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Paediatric otoscopy—clinical and histological correlation

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Abstract
Otoscopy is a subjective clinical method. Its subjectivity has led physicians to verify its accuracy through correlations with findings of otomicroscopy, pneumatic otoscopy, tympanometry, and myringotomy. In the very young population, however, the interpretation of otoscopic findings becomes more difficult. To improve the interpretation of normal otoscopy in young children, an otoscopic-histological correlation was attempted in children up to nine years of age. Twenty-one temporal bones from 15 children aged from two days to nine years who had no evidence of otological disease or congenital anomalies were examined under light microscopy; the thickness of the pars flaccida, posterior superior quadrant, and umbo were measured. Twenty-five eardrums of 15 healthy children without past or present history of otological disease were examined using otoscopy; a photograph of each eardrum was obtained. Our study demonstrates that structural changes in the tympanic membrane during these years of childhood have a good correlation with otoscopic findings. Understanding normal histological changes in the paediatric eardrum may improve our interpretation of otoscopic findings.

Introduction

The clinical importance of otoscopy has led clinicians to attempt to verify its accuracy. The subjective findings of several observers have been compared (Margolis *et al.*, 1979) and have been correlated with findings on otomicroscopy (Holmberg *et al.*, 1985), pneumatic otoscopy (Mains and Toner, 1989), tympanometry (Gimsing and Bergholtz, 1983), and myringotomy (Paradise *et al.*, 1976). These methods, however, are not wholly accurate. Although otomicroscopy has improved our interpretative capabilities, it too remains a subjective method. The pressure applied to pneumatic otoscopes varies widely among observers, and the presence of an abnormal tympanic membrane may lead to a false interpretation of tympanometric findings. The accuracy of otoscopic results has been found to improve with increasing experience of the otoscopist, with increased age of the subjects studied, and in the presence of either a normal or highly abnormal eardrum (Paradise *et al.*, 1976; Gimsing and Bergholtz, 1983; Holmberg *et al.*, 1985; Mains and Toner, 1989).

The interpretation of otoscopic findings becomes even more difficult in the very young child. It has long been recognized that the middle ear continues to change after birth, mainly in the first year of life. These changes are reflected in the otoscopic appearance of the normal eardrum; changes in its colour, transparency, position, and mobility have been described in normal, healthy full-term infants and during their first year of life (McLellan and Webb 1957, 1961; Jaffe *et al.*, 1970; Cavanaugh, 1987).

Three main reasons have been suggested to explain these otoscopic changes.

The first relates to the presence of amniotic fluid, which can remain in the middle ear in small quantities beyond 70 days of age (Northrop *et al.*, 1986). The second relates to the presence of mesenchymal tissue in the middle ear, which remains usually in large quantities up to one year of age (Takahara and Sando, 1986), persisting beyond this time in the presence of otitis media (Paparella *et al.*, 1980) or of congenital anomalies of the ear (Takahara and Sando 1987). The third reason relates to changes in the eardrum itself. We have demonstrated previously (Ruah *et al.*, 1990, 1991) that the eardrum ages in a way similar to the ageing of skin, becoming thinner, less cellular, less vascular, less elastic, and more rigid with ageing. These changes have been found to be more striking at specific anatomical sites such as the pars flaccida, the posterosuperior quadrant of the pars tensa, and the umbo. To evaluate if these histological changes may be observed on otoscopy, and to improve the interpretation of otoscopic findings, an otoscopic-histological correlation has been attempted in children up to nine years of age.

Materials and methods

Otoscopic study

Twenty-five eardrums of 16 healthy children from 24 hours old to seven years of age were examined with an otoscope. To be eligible for this study, the children had to meet the following criteria:

1) Apgar equal to or greater than eight in the first minute and 10 at five minutes;

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FIG. 1a

FIG. 1b

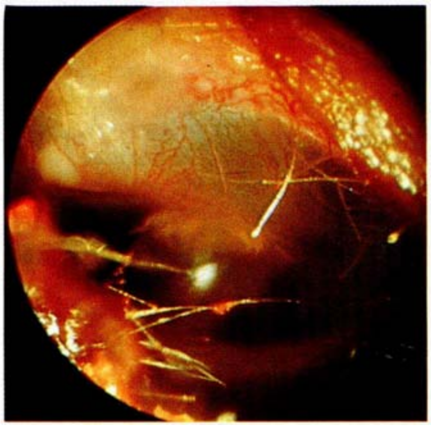

FIG. 1c

FIG. 1d

FIG. 1e

FIG. 1f

FIG. 1g

FIG. 1h

FIG. 1

Otoscopic appearance of the normal tympanic membrane at: (a) 38 weeks of gestation and seven days of age; (b) 40 weeks of gestation and five days of age; (c) Four-and-a-half months; (d) Six-and-a-half months; (e) Ten months; (f) Three years; (g) Five years; (h) Seven years.

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TABLE I
THICKNESS OF TYMPANIC MEMBRANE IN MILLIMETRES

Age	Pars flaccida	Posterosuperior Quadrant	Umbo
2 d	–	0.5	1.1
2 d	2.75	1.43	1.2
2 d	1.75	0.63	1.5
3 d	–	0.48	1.6
3 d	–	0.43	1.2
5 d	2.4	0.5	1.3
13 d	3.0	0.43	0.93
21 d	1.4	0.5	0.7
21 d	2.2	0.36	0.8
1 m	2.5	0.53	1.3
1 ½ m	1.0	0.26	1.3
1 ½ m	0.75	0.18	1.2
2 m	0.6	0.17	0.7
2 m	2.6	0.18	1.3
2 m	2.0	0.33	1.3
8 m	1.8	0.38	1.2
11 m	1.6	0.2	1.0
11 m	1.3	0.16	1.0
3 y	0.9	0.22	0.8
4 y	0.7	0.18	1.0
9 y	0.75	0.2	1.0

d = days; m = months; y = years.

2) no history of acute otitis media, surgery, or trauma to the ear;
3) the tympanic membrane could be visualized without cleaning the external auditory canal;
4) otoscopic results were considered normal by the first two authors;
5) the subjects had normal hearing screening, using methods appropriate for their age. A photograph of each eardrum was taken using an Olympus OM-1 camera coupled with Storz ear telescopes of either 2.7 or 4 mm in diameter and an automatic Storz flash.

Histological study

Twenty-one temporal bones from 15 children aged from two days to nine years with no histological evidence of otologic disease or congenital malformations of the ear, were included in this study. These temporal bones have been harvested at autopsy, fixed in formalin, decalcified, dehydrated, and embedded in celloidin. Sections were cut at thickness of 20 μ, and every tenth section was retained and stained with haematoxylin and eosin. The sections were examined on light microscopy. Thickness of the tympanic membrane was measured at three levels:
1) at the mid-level of the pars flaccida;
2) in the posterosuperior quadrant below the level of the lateral process of the malleus;
3) at the level of the umbo.

Because of the irregularity in thickness of an eardrum, an average of three measurements was obtained at each level, and the results were plotted against age. The least square fitted equation was also plotted and the p value was calculated for each of the levels studied. The changes were considered significant if $p<0.05$.

Our previous reports (Ruah *et al.*, 1990, 1991) did not include the normal evolution of curvature in the tympanic membrane. To evaluate this parameter, those sections taken at the level of the umbo from the 46 temporal bones without evidence of disease that were used in our previous studies (Ruah *et al.*, 1990, 1991) were projected on to a screen. Ages of individuals providing the specimens ranged from two days to 91 years. Ten of these specimens showed artefacts due to preparation, and they were excluded. We used the distance between the plane of the annulus and the mucosa of the mid-umbo to evaluate the degree of curvature of the tympanic membrane, as used by Ars (1989). Because the eardrum reaches an adult position at three years of age (Ars, 1989), the sample was divided into two groups, the first of specimens up to three years of age and the second those beyond three years and the

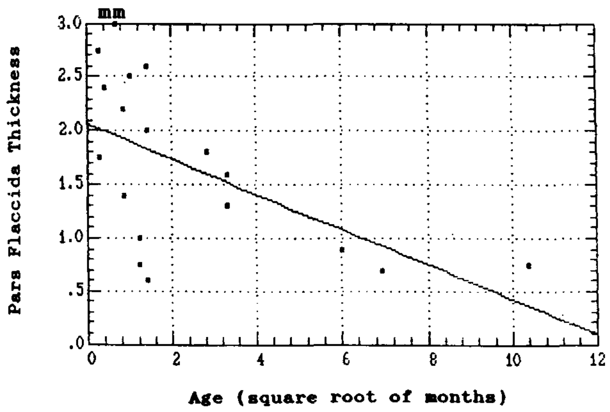

FIG. 2

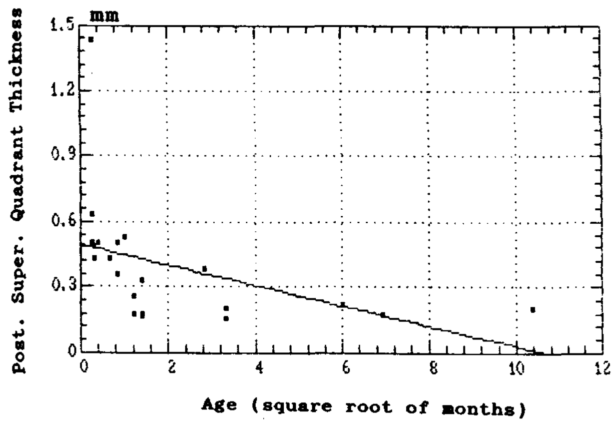

FIG. 3

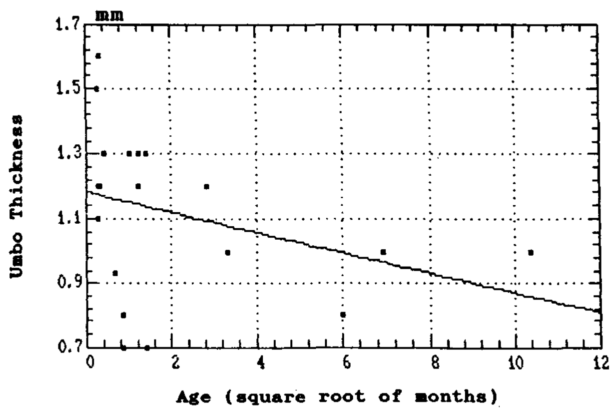

FIG. 4

FIGS. 2, 3, 4

Changes in thickness of the tympanic membrane according to age. The values on the horizontal axis are on a square root scale to spread the sample at the younger ages.

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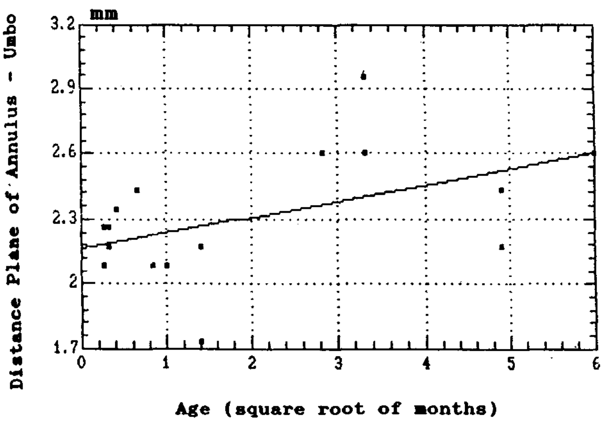

FIG. 5a

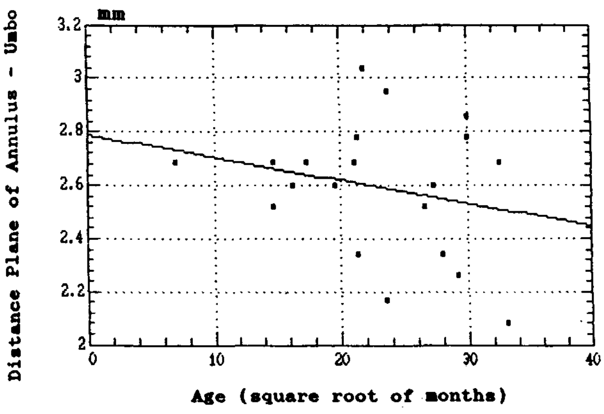

FIG. 5b

FIG. 5

Distance from the plane of the annulus to the umbo in specimens up to three years of age (Fig. 5a) and in specimens older than three years of age (Fig. 5b).

results were plotted against age. The least square fitted equation for each group was also plotted and a p value for each group was determined.

Otoscopic findings

The one-week-old child born after 38 weeks gestation was considered the youngest (Fig. 1a). At that age, the eardrum was quite horizontal and the short process of the malleus was the most prominent structure. The pars flaccida and the posterosuperior quadrant of the pars tensa were very thick, pink, opaque, and difficult to differentiate from the external auditory canal; the vasculature was not clearly seen. The manubrium contrasted in thickness and colour, and neither the umbo nor the annulus could be visualized. A similar picture was observed in children up to 40 weeks of gestation and five days of age (Fig. 1b).

A progressive verticalization of the tympanic membrane was then observed, bringing into view the umbo and the annulus. The pars flaccida and the posterosuperior quadrant remained deep-pink in some children (Fig. 1d), pearly grey in others (Fig. 1c), and could be distinguished quite well from the external auditory canal at four-and-a-half months of age (Fig. 1c). At ten months of age (Fig. 1e), the eardrum was quite vertical. The pars flaccida was still pink and the posterosuperior quadrant of the pars tensa remained thicker than the other quandrants, disclosing quite well its characteristic vascular network. The short process of the malleus, the manubrium, the umbo, and the annulus were easily visible. At three, five, and seven years of age (Fig. 1f, g, h), the otoscopic appearance of the eardrum was similar to that seen in adults. The posterior superior quandrant was now quite transparent, the vascular network became less noticeable and, in the three-year-old child, the long process of the incus was seen through this quadrant (Fig. 1f).

Histological findings

Under light microscopy, we observed that specimens from a newborn differed from those of older children. In the newborn, the pars flaccida showed as a block of mesenchyme filling all the space between the head of the malleus and the external auditory canal. A small, developing Prussak's space was seen at five days of age (Fig. 6a), but there were large individual variations among patients; in some specimens, this space had not reached the mid-level of the flaccida at two months of age. Mesenchyme lateral to the Prussak's space was seen to differentiate progressively into the various connective tissue elements of the lamina propria. This differentiation occurred from near the subepidermis and submucosa towards the middle of the membrane and from the anterior part towards the posterior (generally thicker and presenting mesenchymal vacuolization) (Fig. 6a, b, c). Sometimes there was a difference in stage of development from one ear to the other in the same child. The thickness of the pars flaccida was seen to decrease significantly within the range of ages studied ($p<0.05$) and the values encountered are depicted in Table I and Figure 2. Growth of Prussak's space determines the thickness of the pars flaccida during the first year of life. Differentiation of mesenchymal tissue of the lamina propria at this level is responsible for further thinning of the pars flaccida in patients beyond this age.

The posterosuperior quadrant of the pars tensa was seen to be very thick near its junction with the pars flaccida, thinning progressively towards the umbo and then assuming an appearance similar to that of the other quadrants. This characteristic is mainly due to the presence of a very thick sub-epithelial space, which represents the continuation of the lamina propria of the pars flaccida into the posterosuperior quadrant. A particularly rich vascular network was observed in this quadrant as compared to the other quadrants of the pars tensa. The progressive changes of the subepithelial space was the main factor responsible for the significant thinning of this quadrant with aging ($p<0.05$). The measurements obtained for the posterosuperior quadrant are shown in Table I and Figure 3.

The subepithelial space at the umbo was also very thick and vascular at two days of age, and the changes occuring at this space determined the thickness of this site at each age (Table I, Fig. 4). No significant thinning of this area was found within the ages studied ($p>0.05$).

From analysis of the specimens previously described (Ruah *et al.*, 1991), a progressive increase in distance between the plane of the annulus and the umbo was observed up to the age of three years. Beyond this age and on to 91 years, no significant change occurred in the curvature of the tympanic membrane (Fig. 5a and b).

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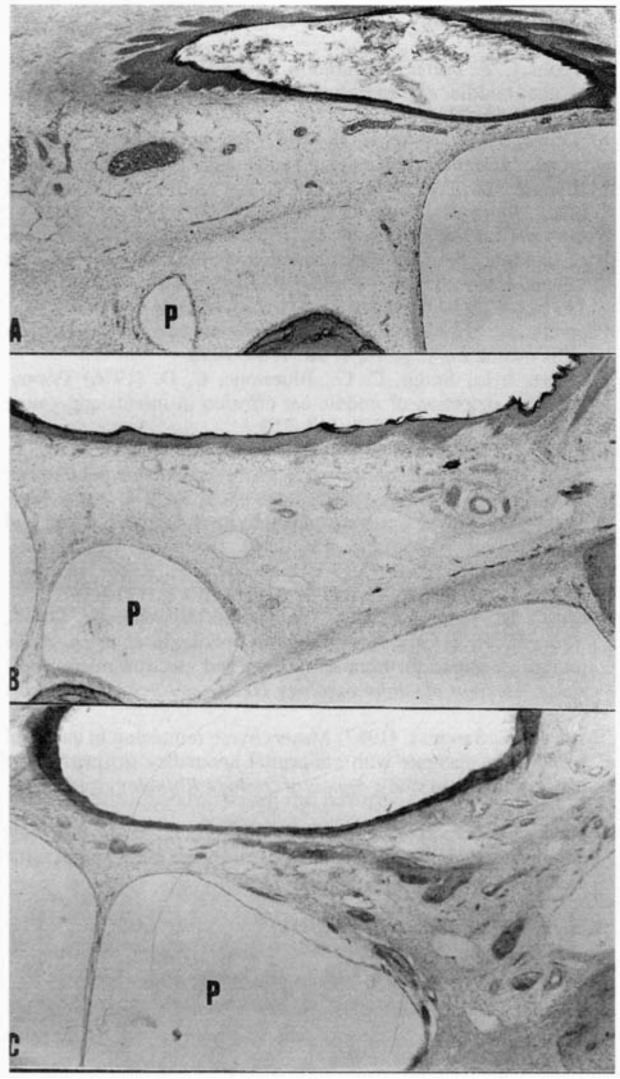

Fig. 6

Changes observed at the midlevel of the pars flaccida at (a) five days; (b) three weeks; (c) eleven months of age. P = Prusak's space. (Haematoxylin and eosin, ×34).

Discussion

Most otoscopists recognize that the appearance of the eardrum depends on the age of the patient, the position of the eardrum, and the nature and intensity of the light source employed. The otoscopic characteristics of the newborn tympanic membrane have previously been described (McLellan and Webb, 1957, 1961; Jaffe *et al.*, 1970; Cavanaugh 1987). Ability to see the tympanic membrane without the need to clean of the external auditory canal is rare until the fourth day of life, occurring in 50 per cent of those observed at the fifth day of life and in 60 per cent at one week of age (McLellan and Webb 1957, 1961).

A pink to red colour of the newborn tympanic membrane (in the absence of fever, illness or crying) has also been mentioned (McLellan and Webb 1957, 1961). According to our observations, this pink to red colour occurs only in the thicker, opaque parts of the tympanic membrane that correspond to the areas of the pars flaccida, the posterosuperior quandrant of the pars tensa and the umbo. These areas are rich in mesenchyme, a particularly vascular tissue. The progressive absorption and differentiation of this mesenchyme leads to the change in colour from pink to pearly grey and allows the vasculature of the tympanic membrane to be seen more clearly. The observation that 37 per cent of eardrums appeared pink or red during the first 72 hours of life, but only 10 per cent maintained this appearance at ten weeks (Cavanaugh, 1987) demonstrates a wide individual variation, also demonstrated histologically in this study.

The progressive thinning at the pars flaccida, posterosuperior quadrant of the pars tensa, and the progressive verticalization of the eardrum, allowed for better visualization of the manubrium, umbo and annulus, despite the fact that the anatomical relationship among these structures and the eardrum are, at birth, similar to those observed in adults (Graham *et al.*, 1978). The particular thickness of the pars flaccida at birth may explain the observation that no spontaneous movements in this area accompany crying, sucking, or obstruction of the nares (McLellan and Webb 1961). Similarly, it is possible that in the presence of otitis media, the persistence of mesenchyme beyond two years of age in the pars flaccida and posterosuperior quadrant of the pars tensa (Ruah *et al.*, 1991), may function as a cushion that prevents the formation of retraction pockets in children below this age. This hypothesis, however, is currently the subject of another study.

Despite its thickness, the posterosuperior quadrant is quite mobile on pneumatic otoscopy at this age; this mobility may serve to differentiate this section from the external auditory canal (Jaffe *et al.*, 1970). A decrease, at this age, in the mobility of this quadrant on pneumatic otoscopy has been associated with a higher incidence of otitis media (Jaffe *et al.*, 1970). One may not, however, compare the mobility of this quadrant at this age with its mobility in older children, since the pressures applied to the pneumatic otoscope vary widely at each use by the same observer, and also among different observers (Gates, 1976; Mains and Toner 1989).

In this particular study, no significant thinning of the umbo was found up to nine years of age. In previous studies, however, (Ruah *et al.*, 1990, 1991) the thickness of the umbo was found to decrease significantly from birth to 91 years of age. The cause of this observation may be the fact that throughout life, the umbo thins at a slower rate than the pars flaccida and the postero superior quadrant of the pars tensa.

Perhaps the most difficult parameter to evaluate otoscopically and histologically is the evolution of the normal concavity of the tympanic membrane, which is flatter at birth and more concave in older children (Ars, 1989). Verticalization of the eardrum is complete around three years of age (Ars, 1989), and in the adult, the membrane has the shape of an asymmetric funnel in which the umbo is eccentric (Kirikae, 1956; Ars, 1989). Since the tympanic membrane is of adult size at birth, the distance between the plane of the annulus and the umbo may be used as a measurement of its curvature. The anatomical changes occuring in the middle ear and the verticalization of the tympanic part of the temporal bone up to three years of age, appear to be responsible for the increase in concavity of the tympanic membrane up to that age. Although not statistically significant, the subtle decrease in this distance into older age may reflect structural changes that occur in the ageing eardrum (Ruah *et al.*, 1990, 1991).

Our study demonstrates a good correlation between the otoscopic and histological findings. We agree with others

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that a good otoscopic examination in the newborn is very difficult to perform (McLellan and Webb, 1957) and that in the absence of bulging, perforation or drainage, the diagnosis of otitis media has to be made with caution during the neonatal period (Cavanaugh, 1987). We believe that understanding the healthy state of the tympanic membrane, especially during the first year of life, may help in recognition of the disease. Otoscopy is, after all, still the mainstay of otological diagnosis.

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