Objective: There is an increased incidence of otitis media in children with cleft palate, which may be related to the pathology of the auditory tube and palatal muscles. In the present study, the head of a human on term born fetus with bilateral palatal cleft was serially sectioned and the anatomy of the auditory tube and palatal muscles were studied by computer-aided three-dimensional reconstruction.

Results: The results showed a nearly horizontal course of the auditory tube. The tensor veli palatini muscle had a bony attachment on either side. The levator veli palatini muscle also showed an abnormal course.

Conclusions: This abnormal course may result in obstruction of the auditory tube during contraction. These pathological findings may explain the higher frequency of otitis media in children with cleft palate.

KEY WORDS: auditory tube, bilateral palatal cleft, palatal muscles

The auditory tube and palatal muscles play an important role in the ventilation of the middle ear (Koch, 1994). Pathological morphology of the middle ear and accumulation of liquid lead to reduced acoustic transduction with consequent amblyacusia (Heumann and Zenker, 1993). Amblyacusia is the cause of retarded development of the acoustic tract of the central nervous system (Kießling, 1985). Children with amblyacusia develop incorrect speech patterns (Eggeling, 1982) and retarded intelligence. In spite of thorough histological (Kuehn and Kahane, 1990) and functional studies (Kuehn et al., 1993; Estema et al., 2002), controversy remains concerning the role of the palatal muscles in auditory tube function. Some authors have postulated that the levator veli palatini muscle physiologically opens the auditory tube (Seif and Dellon, 1978; Sprintzen and Croft, 1981; Rood and Doyle, 1982; Swarts and Rood, 1990; Spaauwen et al., 1991), whereas others deny any functional significance for the auditory tube (Finkelstein et al., 1990). Huang et al. (1998) postulated a synergistic movement of the levator and tensor veli palatini muscles that dilate the auditory tube. In persons with cleft palate, these muscles show only isometric contraction and are not able to open the tube. Matsune et al. (1991a, 1991b) found an abnormal insertion of the tensor veli palatini muscle at the lateral chondroid wall of the auditory tube in persons with cleft palate, which causes obstruction of the auditory tube. This obstruction may be the cause of the high incidence of middle-ear infections in such individuals (Koch et al., 1999).

Given the continued uncertainty regarding the role of the palatal muscles in auditory tube function, the goal of this study was to investigate the morphology of the auditory tube and palatal muscles by using three-dimensional (3D) reconstruction methods in a single case of bilateral cleft palate.

MATERIALS AND METHODS

The head of a full-term, newborn male fetus (birth weight 2200 g) with bilateral cleft palate, who died shortly after delivery because of cardiac dysfunction attributable to heart malformations, was fixed in 10% formalin. Other than the heart malformation and bilateral cleft palate, the fetus showed no other malformations. Before further preparation for histological sectioning, a computed tomography (CT) scan of the head was taken. The head was then cut in the sagittal plane into halves, and both halves were routinely embedded in paraffin. Serial histological sections 10 µm in thickness were cut in the sagittal plane in a medial-lateral direction and in the frontal plane in an anterior-posterior direction. The sections were stained with Masson-Goldner to distinguish the different tissues (green staining for connective tissues and red staining for soft tissues). Two independent investigators (WHA, N.N.) used a Leica DMRB light microscope to identify the relevant structures to be reconstructed on the sections according to their anatomical position in the sections. Photomicrographs of every section were taken and imported into the AutoCAD (Autodesk, USA) computer program, where one investigator consecutively

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traced the outlines of the auditory tube, temporal and sphenoidal bones, and palatal muscles. A 3D wire-frame mesh was created from the traced outlines and imported into 3D Studio (Autodesk, USA) computer program, where different colors were assigned to the structures and then rendered into models and viewed in every direction. The morphology of the auditory tube and the relation of the palatal muscles were studied on the 3D reconstructions. Those reconstructions were also used to check any distortion during paraffin embedding by comparison with the CT scan. Because the septum deviation was the same in the 3D reconstruction as in the CT scan, no distortions occurred during paraffin embedding.

RESULTS

The CT scan showed a bilateral palatal cleft with a deviation of the nasal septum to the right side (Fig. 1). The anterior view of the auditory tube showed a horizontal course with a slight caudal bending at the medial edge (Fig. 2). The cranial view demonstrated a posterior-anterior course of the auditory tube with a sharp posterior bend at the medial edge (Fig. 3). The tensor veli palatini and palatoglossal muscles both originated at the sphenoidal bone. The tensor veli palatini muscle inserted at the posterior-lateral edge of the palatal cleft, whereas the insertion of the palatoglossal muscle was found at the latero-caudal edge of the palatal cleft (Fig. 4). The levator veli palatini muscle originated at the posterior-medial part of the auditory tube. The course of the muscle was parallel, underneath the auditory tube (Figs. 5 and 6) with an insertion at the medial-caudal edge of the palatal cleft. The course of both the tensor veli palatini and the levator veli palatini muscles was parallel to the auditory tube, where the levator veli palatini was found medial and the tensor veli palatini was found lateral to the auditory tube (Fig. 7).
FIGURE 5 A 3D reconstruction of the levator veli palatini muscle and its relation to the auditory tube. Cranial view of right side. The levator veli palatini muscle originates at the posterior lateral wall of the cartilaginous part of the auditory tube and inserts underneath the auditory tube.

FIGURE 6 A 3D reconstruction of the course of the levator veli palatini muscle. Lateral view of left side. The course of the muscle is underneath and parallel to the auditory tube.

FIGURE 7 A 3D reconstruction of the levator veli palatini and tensor veli palatini muscles and their relation to the auditory tube. Anterior cranial view of right side. Both muscles run parallel to the auditory tube.
DISCUSSION

It is well known that a causal connection exists between dysfunction of the auditory tube and otitis media (Alper et al., 1997). Kitajiri et al. (1985) and Matsune et al. (1991a) have reported an increased incidence of otitis media in patients with cleft palate. However, different explanations for the increased incidence of otitis media in patients with cleft palate exist. Some authors reported anomalies of the auditory tube (Dickson, 1976; Sprintzen and Croft, 1981; Matsune et al., 1991b), whereas others discussed disturbances of middle-ear ventilation (Takahashi et al., 1994) or anomalies in the insertion of palatal muscles (Seif and Dellon, 1978; Shibahara and Sando, 1986; Huang et al., 1998). There has been discussion in the literature about the origin and insertion of the tensor veli palatini muscle (Huang et al., 1997). Simkins (1943) and Spauwen et al. (1991) showed the insertion of the tensor veli palatini muscle at the lateral wall of the chondroid part of the auditory tube. Matsune et al. (1991a) agreed with these findings. In contrast, Dickson and Dickson (1972), Dickson (1976), and Rood and Doyle (1982) claimed the insertion to be only at the membranous part of the auditory tube. Other authors showed the insertion on both the membranous and cartilaginous parts (Ross, 1971; Seif and Dellon, 1978; Swarts and Rood, 1990; Huang et al., 1998). The results of this study support the latter findings.

Concerning the function of the tensor and levator veli palatini, Kriens (1969), Proctor (1973), Seif and Dellon (1978), Swarts and Rood (1990), and Koch et al. (1999) agree on the synergistic function of both muscles in dilating the tube opening. However, other authors describe the tensor veli palatini muscle as the only dilating muscle (Ross, 1971; Holso et al., 1979; Rood and Doyle, 1982; Finkelstein et al., 1990). Investigations in cleft palate cases suggest that the auditory tube is obstructed because of an abnormal insertion of the tensor veli palatini muscle (Shibahara and Sando, 1986; Matsune et al., 1991a). This is supported by the findings of this study, where the tensor veli palatini muscle lay under the auditory tube and inserted at the lateral wall of the auditory tube. Given that, as in this case, the origin and insertion of this muscle are at bony structures, it may be assumed that only isometric contraction of this muscle would be possible, which may lead to an obstruction of the auditory tube. On the other hand, Huang et al. (1997) suggested that the function of the tensor veli palatini muscle is probably not affected in palatal clefts. Those different findings may also be due to individual variations in different cases of cleft palate.

The literature also contains discrepancies concerning the origin of the levator veli palatini. Simkins (1943) and Seif and Dellon (1978) describe the origin as from only the petrosal part of the temporal bone, whereas Rood and Doyle (1982) also found an origin from the auditory tube. Huang et al. (1998) found an origin solely from the auditory tube. The course of the levator veli palatini muscle has been described to be parallel inferior to the auditory tube (Fara and Dvorak, 1970; Seif and Dellon, 1978; Rood and Doyle, 1982; Spauwen et al., 1991). The results of this study are in agreement with these authors. The function of the levator veli palatini has also been controversial. Some authors showed a dilation of the auditory tube (Simkins, 1943; Ross, 1971; Seif and Dellon, 1978; Sprintzen and Croft, 1981; Spauwen et al., 1991), whereas others postulated no function in connection with the auditory tube (Honjo et al., 1979; Finkelstein et al., 1990). In this study, the origin of the levator veli palatini muscle was found only at the auditory tube and the insertion at the dorso-medial edge of the palatal cleft. Contraction of this muscle could possibly have obstructed the auditory tube.

CONCLUSIONS

The auditory tube is almost straight in its course from posterolateral to anteromedial in the normal newborn infant. In the present cleft case, the auditory tube was not straight but bent slightly in a caudal direction. This and the anomalies of the auditory tube lumen are considered to be important factors in active dysfunction of the ventilation of the auditory tube.

The tensor veli palatini muscle has a bony attachment on either side of the scaphoid fossa of the sphenoidal bone and of the dorso-lateral portion of the hard palate. Therefore, its action may be almost limited to isometric contraction. The tensor veli palatini muscle fibers that originate from the lateral tubal cartilage may pull this in a caudal-anterial direction. Their actions may be reduced because of their origin to the dorso-lateral portion of the hard palate. The function of the tensor veli palatini muscle on the auditory tube may be also ineffective because of the possible malfunction of the levator veli palatini muscle.

The levator veli palatini muscle stretches from the medial cartilage lamina of the auditory tube to the dorso-medial portion of the hard palate. This means that the opening mechanism of the tube must fail and that the muscle may obstruct the auditory tube during contraction. These results may allow conclusions about the dysfunction of the auditory tube and the high frequency of otitis media in children with cleft palate.

REFERENCES