Effect of Palatoplasty on the Function of the Eustachian Tube in Children with Cleft Palate

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Eustachian tube function of 24 children with cleft palate (37 ears) was evaluated longitudinally utilizing the inflation-deflation and forced-response tests before and after palatoplasty. Our results for children in this longitudinal study showed that the passive function of the tube was improved following palatoplasty. Active tubal function, which measures the muscle-induced tubal dilations, was little affected by the procedure. The majority of ears tested both before and after palatoplasty demonstrated tubal dilations with swallowing. In contrast, cross-sectional data conducted on the children with a history of otitis media and repaired cleft palates, documented a severe defect in this active tubal function with 70 percent of the tests evidencing a tubal constriction. These data suggest that the results of Eustachian tube function tests may be prognostic of the future course of ear disease in these children.

Children with unrepaired palatal clefts are "at risk" to develop a mild-to-moderate fluctuating hearing impairment which is recognized as a complication of the nearly universal prevalence of otitis media with effusion in this population (Skolnik, 1958; Stool and Randall, 1967; Paradise et al, 1969; Yules, 1970). Past studies have supported a primary role for Eustachian tube dysfunction in the pathogenesis of otitis media with effusion, and other studies involving cleft palate children have documented an impairment in the tubal dilatory system (Bluestone 1971; Bluestone et al, 1972, 1974, 1975; Harle and Munker, 1980; Doyle et al, 1980).

However, the majority of these investigations evaluated children with repaired palatal clefts who had tympanostomy tubes inserted, based upon a criterion of chronic or recurrent otitis media with effusion. This selection criterion effectively biases the data to a representation of those children with the poorest tubal function (Doyle et al, 1984). Indeed, a distinction between the tubal function observed in these children and that documented in children without clefts who had chronic otitis media with effusion cannot be made, suggesting that any effect of the cleft on Eustachian tube function is "washed out" by the effect that results in or from the disease state (White et al, 1984). This was evident in one recent study of Eustachian tube function in unselected infants with unrepaired palatal clefts, which documented a better tubal function than that reported in an earlier study of selected older children with repaired palates and a history of chronic otitis media with effusion (Doyle et al, 1984). This result was unexpected in light of the observations that Eustachian tube function improves with advancing age and that the prevalence of otitis media with effusion (and presumably Eustachian tube dysfunction) decreases following palatoplasty (Bylander et al, 1983; Paradise et al, 1969).

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These arguments suggest that the tubal function in cleft palate children and the change in function consequent to palatoplasty can only be defined using a prospective study design with early entry and limited selection bias. This paper presents the preliminary tubal function data for a group of patients studied longitudinally before and after palatoplasty and compares these results with those generated in a cross-sectional study of children with a history of otitis media with effusion who have had cleft palate repair.

Materials and Methods

Sixty-three children with palatal clefts were enrolled before 6 months of age in a longitudinal study of the effect of palatal repair on Eustachian tube function. Of these, 24 children had undergone palatoplasty, and Eustachian tube function was evaluated before and after the surgical procedure. Seventeen children were males and seven were females; nine had bilateral complete palatal clefts, five had unilateral complete palatal clefts, and ten had isolated clefts of the soft palate. All children had tympanostomy tubes inserted bilaterally between 3 and 6 months of age, irrespective of middle ear status. However, at the preoperative test period, one of the tympanostomy tubes was nonpatent in six of the subjects, and an additional five patients had a unilateral otorrhea with drainage through the tube. Palatoplasty was performed between 14 and 18 months of age by surgeons on staff at the Cleft Palate Center of the University of Pittsburgh. This was performed in a standard fashion, employing sharp and blunt dissection to release the levator muscle from the hard palate. The muscle pedicles were displaced posteriorly and sutured in conjunction with a three-layer closure. Thirteen children had bilateral and 11 had unilateral Eustachian tube function testings before and after palatoplasty, resulting in a total evaluable population of 37 ears. The age range for the preoperative testing was 5 to 18 months and for the postoperative testing was 15 to 26 months. All ears had had one preoperative Eustachian tube function test; 21 ears had one postoperative test, and 16 ears had two postoperative tests.

Each test included two testing protocols: the inflation-deflation test and the forced response test. The procedures and equipment used have been described in detail previously (Cantekin et al, 1979). For all tests, the children were placed in a parent's lap, and a hermetic seal was obtained between the test instrument and the child's ear canal. Controlled rates of airflow were applied to this system using a variable-speed, constant-flow pump. Middle ear and system pressures were monitored by pressure sensors, and the rate of airflow was measured by a flow meter coupled to a differential pressure transducer. All pressure signals were recorded on a strip-chart recorder. During the inflation-deflation test, a constant airflow was introduced to the middle ear until the opening pressure of the Eustachian tube was reached, at which time the pump was turned off, and the tube was allowed to close passively. The pressure was then released from the system, and the middle ear was inflated to approximately 200 mm H_2O pressure. The child was induced to swallow by drinking a liquid from a cup or bottle, and the change in middle-ear pressure associated with swallowing was recorded. If an ability to reduce a positive middle ear pressure was documented, the middle ear was deflated to approximately -200 mm H_2O pressure, and the procedure was repeated. For the forced-response test, the middle ear was inflated at a constant airflow rate until the Eustachian tube passively opened. Airflow was then maintained until steady states in airflow through the tube and middle-ear pressure were observed. The child was induced to swallow and the changes in steady-state pressure and flow were recorded. The pump was then turned off, and the tube was allowed to close passively. In general, an attempt was made to define the parameters of the forced-response test for three rates of constant airflow; 12, 24, and 48 cc per minute. Complete results for the 12 cc per minute flow rate were available for all ears tested. The passive resistance of the Eustachian tube to airflow was determined by dividing the steady state pressure by the concurrent airflow through the tube. Similarly, active tubal resistance was determined by dividing the steady-state pressure by the maximum airflow recorded during the induced tubal dilations which accompanied a swallow.

For comparison, cross-sectional Eustachian tube function data collected from 80 ears of 56 children between the ages of 4 and 18 years are reported. These children all had repaired palatal clefts and tympanostomy tubes inserted for chronic or recurrent otitis media with effusion.

They were tested routinely in our Ear, Nose, and Throat Clinic between the years 1979 and 1984.

Results

The study population of 37 ears is rather small and not amenable to tests of the influence on Eustachian tube function of various secondary, but potentially meaningful, factors. These include: age, gender, type of cleft, and timing of repair. Consequently, for purposes of this preliminary communication, the analysis is limited to the effect of palatoplasty on the Eustachian tube function.

The data generated by the Eustachian tube function tests provide information on two properties of the tubal system. The first, passive tubal function, evaluates the mechanical properties of the tube in terms of compliance, resistance, and closing forces. The second, active tubal function, evaluates the ability of the paratubal musculature to dilate the Eustachian tube during such activities as deglutition. The presented results compare the mean values of the various parameters which measure these functions in the 37 ears evaluated before and after palatoplasty. Three parameters of the passive tubal function were measured during the testings: the middle ear pressure at which the Eustachian tube is passively opened (opening pressure); the middle ear pressure retained after the Eustachian tube passively closes (closing pressure); and the passive resistance of the Eustachian tube to airflow.

Mean values of the opening and closing pressures for the three groups of tests recorded at each of three constant airflow rates are shown in Figure 1. For tests on children in this longitudinal study, the mean values of the opening pressure were similar before and after palatoplasty. These were on the average 30 to 40 mm H_2O higher than those recorded for the tests conducted on the older children in the cross-sectional sample. However, the rather large standard deviations associated with this parameter (mean coefficient of variation = 0.33) obscure the significance of this difference. For the closing pressures, the mean values were on the average 20 to 40 mm H_2O higher for the tests conducted preoperatively when compared to either group of children with repaired palates.

Figure 2 shows the mean values of the passive tubal resistance recorded at the three constant flow rates. At low flow rates, the mean value of this parameter was greatest for the tests on children with unrepaired palatal clefts, intermediate for the tests on children with repaired palates, and lowest for the tests on the older children with repaired palatal clefts and a history of recurrent or chronic otitis media with effusion.

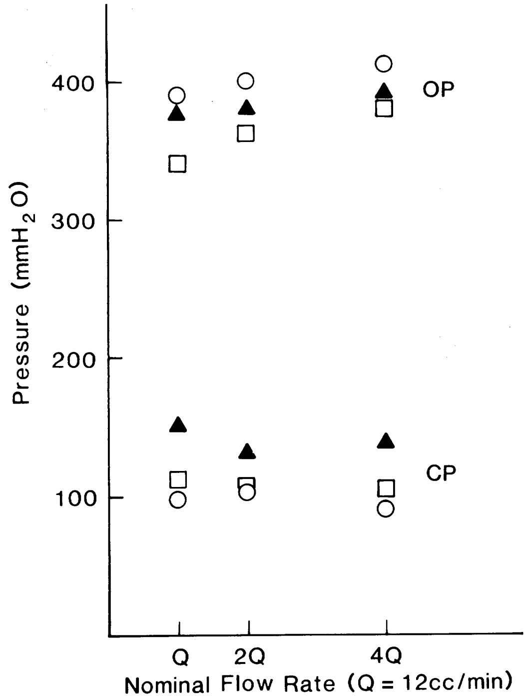

FIGURE 1 Mean values of the opening pressure (OP) and closing pressure (CP) recorded at three rates of constant airflow for the preoperative children in the longitudinal study (triangles), postoperative children in the longitudinal study (circles) and the postoperative children in the cross-sectional sample (squares).

Three measures of active tubal function are determined from the tests. These include the ability of the muscular system to dilate the Eustachian tube under conditions of an induced negative and positive middle-ear pressure or when the tube is predilated by a constant low-volume airflow. Figure 3 shows the percentage of positive test results for these three measures for the same ears evaluated pre- and postpalatoplasty and for the ears of those children with repaired palates and a history of chronic or recurrent otitis media with effusion. For the children enrolled in this longitudinal study, there appear to be no differences in the percentage of tests evidencing an ability

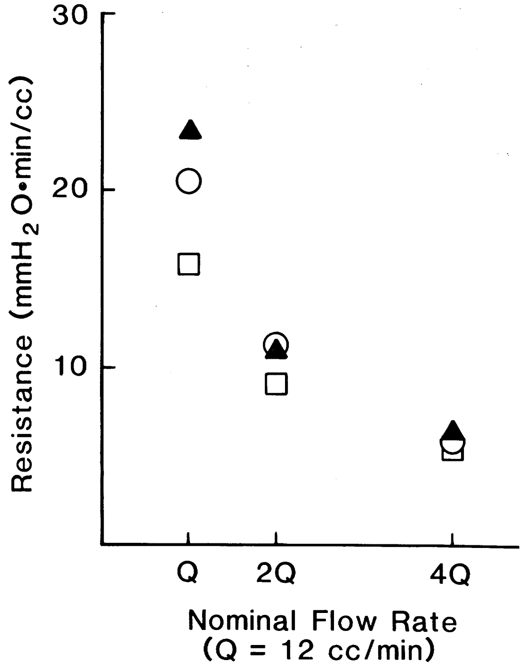

FIGURE 2 Mean values of the passive tubal resistance recorded at three rates of constant air flow for the preoperative children in the longitudinal study (triangles), postoperative children in the longitudinal study (circles) and the postoperative children in the cross-sectional sample (squares).

to reduce an applied negative (0% pre vs. 4% post) or positive (21% pre vs. 13% post) middle-ear pressure. Moreover, 88 percent of the preoperative tests and 84 percent of the postoperative tests documented a further dilation of a predilated Eustachian tube during deglutition. The remaining tests documented a constriction of the tube during this activity. For the ears of the children in the cross-sectional study, similar percentages to those reported above were observed for the ability to reduce applied positive and negative middle ear pressures. However, only 30 percent of these tests documented a tubal dilation during deglutition, but 70 percent evidenced a tubal constriction.

A measure of the efficiency of the tubal dilations is provided by the ratio of the passive tubal resistance to the active tubal resistance and is defined only for those cases evidencing dilation. The mean values of this ratio recorded at the three constant airflow rates of 12, 24, and 48 cc per minute were 7.3, 5.2, and 2.1 for the preoperative tests and 15.1, 6.9, and 2.1 for the postoperative tests on the children in the longitudinal sample. The mean values of this ratio for the tests on the children in the cross-sectional sample were 3.3, 2.7, and 1.9.

Discussion

The prevalence of otitis media with effusion has been reported to approach 100 percent in the population of children with unrepaired palatal clefts (Paradise et al, 1969). A moderate fluctuating conductive hearing loss is a complication of the disease and is believed by some to affect the child's educational, linguistic, and psychosocial development adversely (Sataloff and Fraser, 1952; Ruben and Rapin, 1980). While a number of reports have described an alleviation or attenuation of the disease following palatoplasty, a significant number of children retain the disease as a chronic or recurrent condition throughout childhood (Paradise et al, 1969).

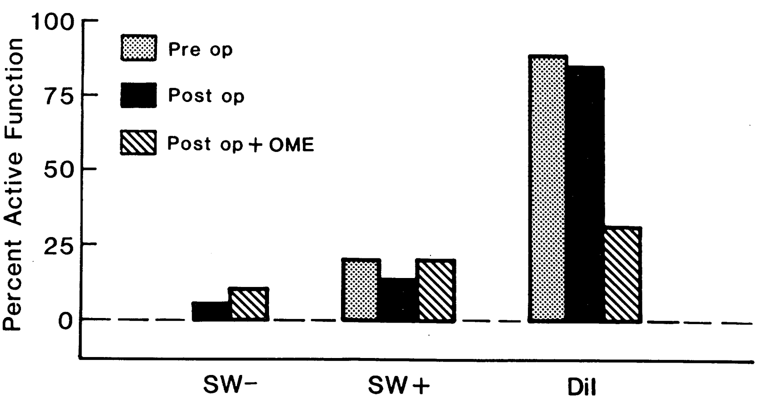

FIGURE 3 Percentage of tests evidencing the ability to reduce an applied negative (SW−) and positive (SW+) middle ear pressure or further dilate a predilated Eustachian tube (Dil) with swallowing for the three groups.

Consequently, early diagnosis and management of otitis media with effusion have been emphasized.

Past research into the pathogenesis of otitis media with effusion in the cleft palate population has focused on a possible dysfunction of the Eustachian tube. In this regard, it was suggested that anatomic abnormalities in the tubal musculature or its cartilaginous framework resulted in a functional tubal obstruction (Bluestone, 1971). However, the majority of anatomic and histologic studies failed to document gross abnormalities in the tubal system, though all have reported abnormal insertions of the paratubal musculature, a condition which could compromise their function (Fara and Dvorak, 1970; Kriens, 1969; Doyle et al, 1983). Concurrent physiological studies were performed in an attempt to define the functional disturbances resulting from the aberrant anatomy of the system. These studies used both radiographic and manometric testing techniques and documented a functional tubal obstruction associated with an impaired ability of the muscular system to dilate the tube. Better tubal function was reported for a group of children with repaired palatal clefts when compared with a second group with unrepaired cleft palates (Bluestone et al, 1972, 1974, 1975; Harle and Munker, 1980; Doyle et al, 1980).

However, the interpretation of the results of these studies is compromised by a number of considerations. First, the majority of studies evaluated rather small numbers of patients and employed quite different testing methodologies. Second, a clear definition of the population being tested was often lacking (e.g., repaired vs. unrepaired; otitis media with effusion vs. no otitis media with effusion). Third, until recently the selection bias introduced by the study of children with repaired palatal clefts and tympanostomy tubes inserted because of a history of chronic or recurrent otitis media with effusion was not recognized. Fourth, in comparing the Eustachian tube function in groups of children before and after palatoplasty, the possible contribution of the difference in mean age of the two groups was not adequately addressed.

The methods utilized in the present study largely obviated these criticisms. The study was prospective in design and tested a total of 37 ears pre- and postoperatively. The maximum time difference between these tests was one year, thereby minimizing the effect of age on the results. Additionally, all children had tympanostomy tubes inserted prophylactically and, consequently, the study population was not biased by this variable. For these reasons, it is felt that the data reported here are more representative of the tubal function in the cleft palate population than those previously reported.

The results show that the passive function of the Eustachian tube measured in children with unrepaired palatal clefts is abnormal when compared to the same children evaluated postoperatively. This is particularly true of the tubal closing pressures which were of greater magnitude in the preoperative tests. Since the closing pressure reflects the contribution of extra- and intraluminal forces, an explanation for this effect may reside with the abnormal position of the levator veli palatini muscle in the children with unrepaired palatal clefts (Kriens, 1969; Surina and Jagr, 1969). Prior to repair, the levator veli palatini muscle lies under the tube for its entire course and has a bony origin and insertion. This arrangement creates an inferiorly positioned muscular strut which effectively limits the inferior displacement of the tubal floor and thereby could increase the extraluminal pressure. With palatal repair, the muscle is freed from its bony insertion and is reapproximated at the midline within the mobile velum. The stiffness of the inferior strut is released and the increased extraluminal pressure is alleviated.

With respect to active tubal function, almost identical percentages of positive test results were recorded before and after palatoplasty for the three active function parameters. While only a small number of tests evidenced an ability to open the tube under conditions of an applied positive or negative middle-ear pressure, the majority of tests showed a tubal dilation with swallowing when predilated by a constant airflow. The efficiency of this dilation, as measured by the resistance ratio, was better after palatoplasty suggesting some improvement in tubal function consequent to palate repair. Since this ratio reflects the increase in airflow accompanying a dilation, it is possible that in the preoperative condition the inferior strutting of the levator veli palatini muscle could have limited the increase in tubal diameter associated with the contraction of the tensor veli palatini muscle. Surgical repositioning of the levator veli palatini muscle during palate repair would then have freed the system from such constraints. Thus, these data imply that the effect of palatoplasty on Eustachian tube function is minimal and can be accounted for solely on the basis of the changes in the relative position of the levator veli palatini muscle. There is little to no evidence that the efficiency of the tensor veli palatini muscle, recognized as the sole tubal dilator, is much improved by palate repair.

A comparison of the data for the two groups of children with repaired palatal clefts provides a number of interesting observations. In the unselected children followed longitudinally, the majority of tests (70%) documented a tubal dilation with swallowing. This was not true of those tests conducted on the older postoperative children with tympanostomy tubes inserted for chronic or recurrent otitis media with effusion. For these ears, a constriction of the Eustachian tube with swallowing was documented in over 70 percent of the cases. Further, of those ears capable of dilation the efficiency estimated by the resistance ratio was very poor when compared to the postoperative children in the longitudinal study. Since tubal constriction with swallowing is an abnormal condition indicative of severely impaired tubal function, these data are in conflict with the well documented observations that tubal function improves with advancing age (Bylander et al, 1981).

A resolution of this paradoxical finding may lie with the bounding parameters of the two populations. The children enrolled in the longitudinal sample are representative of the population of children with repaired palatal clefts; those in the cross-sectional sample are a subpopulation of these children who also are defined on the basis of a history of recurrent or chronic otitis media with effusion. If it is accepted that poor Eustachian tube function predisposes a child to otitis media with effusion and that the disease becomes a chronic condition in only a subset of all children with repaired palatal clefts, then children with a disease history are preselected for their poor tubal function. In this regard, it is tempting to suggest that the 30 percent of the children in the unselected sample who showed tubal constriction with swallowing are those who will manifest the disease as a chronic state. If true, this test could provide a prognostically valuable tool for the early detection of the otitis-prone child. Continued follow-up of the children enrolled in this longitudinal study will allow for the testing of this interesting hypothesis.

References

BLUESTONE CD. Eustachian tube obstruction in the infant with cleft palate. Ann Otol Rhinol Laryngol 1971; 80(2):1.

BLUESTONE CD, WITTEL RA, PARADISE JL. Roentgenographic evaluation of the Eustachian tube function in infants with cleft palate and normal palates. Cleft Palate J 1972; 9:93.

BLUESTONE CD, BEERY QC, ANDRUS WS. Mechanics of the Eustachian tube as it influences susceptibility to and persistence of middle ear effusions in children. Ann Otol Rhinol Laryngol 1974; 83(11):27.

BLUESTONE CD, BEERY QC, CANTEKIN EI, PARADISE JL. Eustachian tube ventilatory function in relation to cleft palate. Ann Otol Rhinol Laryngol 1975; 84:333.

BYLANDER H, TJERNSTROM O, IVARSSON A. Pressure opening and closing functions of the Eustachian tube by inflation and deflation in children and adults with normal ears. Acta Otolaryngol, (Stockh) 1983; 96:255.

CANTEKIN EI, SAEZ CA, BLUESTONE CD, BERN SA. Airflow through the Eustachian tube. Ann Otol Rhinol Laryngol 1979; 88:603.

DOYLE WJ, CANTEKIN EI, BLUESTONE CD. Eustachian tube function in cleft palate children. Ann Otol Rhinol Laryngol 1980; 89(68):34.

DOYLE WJ, KITAJIRI M, SANDO I. The anatomy of the auditory tube and paratubal musculature in a one month cleft palate infant. Cleft Palate J 1983; 20(3):218.

DOYLE WJ, REILLY JS, STOOL SE. Eustachian tube function in children with unrepaired cleft palate. Proceedings of the Third International Symposium. In: Lim DJ, Bluestone CD, Klein JO, Nelson JD, eds. Recent advances in otitis media. Toronto: BC Decker 1984:59.

FARA M, DVORAK J. Abnormal anatomy of the muscles of palatopharyngeal closure in cleft palates. Plast Reconstr Surg 1970; 46:488.

HARLE F, MUNKER G. Eustachian tube function and the cleft palate. In: Munker G, Arnold W, eds. Physiology and pathophysiology of Eustachian tube and middle ear. New York: Thieme-Stratton 1980:86.

KREINS O. An anatomic approach to veloplasty. Plast Reconstr Surg 1969; 43(1):29.

PARADISE JL, BLUESTONE CD, FELDER H. The universality of otitis media in fifty infants with cleft palate. Pediatrics 1969; 44:35.

RUBEN RJ, RAPIN T. Plasticity of the developing auditory system. Ann Otol Rhinol Laryngol 1980; 89:303.

SATALOFF J, FRASER M. Hearing loss in children with cleft palate. Arch Otolaryngol 1952; 55:61.

SKOLNIK EM. Otologic evaluation in cleft palate patients. Laryngoscope 1958; 68:1908.

STOOL SE, RANDALL P. Unexpected ear disease in infants with cleft palate. Cleft Palate J 1967; 4:99.

SURINA I, JAGR J. Action potentials of levator and tensor muscles in patients with cleft palate. Acta Chirurg Plast 1969; 11:21.

WHITE BL, DOYLE WJ, BLUESTONE CD. Eustachian tube function in infants and children with Down's syndrome. Proceedings of the Third International Symposium. In: Lim DJ, Bluestone CD, Klein JO, Nelson JD, eds. Recent advances in otitis media with effusion. Toronto: BC Decker 1984:62.

YULES RB. Hearing in cleft palate patients. Arch Otolaryngol 1970; 91:319.