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The disease burden of untreated chronic otitis media in Indigenous children from remote communities does not improve over time. A longitudinal study

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Key words
Australian Aboriginal and Torres Strait Islander People, conductive hearing loss, natural history, otitis media, tympanic membrane.

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Abstract

Background: In Australia, middle ear disease disproportionately affects Indigenous children, leading to poor hearing outcomes. This study aimed to determine the natural history of untreated chronic otitis media in Indigenous children in remote South Australia.

Methods: Baseline and 3 year follow-up data was collected from Indigenous children aged 5–18 years living on the Anangu Pitjantjatjara Yankunytjatjara Lands. 4-frequency puretone audiometry was used to determine hearing levels. Middle ear pathology was determined by video-otoscopy with tympanometry and classified at baseline as group 1 (normal), group 2 (abnormal with intact tympanic membrane), or group 3 (perforated tympanic membrane).

Results: A total of 253 children were included in this study. Children in group 1 (20.6 ± 1.5 dBHL; Mean ± SD) had significantly better hearing outcomes at 3 year follow-up than children with abnormal ears (groups 2 and 3) (23.8 ± 7.0 dBHL), $P < 0.001$. The difference was greatest for group 1 versus 3 (27.6 ± 8.4 dBHL), $P < 0.001$, followed by 1 versus 2 (22.4 ± 5.8 dBHL), $P = 0.009$, and between 2 (22.4 ± 5.8 dBHL) and 3 (27.6 ± 8.4 dBHL), $P < 0.001$.

Conclusion: Hearing in Indigenous children with untreated middle ear pathology remains poor at follow-up compared to those without pathology. Intervention is therefore critical to prevent persisting poor hearing outcomes.

Background

Otitis media (OM) is an infection or inflammation of the middle ear that can be classified as acute OM (AOM), OM with effusion (OME) and chronic OM (COM).[1] OM is among the most common childhood infections, having affected most children by the age of 3 years.[2] Australian Aboriginal and Torres Strait Islander children ('Indigenous children') are more likely to suffer from severe, frequent, and persistent OM, which presents at a younger age and is associated with more complications.[3–6] Indigenous Australian children have among the highest rates of AOM and COM worldwide.[7–9]

Repeated episodes of OM or progression to OME or COM during childhood can lead to significant conductive hearing loss (CHL). CHL, often unrecognized, can negatively affect cognitive, speech and language development, resulting in worse educational and employment outcomes.[10–12] Hearing loss from OM is a leading cause of disability among Indigenous children and contributes

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significantly to health and wellbeing inequities compared to non-Indigenous Australians.[13–15]

Various cross-sectional studies have illustrated the high prevalence of OM among rural Indigenous children.[5,7,13,16] Longitudinal studies have been historically difficult to perform due to participant retention, consistency of research methods and continuation of funding. However, recent longitudinal studies performed have shown a high incidence and prevalence of OM in Indigenous children which is highly persistent and severe.[7,17–19] These studies have primarily focused on the clinical diagnosis of OM and the impact of health programmes on prevalence of disease. Few recent studies have assessed hearing loss and OM together in this population, with those that have not utilizing audiometry and otoscopy.[20,21] As OM most commonly affects children of pre-school age there is also limited research surrounding OM in school age children, including in Indigenous populations.[22] Our research extends the current literature by following clinical progression of OM with hearing impairment over time in a school age remote Indigenous population.

The present study reports data from a 3-year project in remote communities in the Anangu Pitjantjatjara Yankunytjatjara Lands (APY) in northern South Australia which collected hearing and otoscopy data from 813 Indigenous children. Data were collected from Indigenous children aged 5–18 over 6 visits to their community schools. 4-frequency pure-tone audiometry (PTA), tympanometry and video-otoscopy data were obtained on each visit to characterize OM status and hearing.

Methods

Anangu Children aged 5–18 years old from 7 schools on the APY Lands and Maralinga Lands of South Australia were included in this study. The APY Lands span over 200 000 km^2 across the north-west of the state of South Australia, and are populated by 3500–4000 people.[23] Staff from Flinders University (audiologists and otorhinolaryngologists) visited the 7 schools each summer and winter over 3 years, totalling 6 visits, and assessed hearing and ear health. Visits were facilitated by the Anangu Education Service of the Department of Education (Government of South Australia). The population studied was naïve to specialist otolaryngology intervention across the duration of the study. For the duration of this study, the role of visiting staff was to assess ear health and hearing, and provide management recommendations, but not directly deliver interventions. Assessments made, including middle ear diagnoses, hearing results and treatment recommendations, were provided to the local health service. Data pertinent to hearing and the status of each tympanic membrane (TM) were collected at each visit, and these data were analysed in this study. The dataset was originally collected as part of a larger study on ear health and hearing.[24]

At each visit, PTA at 0.5, 1, 2 and 4 kHz, tympanometry and video-otoscopy outcomes were collected from each child. Audiometry was performed in a quiet location with a recorded ambient noise range of 22–36 dBA, and Auraldomes were used to reduce ambient noise exposure. Video-otoscopy was performed using a WelchAllyn (Hillrom) video-otoscope. Recordings were subsequently reviewed by otorhinolaryngologists (>90% concordance previously established[24]) and diagnosed according to the Browning classification.[1] Video-otoscopy classification in conjunction with tympanometry results were used to further classify middle ear disease according to McCafferty's categorisation, this being category 1 – normal TMs; category 2 – abnormal but intact TMs; and category 3 – perforated TMs.[25]

The inclusion criteria for each pathology category were as follows:

- Category 1: Tympanic membrane intact with no significant otoscopic abnormality (i.e. normal or healed COM), and normal tympanometry (type A, suggestive of normal middle ear pressure).
- Category 2: intact tympanic membrane with an otoscopic abnormality (i.e. inactive squamous COM, fluid [OME] TM intact, or pus [AOM] TM intact), or abnormal tympanometry (type B [reduced TM mobility suggestive of middle ear effusion], or type C [negative middle ear pressure suggestive of retracted TM]).
- Category 3: perforated TM (i.e. inactive mucosal COM or active mucosal COM).

Hearing outcomes were represented continuously by each child's PTA score. Hearing was considered to be normal for those with PTA values of 20 dBHL or less, mild hearing loss for those with PTA values between 21 and 40 dBHL, and moderate or worse hearing loss for those with PTA values of 41 dBHL or greater.

Children for whom baseline data and a minimum of 2 year follow-up data was available were included. Each child's hearing was represented by their better hearing ear as measured by their lowest average PTA score, as this is considered to be an accurate representation of individual hearing. For data analysis only the ear with the lower average PTA score at baseline for each child was used, and the video-otoscopy and tympanometry findings for that ear were used to determine which pathology category was present. Hearing outcomes across each pathology category were determined and compared at baseline, and at follow-up.

The dataset was collated on a Microsoft Excel spreadsheet and then transferred into IBM SPSS (version 28.0.1.1) for statistical analyses. Data are represented as number (%) or mean and standard deviation (SD). Differences between the means of sets of unpaired continuous variables were assessed for significance either using Students t-test, or one-way analysis of variance (ANOVA), and Games-Howell post-hoc tests were used following ANOVA when indicated. $P < 0.05$ was considered to be statistically significant. The study was reviewed and approved by the Flinders University Human Research Ethics Committee (approval number: 8635).

Results

Of the total 813 children assessed, 253 children met the inclusion criteria and provided data for analysis in this longitudinal study. Of these, 11 missed a single data point and 3 missed 2 data points, usually due to poor video-otoscopy preventing an accurate middle ear diagnosis at specific time points. A single child had incomplete baseline audiometry. 144 (56.9%) were female and 109 (43.1%) were male. Age at baseline ranged from 5 to 18 years (mean 9.5, SD = 2.9).

At the commencement of the study 74.1% of children had abnormal ears, and 42.4% had measured hearing loss in their better ear. At 2 to 2.5 year follow-up (Table 1) there was a decrease in the number of children with abnormal ears, although most still had abnormal TMs (57.9%). Hearing outcomes remained stable at follow-up, with 42.7% having some degree of hearing loss.

There was no significant change from baseline to follow-up in hearing outcomes at the whole population level, with the baseline mean PTA of 23.69 (SD = 7.14) and the follow-up mean PTA of 22.94 (SD = 6.22) ($P = 0.052$, paired samples t-test). Table 2 summarizes the mean PTA scores at baseline and 2 to 2.5 year follow-up for children for each ear pathology category. Significant differences were seen between all groups at both baseline and at follow-up, that is, groups 1 versus 2, 1 versus 3 and 2 versus 3 at each time point. At follow-up, the largest difference was between categories 1 versus 3 (Cohen's $d = 1.20$). A large effect size was also found between category 2 versus 3 ($d = 0.79$) However, a small effect size was found between category 1 versus 2 ears ($d = 0.37$). These results suggest larger differences in hearing outcomes between children with intact tympanic membranes regardless of pathology, when compared with children with perforated tympanic membranes at baseline.

No children with a normal ear at baseline (category 1) progressed to moderate or worse hearing loss, with most having normal hearing at follow-up (Fig. 1a). Outcomes were more variable for category 2, with 44% having abnormal hearing at follow-up (Fig. 1b). For children with perforated TMs (category 3) at baseline only 27.3% had normal hearing at follow-up (Fig. 1c).

At follow-up, 74.6% of those originally in category 1 remained in category 1, with 23.8% developing category 2 ear pathology and 1.6% deteriorating into category 3 (Fig. 2a). In comparison, 52.8% of those in category 2 at baseline still had category 2 ears at follow-up, with 39.8% improving to have category 1 ears at follow-up (Fig. 2b). Furthermore, 67.9% of those in category 3 at baseline had category 3 ears at follow-up, demonstrating that most perforations persisted over the course of the study period (Fig. 2c).

Discussion

This was a 3-year prospective study conducted among Indigenous schoolchildren living in the APY Lands of South Australia to assess: (a) the prevalence of open and closed COM; (b) the persistence of hearing loss with middle ear pathology; and (c) the progression and development of middle ear pathology. This study is the most recent to quantify the relationship between middle ear

Table 1 Ear pathology and hearing outcomes at baseline and follow-up

	Baseline	2–2.5 year follow-up
Ear Pathology Category		
Category 1	63 (25.9%)	104 (42.1%)
Category 2	125 (51.4%)	97 (39.3%)
Category 3	55 (22.6%)	46 (18.6%)
Hearing outcomes, *n* (%)		
Normal hearing	145 (57.5%)	145 (57.3%)
Mild hearing loss	91 (36.1%)	98 (38.7%)
Moderate or worse hearing loss	16 (6.3%)	10 (4.0%)

All data represented as number (%).

Table 2 PTA scores (dBHL)

Ear pathology category at baseline	Baseline PTA	2–2.5 year follow-up PTA
Category 1	20.18 (0.49)	20.58 (1.54)
Category 2	22.83 (6.11)	22.35 (5.77)
Category 3	30.37 (9.46)	27.63 (8.44)

All data represented as mean (SD). ANOVA for cat 1 versus 2 versus 3 at baseline – $P < 0.001$ (post-tests 1 versus 2, $P = 0.018$; 2 versus 3, $P < 0.001$; 1 versus 3, $P < 0.001$). ANOVA for cat 1 versus 2 versus 3 at follow-up – $P < 0.001$ (post- tests 1 versus 2, $P = 0.004$; 2 versus 3, $P < 0.001$; 1 versus 3, $P < 0.001$). dBHL, decibel hearing level.

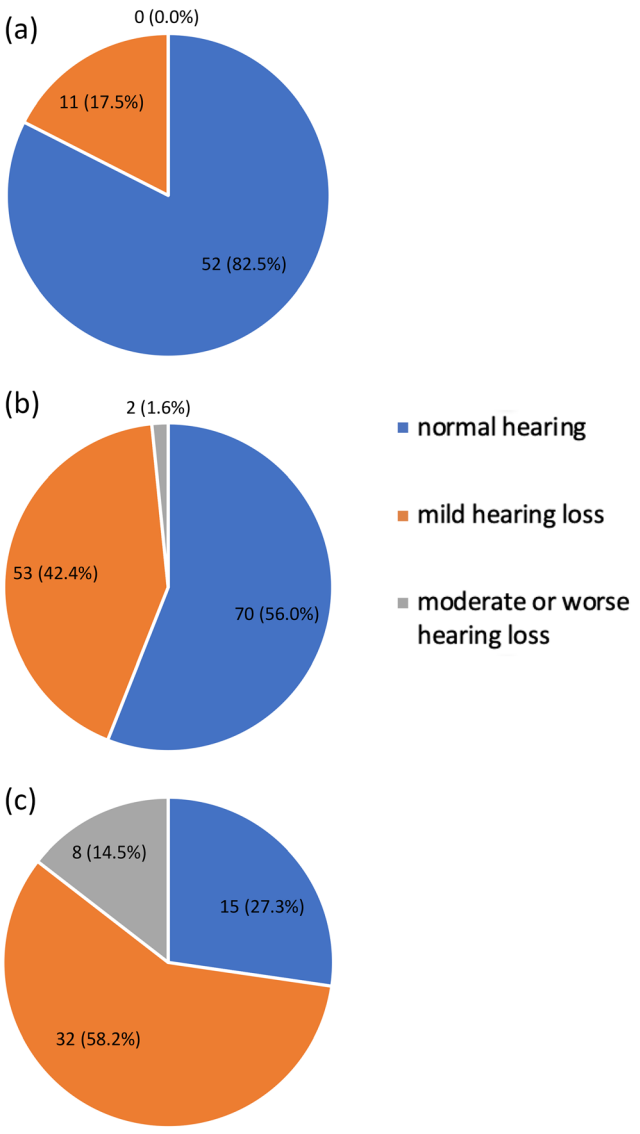

Fig. 1. Hearing follow-up outcomes for different baseline ear pathology. (a) Outcomes for children in Category 1 (normal ears) at baseline. (b) Outcomes for children in Category 2 (abnormal but tympanic membranes) at baseline. (c) Outcomes for children in Category 3 (perforated tympanic membranes) at baseline.

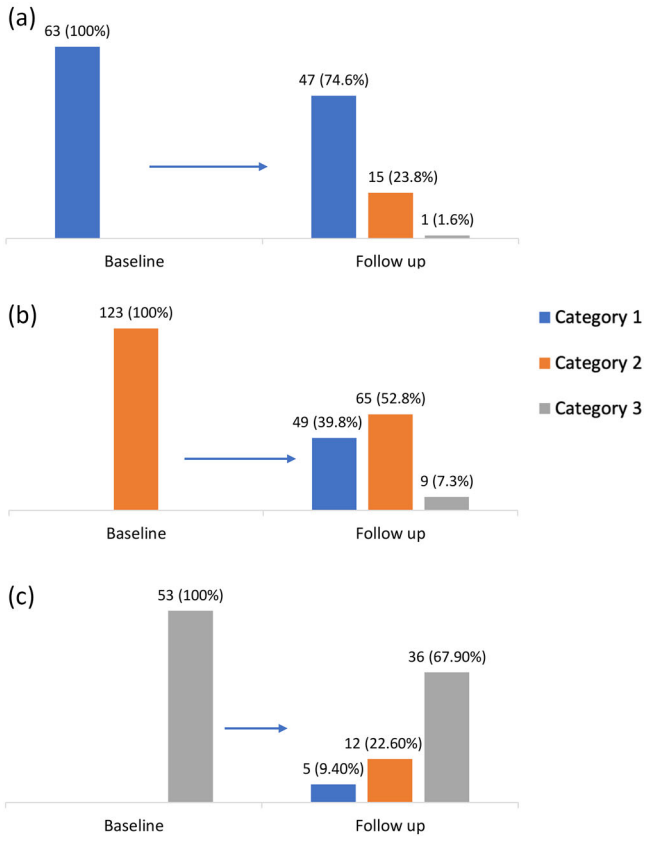

Fig. 2. Changes in ear pathology from baseline to follow-up for each ear disease baseline category. (a) Follow-up ear pathology (*n*[%]) of baseline category 1 (normal ears) children. (b) Follow-up ear pathology (*n*[%]) of baseline category 2 (abnormal but tympanic membranes) children. (c) Follow-up ear pathology (*n*[%]) of baseline category 3 (perforated tympanic membranes) children.

disease and hearing loss over time in Indigenous Australian children.

These results demonstrate that OM is highly prevalent, persistent, and strongly associated with significant hearing loss among school-age Indigenous children in remote communities. Nearly 75% of the study population had some form of COM at baseline, which is significantly higher than the 4% threshold that the World Health Organization considers a 'massive public health problem'.[8] This correlated with over 40% of children experiencing hearing impairment in their better ear. Children with middle ear pathology at baseline experienced significantly worse hearing impairment over time compared to those without. There was little spontaneous resolution of pathology or hearing loss over follow-up, particularly in those with a perforated TM. Although the total number of children with abnormal middle ears decreased somewhat from baseline to follow-up, the number experiencing hearing loss remained constant. This suggests that hearing loss resulting from COM persists despite improvements in pathology, likely due to irreversible damage to the middle ear ossicles.

The results of our study support a natural history of middle ear disease associated with a high degree of long-term hearing loss in this population. While the conductive hearing loss from COM is thought to be reversible, our study demonstrates that hearing impairment can persist long term into adolescence. Hearing loss is the cause of significant social, educational, and economic harm from OM.[10,11,26] Notably, 90% of incarcerated Indigenous youth and adults have some degree of hearing loss and 35% have a significant hearing loss of >35 dBHL.[27,28] Therefore, primary prevention of OM, early intervention and addressing social determinants of health are imperative to prevent long term hearing loss from OM.

The high prevalence of middle ear disease and hearing loss found in this study is similar to that reported in other communities in remote Australia.[5,17] Literature has previously documented high rates of OM in young preschool Indigenous Australian children,[22] but we demonstrate this pattern extending into adolescence. High prevalence was also associated with high rate of perforation of 23% at baseline, aligning with literature reporting Indigenous Australians as experiencing among the highest perforation rates in the world.[8] Non-Indigenous children have a 0.1% reported prevalence of TM perforation.[29] The National Aboriginal and Torres Strait Islander survey found a similarly high rate of hearing loss of 59% in Indigenous children in remote settings, notably higher than that of their regional and urban counterparts, with 39% of these children having hearing loss.[18] This survey relied on self-reported data, and as such our findings provide more objective evidence in support of this high prevalence.

The protracted natural history of COM in our study is similar to that described in the 1985 longitudinal study of ear disease in Australian Indigenous children, which also followed OM and hearing status in a similar study population.[25] This landmark paper described children with persistently perforated TMs, children with closed OM fluctuating between normal ears and disease, and those with persistently normal ears. These periodic changes in pathology were also observed in our study. Furthermore, the persistence within categories of pathology was very similar to our study. A recent longitudinal study in Indigenous children described similar trajectories of OM of non-severe OM, early/persistent severe OM and late severe OM, also with very minimal spontaneous change between categories.[21] Our study and previous literature show those with severe OM have the greatest degree of hearing loss and the least resolution of disease. Those living in households with more than two adults and with socio-economic disadvantage had a greater risk of severe OM.[21] Overall, our study shows that OM in Indigenous children and youth remains highly persistent, prevalent and consequential almost 40 years after the original 1985 study. The prevalence and burden of OM has remained high despite national and regional public health measures.[7]

For persistent COM, surgery to repair the TM can offer clinical and hearing improvement.[30] Furthermore, hearing aids and audiological services are options for hearing rehabilitation. However, these resources are limited in remote Australia and often not available or practicable for younger children. OM, in particular OME, is often an under recognized disease and high rates in Indigenous communities can lead to higher tolerance in Indigenous families of ear disease, with less follow-up and intervention as a result.[31] A multi-faceted approach including early detection and treatment, developmental and educational support and other public health measures to address the primary social determinants of health

should be implemented to address this urgent problem affecting Indigenous children.

Findings from our study might be limited in their generalisability. The population studied were exclusively located in remote communities in South Australia, and as such the outcomes may not reflect the ear health of children in metropolitan areas. The rates of OM were higher in our study than would likely be expected in Indigenous children living in metropolitan areas, who have previously been found to have a lower prevalence of ear disease than those in remote communities.[32] However, our conclusion that COM in Indigenous children is generally not self-resolving and associated with significant and disabling long term hearing loss is likely to apply to other settings. Our findings are also unique as they are from communities that were assessed by both audiologists and otolaryngologists but untreated, and therefore uniquely inform our understanding of the natural history of COM. This study employed best available quantitative measures over long term follow-up to quantify middle ear disease and hearing impairment in a large number of children, and so provides objective evidence of the progression of OM and hearing loss in Indigenous children. Self-reported hearing outcomes without full audiology assessment can lead to underreporting of hearing impairment in the Indigenous Australian population.[33]

This study underscores the urgent need for ENT and primary healthcare services in remote Indigenous Australian communities to address the long-term hearing loss associated with COM. We found high rates of COM of varying severity, with those with TM perforations having the worst and most persistent hearing deficits, suggesting a need for early surgical intervention. Confronting this significant public health issue requires primary health pathways, hearing rehabilitation services and adequately funded surgical programs. Ultimately, addressing social determinants of health associated with OM is crucial to treat the aetiology of the disease rather than its consequences.[34] As of 2023 no ear health outreach programme or ENT services exist on the APY Lands. While a substantial body of epidemiological data regarding OM and associated hearing loss in Indigenous children exists, previous studies have been largely cross-sectional.[5,13,18] Therefore, this current study and further longitudinal studies can provide new epidemiological perspectives to guide future public health decision-making.

Author contributions

Abigail C. Watson: Data curation; formal analysis; methodology; writing – original draft. **Benjamin Voyvodic:** Formal analysis; methodology; writing – original draft. **Charmaine Woods:** Conceptualization; data curation; methodology; supervision; writing – review and editing. **Linnett Sanchez:** Conceptualization; data curation; supervision; writing – review and editing. **A. Simon Carney:** Conceptualization; data curation; methodology; supervision; writing – review and editing.

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Conflict of interest

None declared.

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