Certain Effects of Cleft Palate Repair on Eustachian Tube Function*

CHARLES D. BLUESTONE, M.D.
JACK L. PARADISE, M.D.
QUINTER C. BEERY, M.A.
RONALD WITTEL, M.D.
Pittsburgh, Pennsylvania 15213

Previous studies have shown that infants with unrepaired cleft palate regularly have middle ear effusions (*1, 2*) and that they demonstrate roentgenographic evidence of retrograde obstruction to the flow of radiopaque media at the nasopharyngeal end of the Eustachian tube (*2, 3*). The Eustachian tube probably has at least three physiologic functions with respect to the middle ear: ventilation, protection from unwanted nasopharyngeal secretions, and drainage of secretions normally or abnormally produced by the middle ear itself. This study represents an attempt to evaluate and correlate these three functions of the Eustachian tube in 22 infants with cleft palate, and also to evaluate the effect on these functions of surgical repair of the palate. Twelve patients also received unilateral hamulotomy in an effort to determine the effect of this procedure—often done as part of the palate repair—on Eustachian tube function and middle ear status.

Protective function of the Eustachian tube was evaluated by roentgenographic study after instillation of radiopaque media into the nasopharynx. Drainage function was evaluated on the basis of clearance of radiopaque media from the middle ear and Eustachian tube into the nasopharynx. Ventilatory function was evaluated by means of tympanometry if the tympanic membrane was intact, and by means of an inflation-deflation manometric technique if a functioning tympanostomy tube was present.

These findings were then correlated with otologic status before and after repair of the palate.

Subjects and Methods

The study group consisted of 22 infants with unrepaired cleft palates. There were 14 males and 8 females. All had first received myringotomy

Supported in part by U.S. Public Health Service Grant DE-01697, National Institute of Dental Research.

From the University of Pittsburgh Cleft Palate Center; the Departments of Otolaryngology, Pediatrics, and Radiology of the University of Pittsburgh School of Medicine; and the Children's Hospital of Pittsburgh.

* Presented at the 30th Annual Meeting of the American Cleft Palate Association, Phoenix, Arizona, April 14, 1972.

and tympanostomy tube insertion during the first three months of life. Between 18 and 24 months of age, the secondary palate was surgically repaired employing a V-Y pushback, and in some, a Millard island flap. Twelve of the infants also received unilateral hamulotomy, consisting of osteotomy and infracture; the tensor veli palatini tendon was not severed. Eustachian tube function studies were performed prior to, and six months following, repair of the palate. Subsequent to the initial myringotomy, otoscopic evaluation was repeated at 6 to 12 week intervals. Wherever middle ear fluid reaccumulated following spontaneous extubation, myringotomy and tympanostomy tube insertion were repeated.

Roentgenographic studies of the nasopharynx and Eustachian tubes were performed employing a technique described in detail elsewhere (*2–4*).

Ventilatory function of the Eustachian tube was studied by means of a Madsen ZO-70 Electro-Acoustic Impedance Bridge. If the tympanic membrane was intact, a tympanogram was obtained. Jerger's (*6*) system of classifying tympanograms was followed. If a tympanostomy tube or perforation was present, the manometer portion of the bridge was used. Figure 1 shows the symbols employed, and examples of the results obtained, in ventilation studies. Example (A) describes a study of a normal adult with a traumatic perforation but an otherwise negative otologic history. After sealing the external canal with the probe tip, pressure is applied—*inflation*—to a limit of +400 mm H_2O and held. As a result of swallowing by the patient, this positive pressure is equilibrated. The external canal-middle ear pressure is then reduced—*deflation*—to −200 mm H_2O. This negative pressure is then also equilibrated by the patient's swallowing activity. Example (B) describes a study of a 4-year old patient with a repaired cleft palate. The test ear had a functioning tympanostomy tube in place. The Eustachian tube opened before the +400 mm H_2O pressure could be reached. This pressure-induced tubal opening can be called the *opening pressure*, and the residual external canal-middle ear pressure, after the tube closes, the *closing pressure*. Subsequent swallowing failed to reduce further the residual pressure. In the deflation phase of the study, the child was entirely unable to equilibrate negative pressure.

Ventilatory function tests were performed only *following* palate repair in these children, since the technique was not available to us during earlier phases of this investigation.

Results

Pre- and Post-Palate-Repair Roentgenographic Studies. Roentgenographic studies of *retrograde function* at the nasopharyngeal end of the Eustachian tube were completed in all of the 22 patients. Figure 2 shows schematically that prior to repair of the palate, all of the 44 Eustachian tubes appeared to show either retrograde obstruction or dysfunction. Normal function was not observed. Following palate repair,

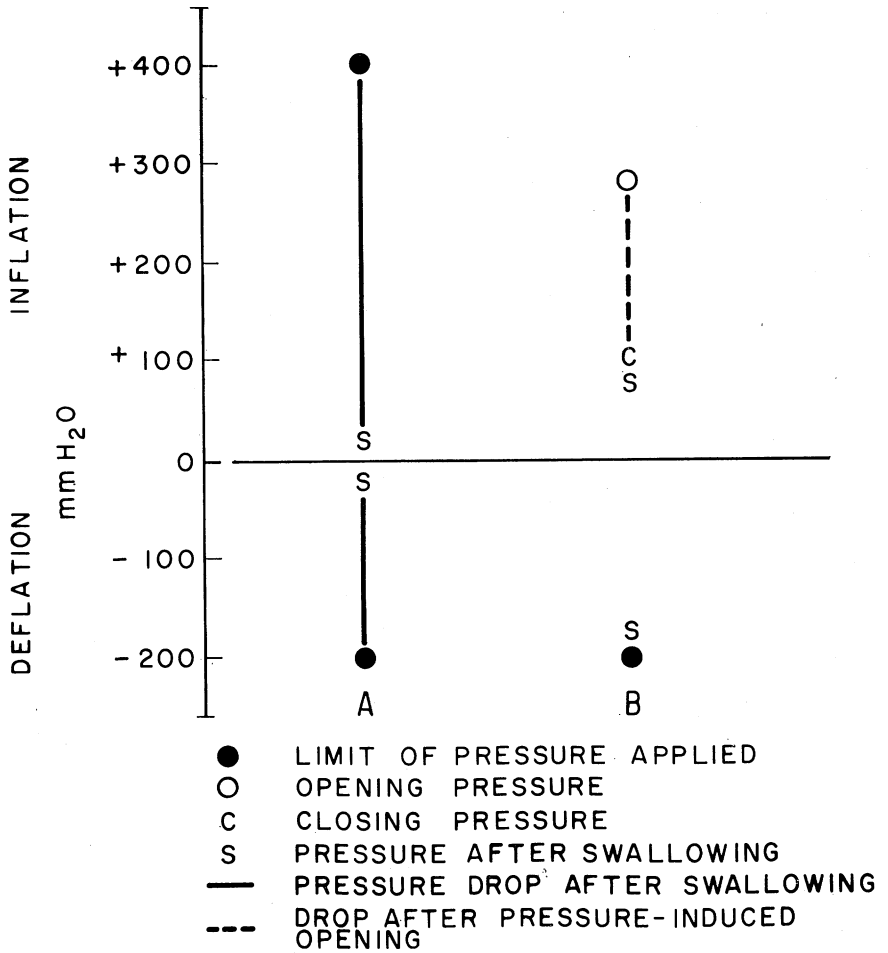


FIGURE 1. Symbols and examples of results during inflation-deflation ventilation studies: (A) a normal adult with a traumatic perforation but an otherwise negative otologic history, and (B) a 4-year old patient with a repaired cleft palate and a functioning tympanostomy tube in the test ear.

however, normal retrograde function was observed in 24 of the 44 (55%) Eustachian tubes, while 20 (45%) remained obstructed to some degree.

Figure 3 shows the interrelationships among retrograde function, the "roentgenographic Toynbee test," and prograde clearance, before and after palate repair. [The "Roentgenographic Toynbee Test" was considered positive if, upon manually closing the nose during the retrograde study, contrast material which had previously failed to enter the middle ear, now did so (Figure 4).] Prior to repair of the palate, the "roentgenographic Toynbee test" had been negative in all 44 ears. Following repair, however, the test was positive in 38 of the 44 ears (86%).

Prograde clearance was demonstrated to some degree in all ears both

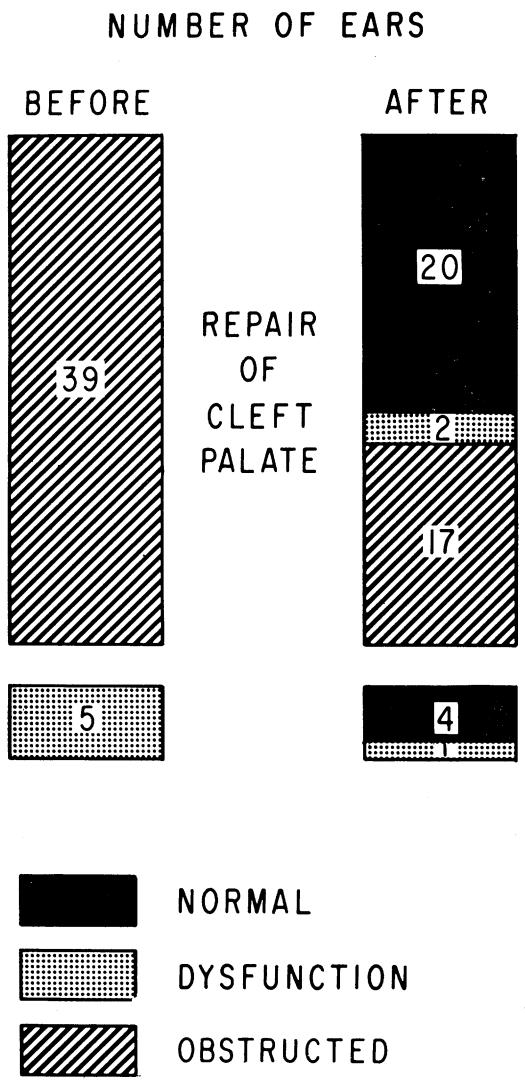


FIGURE 2. Roentgenographic assessment of retrograde Eustachian tube function in 22 cleft palate patients (44 ears) before and after repair of the palate.

before and after palate repair. However, differences in the type of clearance were observed. Prior to repair, the degree of clearance of the material varied with both viscosity and the position of the patient: in many ears, higher viscosity media and the supine position were associated with incomplete clearance of media from the middle ear and mastoid, and in three infants, clearance appeared to depend on the presence of a functioning tympanostomy tube. Following palate repair, however, prograde clearance was not dependent on any of these factors.

PRE- AND POST-PALATE-REPAIR CLINICAL OTOLOGIC STATUS. Figure 5 deals with clinical otologic status before and after palatal repair. Prior

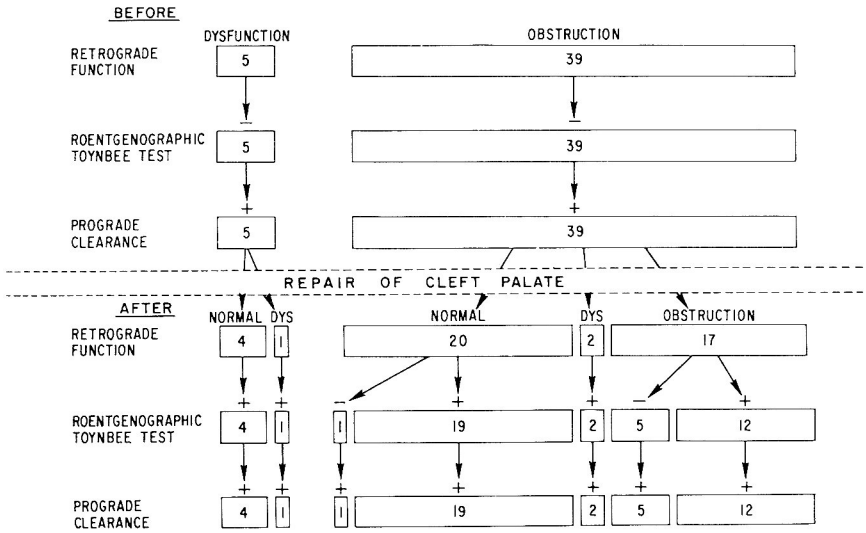


FIGURE 3. Roentgenographic studies of Eustachian tube function in 22 cleft palate patients (44 ears) before and after repair of the palate.

FIGURE 4. Submental-vertex roentgenogram of an infant with a repaired cleft palate demonstrating a "positive roentgenographic Toynbee test". Note the contrast material (arrow) in the middle ear cavity.

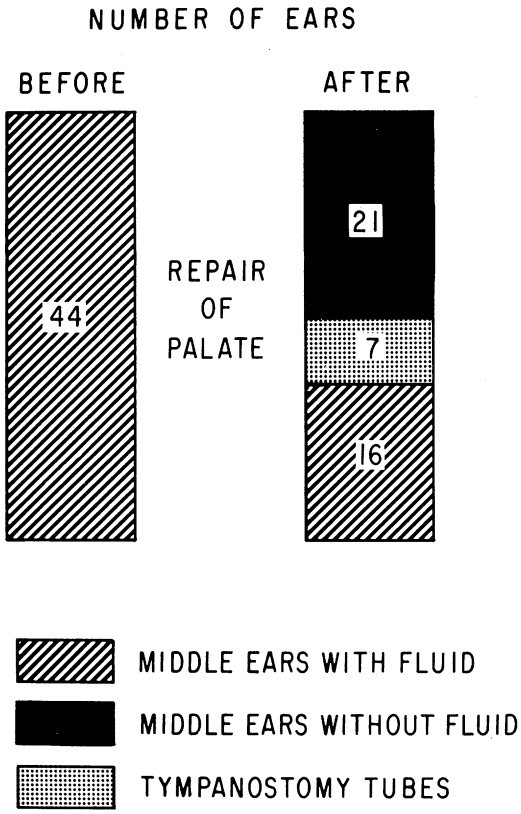


FIGURE 5. Secretory otitis media in 22 cleft palate patients (44 ears) before repair of the cleft palate, and six to twelve months after repair.

to repair, middle ear effusion was uniformly present (44 ears). Six to twelve months following repair, 16 (36%) had middle ear fluid, 21 (48%) were free of fluid, and seven (16%) had tympanostomy tubes in place.

CORRELATION BETWEEN POST-CLEFT-PALATE-REPAIR ROENTGENOGRAPHIC STUDIES AND RECURRENCE OF MIDDLE EAR EFFUSIONS. Figure 6 shows the correlation between the recurrence of middle ear effusions, as described above, and roentgenographic findings. Sixteen of 24 (66.6%) ears showing normal retrograde function were normal, without tubes, as compared with only 5 of 20 (25%) when the Eustachian tube showed either dysfunction or obstruction ($\chi^2 = 6.01$; $P < .02$).

CORRELATION BETWEEN POST-CLEFT-PALATE-REPAIR ROENTGENOGRAPHIC AND VENTILATORY STUDIES. Figure 7 shows the inflation-deflation ventilation results obtained in 15 children who still had functioning tympanostomy tubes following repair of the palate. Most of the Eustachian tubes opened before a positive pressure of 400 mm H_2O within the middle ear was reached, and in all instances, residual positive pressures remained in the middle ear following either pressure-induced opening of the Eustachian tube, or swallowing, or both. In two ears, the Eustachian tube

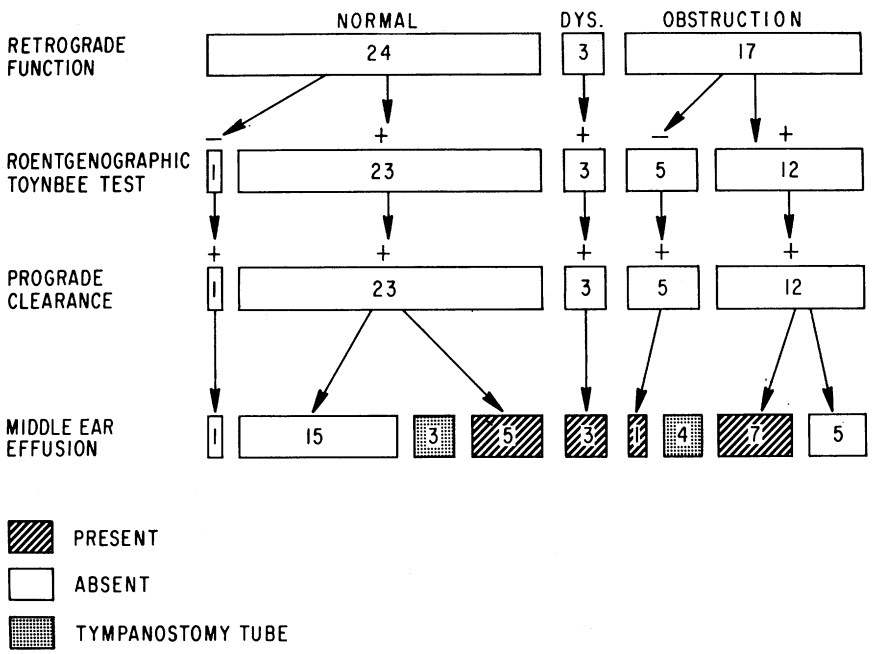


FIGURE 6. Correlation following palate repair between roentgenographic assessment of Eustachian tube function and recurrence of middle ear effusions in 22 patients (44 ears).

appeared not to open at all. None of the infants tested were able to equilibrate negative middle ear pressure of −200 mm H_2O following swallowing.

There appeared to be no correlation between variations in ventilatory function on the one hand, and types of retrograde function observed roentgenographically, on the other.

Effect of Unilateral Hamulotomy on Post-Palate-Repair Roentgenographic and Ventilatory Studies. Figure 8 is an attempt to correlate the findings of ventilatory (inflation-deflation or tympanometric) studies with roentgenographic findings in 12 patients who received unilateral hamulotomy at the time of cleft palate repair. No consistent difference between the fractured and unfractured sides was noted with regard to either ventilatory or roentgenographic findings.

Discussion

Eustachian Tube Compliance and Obstruction. In patients with normal palates, Perlman (*5*) has studied nasopharyngeal air pressures during closed-nose swallowing—the classical Toynbee test. He described an initial positive pressure phase followed by a negative phase. We have modified this test using radiopaque fluid media and refer to this as the "roentgenographic Toynbee test."

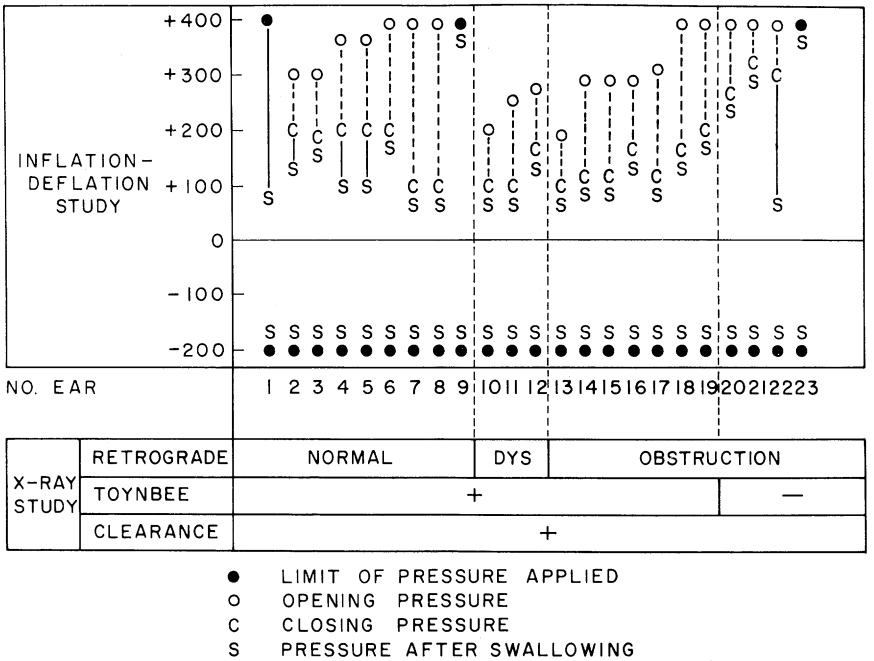
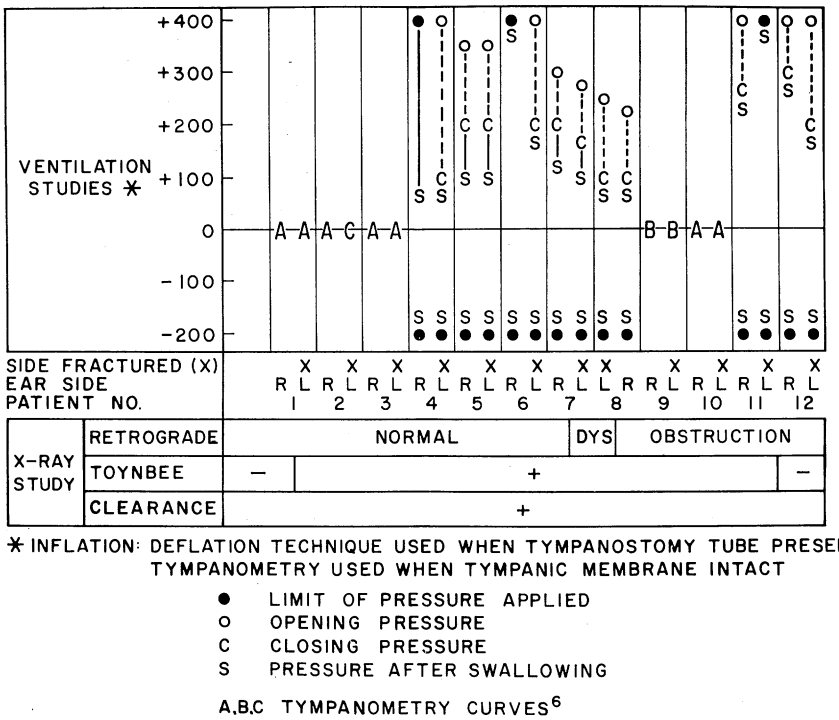


FIGURE 7. Correlation following palate repair between roentgenographic and inflation-deflation ventilatory assessment of Eustachian tube function in 13 patients (23 ears).

In a previous study of patients who had normal palates, no evidence of middle ear disease, and a negative otologic history, the "roentgenographic Toynbee test" was negative—i.e., contrast media failed to enter the middle ear following closed-nose swallowing (*4*). The positive tests obtained in most infants in the present study following palate repair suggest that their Eustachian tubes may be abnormally *distensible* when confronted with retrograde flow of fluid under increased pressure. It seems likely that prior to palate repair, their tubes had been just as distensible, but the "roentgenographic Toynbee tests" were negative because the open clefts prevented the development of increased fluid pressure.

Infants with unrepaired cleft palates are able to clear radiopaque fluid media from the middle ear and Eustachian tube into the nasopharynx, but there is obstruction to retrograde flow from the nasopharynx into the Eustachian tubes. Such infants, like those following repair in the present study, also appear to have a variable degree of difficulty equilibrating increased middle ear air pressure, and are unable to equilibrate negative pressure (*7*). These observations indicate that the Eustachian tube is not intrinsically blocked, but that varying degrees of *functional obstruction*, depending on the direction of flow, may exist. Following repair of the palate, the Eustachian tube appeared not only still functionally ob-



✳ INFLATION: DEFLATION TECHNIQUE USED WHEN TYMPANOSTOMY TUBE PRESENT; TYMPANOMETRY USED WHEN TYMPANIC MEMBRANE INTACT

● LIMIT OF PRESSURE APPLIED
O OPENING PRESSURE
C CLOSING PRESSURE
S PRESSURE AFTER SWALLOWING

A,B,C TYMPANOMETRY CURVES[6]

FIGURE 8. Correlation following palate repair between roentgenographic and ventilatory assessment of Eustachian tube function in 12 patients (24 ears) who received unilateral hamulotomy at the time of repair of the cleft palate.

structed in some degree, but also abnormally distensible in response to both increased retrograde fluid pressure and increased middle ear air pressure. This distensibility may be an inverse function of the degree of *stiffness* of the tube itself, which might in turn be related to its cartilage or muscle support, or both. The degree of distensibility might then be considered a reflection of Eustachian tube *compliance*. It would appear that the Eustachian tube of children with cleft palate, both before and after repair, may lack stiffness or have increased compliance. Collapse of such a tube might then result in functional tubal obstruction. If this is so, the tube would collapse further and block in response to negative pressures. It would not open in response to low positive pressures, but would open and then distend in response to progressively higher pressures. While still collapsed, a greater than normal pressure differential between the nasopharynx and the middle ear would be required to open the tube and accomplish middle ear ventilation. In support of this concept are: (1) the frequent finding of tympanic membrane retraction and (2) tympanometric evidence of negative middle ear pressure in many children with repaired cleft palates.

PTERYGOID HAMULOTOMY AND EUSTACHIAN TUBE FUNCTION. The tech-

nique of pterygoid hamulotomy has been widely utilized during the repair of the cleft palate in an effort to reduce the tension placed on the muscle sling (*8*). This practice has been related to the occurrence of otitis media by some investigators (*9–11*), while others have reported no increased incidence following the procedure (*12*). Following unilateral "hamulotomy" in animals, Odoi and co-workers (*13*) reported the development of middle ear effusions. They, however, "expunged" the hamulus in these animals. The method of unilateral hamulotomy performed in the 12 patients in the present series is more in keeping with usual surgical technique. No difference in Eustachian tube function was observed as a result of this procedure, and although follow-up has been short, recurrences of middle ear effusion have also appeared unrelated. These findings are in agreement with those of Noone et al (*14*) in a much larger series of patients.

Prior to closure of the palate, middle ear fluid is present in all untreated infants. Since this seems to be related to functional obstruction of the Eustachian tube, ventilation of the non-aerated middle ear cavity is indicated. A previous study has shown that closure of the secondary palate is often followed by a reduction in the prevalence of middle ear disease. (*15*) The present investigation confirms this finding and suggests a relationship to improvement in Eustachian tube function. It would, therefore, seem worthwhile to consider repairing the palatal defect at as early an age as possible, especially when otorrhea through a tympanostomy tube has failed to respond to medical treatment. Following repair of the palate, recurrence of middle ear effusion warrants repetition of myringotomy and insertion of tympanostomy tubes. However, if Eustachian tube function is improved following palate repair, or if otorrhea develops through the tympanostomy tubes, their removal on a trial basis may be indicated.

Summary and Conclusions

Certain aspects of Eustachian tube function were studied in a group of 22 infants with cleft palate, both before and after surgical repair.

Protective function was evaluated by roentgenographic studies after instillation of radiopaque media into the nasopharynx. Drainage function was evaluated on the basis of clearance of radiopaque media from the middle ear and Eustachian tube into the nasopharynx. Ventilatory function was studied by an inflation-deflation technique through a tympanostomy tube, or by tympanometry when the tympanic membrane was intact.

Infants with unrepaired palatal clefts were conditionally able to clear radiopaque fluid media in prograde direction from the Eustachian tube and middle ear into the nasopharynx, but there was obstruction to retrograde flow from the nasopharynx into the Eustachian tubes. Following surgical repair of the palate, there was improvement in prograde clearance and, in over half the ears tested, retrograde flow appeared normal.

Abnormal distensibility of the Eustachian tube in infants with cleft palate was suggested by the results of both roentgenographic studies and ventilatory function tests following repair of the cleft. This distensibility may be a function of reduced tubal stiffness (increased compliance) which may in turn contribute to functional obstruction of the tube by rendering its opening more difficult.

Middle ear effusions are uniformly present in infants with unrepaired palatal clefts. The appreciable reduction in their prevalence following palatal repair appears related to improved Eustachian tube function.

Hamulotomy undertaken during the course of cleft palate repair appears to have no effect on either Eustachian tube function or the recurrence of middle ear effusions.

References

1. Paradise, J. L., Bluestone, C. D., and Felder, H.: The universality of otitis media in fifty infants with cleft palate. *Pediatrics, 44:* 35–42, 1969.
2. Bluestone, C. D.: Eustachian tube obstruction in the infant with cleft palate. *Ann. Otol., Supplement No. 2,* 1–30, August, 1971.
3. Bluestone, C. D., Wittel, R. A., and Paradise, J. L.: Roentgenographic evaluation of Eustachian tube function in infants with cleft and normal palates: (With special reference to the occurrence of otitis media). *Cleft Palate Journal, 9:* 93–100, April, 1972.
4. Bluestone, C. D., Wittel, R. A., Paradise, J. L., and Felder, H.: Effect of adenoidectomy on Eustachian tube function. Presented at the Annual Meeting of the American Academy of Ophthalmology and Otolaryngology, Las Vegas, Nevada, September 22, 1971. Trans. American Academy of Ophthalmology and Otolaryngology (in press).
5. Perlman, H. B.: Observations on the Eustachian tube. *AMA Arch. Otolaryngology, 55:* 370–385, 1951.
6. Jerger, J.: Clinical experience with impedance audiometry. *AMA Arch. Otolaryngology, 92:* 311–324, October, 1970.
7. Bluestone, C. D., Beery, Q. C., and Paradise, J. L.: Unpublished observations.
8. Bilroth, T.: Ueber Uranoplastik. *Wien. Klin. Wsch, 2:* 241, 1889.
9. Skolnik, E. M.: Otologic evaluation in cleft palate patients. *Laryngoscope, 68:* 1908–1949, 1958.
10. Holborow, C. A.: Deafness associated with cleft palate. *J. Laryng., 76:* 762–773, 1963.
11. Ross, M. A.: Functional anatomy of the tensor palati. *AMA Arch. Otolaryng., 93:* 1–8, January, 1971.
12. Bennett, M., Ward, R. H., and Tate, C. A.: Otologic audiologic study of cleft palate children. *Laryng., 73:* 1011, 1968.
13. Odoi, H., Proud, G. O., and Toledo, P. S.: Effects of pterygoid hamulotomy upon Eustachian tube function. *Laryngoscope, 81:* 1242–2144, 1971.
14. Noone, R. B., Randall, P., Hamilton, R., Stool, S. E., and Winchester, R. A.: The effect of hamulus fracture on middle ear disease in children with cleft palate. Presented at the 30th Annual Meeting of the American Cleft Palate Association, Phoenix, Arizona, April 14, 1972.
15. Paradise, J. L., and Bluestone, C. D.: More on the universal occurrence of otitis media in infants with cleft palate, and a prelimary evaluation of its treatment. Presented at the 29th Annual Meeting of the American Cleft Palate Association, Pittsburgh, Pennsylvania, April 23, 1971.