperative courses. Such troublesome postoperative courses are, fortunately, relatively uncommon. Although many potential subjects were not enrolled in this study because of patient scheduling (e.g., travel) conflicts, no patients were excluded because of postoperative complications throughout the course of study enrollment. Hence, this study population is representative of our experience with both CO<sub>2</sub> and KTP laser stapedotomy.

Laser stapedotomy techniques certainly are not without risk of such adverse events. One of our earlier patients showed profoundly, transiently depressed bone conduction thresholds after KTP laser stapedotomy; he was the impetus for this study. Bleeding, displacement of bone fragments, hydraulic traction (footplate avulsion), violation of the membranous labyrinth, and transmission of vibroacoustic energy (microdrill), previously thought to be the causes of inner ear injury with conventional stapedectomy techniques, are less problematic with laser stapedotomy techniques. Although laser stapedotomy techniques have not eliminated the risk for permanent sensorineural hearing loss or anacusis with stapedectomy, our observations indicate that such cases are far from the normal postoperative course.

**Acknowledgments:** The authors thank the audiology department at the University of Florida, Tulane University, the Michi-

gan Ear Institute, and Providence Hospital, for performing the audiometric testing. The authors also thank Paul Kubilis, MS, for performing the data statistical analysis.

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