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ORIGINAL ARTICLE

Impact of hearing impairment on early childhood development in Australian Aboriginal children: A data linkage study

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Aim: To investigate the association between hearing impairment (HI) and measures of early childhood development in Aboriginal children at age 5 years.

Methods: An observational cohort study (n = 1037) of children aged 4.0–7.3 years (median 5.4 years), living in remote Northern Territory (NT) communities, was conducted using multiple linked administrative datasets, including the NT Perinatal Data Register, Remote Hearing Assessment records (2007–2015) and Australian Early Development Censuses (AEDC, 2009, 2012 and 2015). Outcome measures were summary and domain-specific AEDC results using both dichotomous and continuous variables (domain scores).

Results: Compared with normal hearing children, after adjustment for selected confounding factors, those with moderate or worse HI had an adjusted odds ratio of 1.69 (95% confidence interval (CI), 1.03–2.77) for being developmentally vulnerable in two or more of the five AEDC domains. Children with mild HI and those with moderate to worse HI had lower domain score sum by −1.60 (95% CI, −3.02 to −0.18) and − 2.40 (95% CI, −4.50 to −0.30), respectively. There was also evidence for an association between HI and poorer outcomes in the 'language and cognitive skills', 'communication skills and general knowledge' and 'physical health and wellbeing' domains.

Conclusions: Otitis media-related HI is associated with increased risk for poorer outcomes in early childhood development and this risk appears to increase with higher levels of HI. Prevention and early treatment of otitis media will reduce both the disease and the associated negative impact on early child development, especially the development of language, cognitive and communication skills and physical health and wellbeing.

Key words: child development; hearing impairment; indigenous population; medical record linkage; otitis media.

What is already known on this topic

1. The extremely high prevalence of otitis media and associated hearing impairment among Aboriginal children in Australia's Northern Territory has persisted despite decades of research and public health intervention.
2. Past research that has assessed the effect of otitis media-related hearing impairment on early childhood development and education has been inconclusive.
3. No previous studies have examined the association between hearing impairment and measures of early childhood development in Australia's Aboriginal children.

What this paper adds

1. This study found evidence for an association between otitis media-related hearing impairment and increased risk of poorer outcomes in early childhood development and this risk appears to increase with higher levels of hearing impairment.
2. It also found evidence for an association between hearing impairment and poorer outcomes in the 'language and cognitive skills', 'communication skills and general knowledge' and 'physical health and wellbeing' domains.
3. These findings suggest that prevention and early treatment of otitis media will not only reduce disease but may also moderate the negative impact of hearing impairment on early child development.

In Australia, high prevalence of otitis media (OM) in Aboriginal children has persisted in recent decades despite clinical and public health interventions.[1] In this population, OM affects children early in life, is more severe, and persists longer,[2] with reported prevalence as high as 91% in some remote Northern Territory (NT) communities and peaking between 5–9 months.[3] If untreated or not treated adequately OM commonly progresses to chronic suppurative OM and tympanic membrane perforation, and causes long-term conductive hearing impairment (HI).[4] As the period of 0–5 years is critical for cognitive and language development[5] and children learn to speak by imitating the sounds around them, HI occurring in this period can hamper their language development, which may in turn adversely affect their life course trajectory, including social and emotional development.[5]

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To date, studies investigating the impact of OM-related HI on various aspects of early childhood development, including cognitive and language development, and educational outcomes, have produced equivocal results.[6,7] Several reasons have been proposed for such inconclusiveness, including: limited sample size and statistical power inherent to the survey methods used in many studies; the use of a clinical diagnosis of OM, and not hearing assessment, as the predictor variable causing uncertainty of the presence of HI; and, failing to control for confounding or moderating variables, such as maternal education and socio-economic status.[4,7] Further, current educational policy and practice limit the types and extent of educational support for children with a mild to moderate conductive hearing loss.[8] Given the inconclusive research results on the educational impact of HI among non-Aboriginal populations,[6,7] the potential needs of Aboriginal children with HI has generally not been factored into resource allocation. Over recent decades the high prevalence and persistence of hearing loss among Aboriginal children has been widely recognised,[1] and there has been mention in policy documents of the need for services, but this has not been matched with increased resources to reduce HI's impact on educational outcomes.

Population level studies to investigate the impact of HI on early childhood development among Aboriginal children have not previously been undertaken in Australia. Two datasets recently becoming available for data linkage have now made such investigation possible. The first dataset contains results from the Australian Early Development Census (AEDC), a national census of early childhood development, which has been conducted triennially since 2009.[9] The AEDC involves classroom teachers assessing children, aged about 5 years, across five domains of early childhood development associated with readiness for school learning, namely 'physical health and wellbeing', 'social competence', 'emotional maturity', 'language and cognitive skills', and 'communication skills and general knowledge'. The AEDC collection instrument has been validated for use with Aboriginal children.[10] The second dataset is the Remote Hearing Assessment (RHA) dataset, which contains clinical and audiometric assessment data collected, from 2007 onwards, by the NT Outreach Hearing Health Program.[11] This is an Australian Government-funded programme that provides specialist hearing health services to remote NT communities and is available to Aboriginal children and young people, aged under 21 years. The coverage of this programme has recently been reported to have reached 28% of the NT Aboriginal population in this age group.[11]

The aim of this study was to investigate the association between OM-related HI and measures of early childhood development in Aboriginal children at age 5 years.

Methods

Design and participants

This was a retrospective observational cohort study using linked administrative datasets held in an extensive data repository. The datasets contain de-identified unit-level information for NT children with individual linkage keys prepared by SA NT DataLink using probabilistic linkage with clerical review for uncertain matches. A detailed description of the data linkage process and data repository has been reported elsewhere.[12] The study cohort consisted of NT Aboriginal children with linked records from three key sources: AEDC and RHA datasets, described above, and the NT Perinatal Data Register. The NT Perinatal Data Register is a statutory administrative collection containing comprehensive maternal and perinatal information for all births in the NT and was available from 1994 to 2014.

Children who underwent surgical treatment for OM before the age of 4 years (n = 15) were excluded because the surgery could alter the impact of HI. This was done by searching linked records in a fourth dataset, the Hospital Separations Dataset and excluding children admitted before age 4 years with a combination of diagnosis codes for OM and related procedure codes (Table A1). The hospital separations dataset contains diagnosis and procedure information for all hospital admissions for all six NT public hospitals for the period of 2000–2017. We also excluded Aboriginal children living in the 'outer regional' area of the NT (Darwin and immediate surrounds) using the level of relative remoteness of their school location, as measured with the Accessibility and Remoteness Index of Australia (ARIA+).[13] The NT Outreach Hearing Health Program is a remote service and does not routinely service children in Darwin and surrounds. These children may also have different factors which influence their health and have different access to services including specialist health services.

Explanatory variables

Hearing assessment results were retrieved from the RHA database which contains all hearing assessments for children and young people undertaken in remote communities. The assessments were performed using pure tone audiometry with results reported as the average threshold of hearing (as deviation from the normal threshold, in decibels hearing level (dB HL)) for the three frequencies: 500 hertz (Hz), 1000 Hz and 2000 Hz. The result for each ear was classified as either normal or one of four levels of hearing loss, namely mild (16–30 dB HL), moderate (31–60 dB HL), severe (61–90 dB HL) and profound (≥ 91 dB HL), a comparatively conservative classification which was deemed more suitable for children aged under 15.[11] As the focus of this study was OM-related HI, only results of conductive and mixed hearing loss were included in the analysis.

The explanatory variable, HI, consisted of four categories:

- Normal hearing: normal audiometry results in both ears.
- Unilateral hearing loss (UHL): normal hearing in one ear and any degree of hearing loss in the other.
- Mild HI: mild hearing loss in the better hearing ear.
- Moderate or worse HI: moderate or worse hearing loss in the better hearing ear.

Given that OM in NT Aboriginal children tends to develop early in life, be persistent and often asymptomatic,[2–4] it is usually diagnosed at an older age due to easier diagnosis and greater health-care access. We therefore assumed the first recorded audiometry result was representative of a child's hearing level in early childhood regardless of the age at time of assessment.

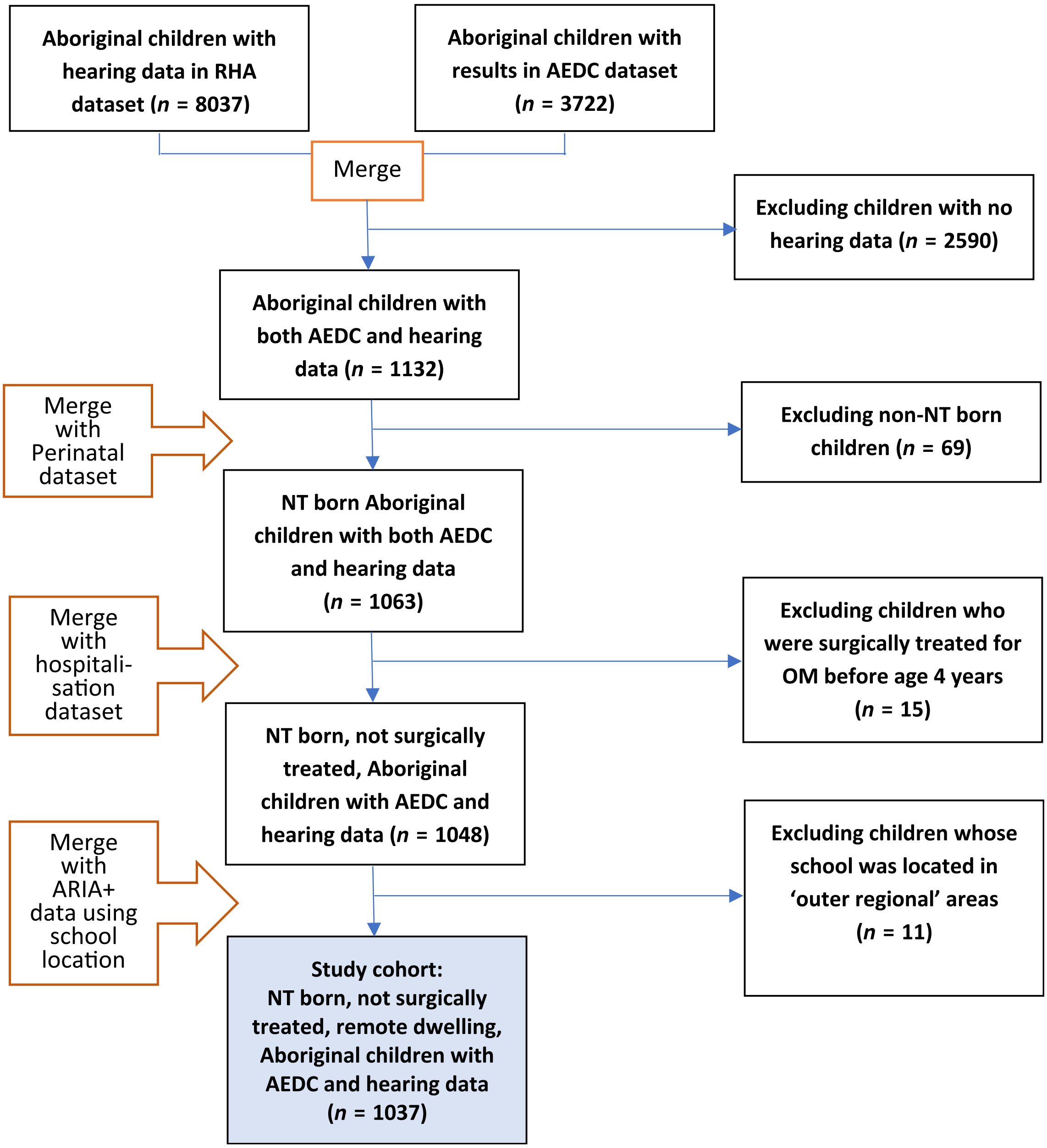

Fig 1 Flow chart of processes for selecting children for the study cohort. AEDC, Australian Early Development Censuses; ARIA+, Accessibility and Remoteness Index of Australia; NT, Northern Territory; OM, otitis media; RHA, Remote Hearing Assessment.

Outcome variables

The scale scores for each AEDC domain range from 0 to 10, with higher scores indicating higher levels of development. A score falling below the 10th percentile, benchmarked to the national 2009 AEDC results, is deemed to indicate a 'developmentally vulnerable' result on that domain.[14] The outcome variables included the dichotomous results of developmental vulnerability for each of the five domains, as well as the summary measure 'being developmentally vulnerable in two or more domains' (DV2). Children assessed as vulnerable in two or more domains are considered to be at higher developmental risk and generally require additional support to progress through early schooling.

Because the dichotomous AEDC variables identified more than half of NT Aboriginal children to be developmentally vulnerable,[15] the domain scores were also used to establish continuous outcome measures as it was anticipated that these would be more sensitive in defining possible targeted associations. This involved using the individual AEDC scale scores in domain-specific analyses, and also using the sum of all five domain scores as an overall measure of developmental outcome.

Table 1 Regression modelling results for the association between hearing impairment and overall developmental outcomes in terms of 'vulnerable in two or more domains' and domain score sum in Australian Early Development Censuses (AEDC)

Hearing impairment category	Vulnerable in two or more domains			Domain score sum	
	n†	OR_{unadj} (95% CI)	OR_{adj} (95% CI)	$COEF_{unadj}$ (95% CI)	$COEF_{adj}$ (95% CI)
Normal hearing	194/181	Reference	Reference	Reference	Reference
Unilateral HL	98/86	1.06 (0.75–1.51)	0.99 (0.67–1.44)	−0.37 (−2.04 to 1.29)	0.07 (−1.58 to 1.73)
Mild HI	181/125	1.35 (1.00–1.83)	1.33 (0.95–1.84)	−1.75 (−3.16 to −0.34)*	−1.60 (−3.02 to −0.18)*
Moderate or worse HI	62/38	1.52 (0.97–2.39)	1.69 (1.03–2.77)*	−1.95 (−4.03 to 0.14)	−2.40 (−4.50 to −0.30)*

*$P < 0.05$; **$P < 0.005$; ***$P < 0.0005$.

†Statistics are presented as vulnerable/not vulnerable; 63 of the 1037 children in the study cohort could not be classified into any category of hearing impairment.

Covariates in the final regression models: sex (male), low birthweight, antenatal visit<7 times, child's age at AEDC, community average household size>5, the community quintiles of Index of Relative Socio-Economic Disadvantage, and living in very remote areas. adj, adjusted; CI, confidence interval; COEF, regression coefficient; HI, hearing impairment; HL, hearing loss; OR, odds ratio; unadj, unadjusted.

Table 2 Multivariate regression model results for the association between hearing impairment (HI) and domain-specific developmental outcomes

Domain	HI category	n†	OR_{adj} (95%CI)	$COEF_{adj}$ (95%CI)
Language and cognitive skills	No HI	215/157	Reference	Reference
	Unilateral HL	106/76	0.90 (0.61–1.32)	−0.06 (−0.47 to 0.34)
	Mild HI	183/123	1.03 (0.74–1.43)	−0.41 (−0.76 to −0.06)*
	Moderate or worse HI	61/38	1.11 (0.68–1.82)	−0.51 (−1.03 to 0.005)
Communication skills and general knowledge	No HI	145/229	Reference	Reference
	Unilateral HL	81/103	1.16 (0.79–1.70)	−0.13 (−0.66 to 0.39)
	Mild HI	142/164	1.33 (0.96–1.84)	−0.42 (−0.88 to 0.03)
	Moderate or worse HI	56/44	2.41 (1.49–3.92)***	−0.89 (−1.56 to −0.23)*
Emotional maturity	No HI	124/244	Reference	Reference
	Unilateral HL	48/131	0.68 (0.44–1.05)	0.18 (−0.18 to 0.53)
	Mild HI	105/198	1.09 (0.76–1.55)	−0.12 (−0.43 to 0.18)
	Moderate or worse HI	37/60	1.41 (0.85–2.36)	−0.18 (−0.63 to 0.27)
Physical health and well being	No HI	134/241	Reference	Reference
	Unilateral HL	68/116	0.92 (0.62–1.36)	−0.007 (−0.34 to 0.32)
	Mild HI	131/175	1.31 (0.94–1.82)	−0.36 (−0.65 to −0.08)*
	Moderate or worse HI	43/57	1.50 (0.93–2.44)	−0.48 (−0.90 to −0.07)*
Social competence	No HI	135/239	Reference	Reference
	Unilateral HL	65/118	0.84 (0.56–1.25)	0.05 (−0.37 to 0.47)
	Mild HI	119/187	1.08 (0.77–1.52)	−0.16 (−0.52 to 0.21)
	Moderate or worse HI	43/57	1.34 (0.82–2.19)	−0.30 (−0.83 to 0.23)

*$P < 0.05$; **$P < 0.005$; ***$P < 0.0005$.

†Statistics are presented as vulnerable/not vulnerable.

Covariates in the final regression models: sex (male), low birthweight, antenatal visit<7 times, child's age at AEDC, community average household size>5, the community quintiles of Index of Relative Socio-Economic Disadvantage, and living in very remote areas. CI, confidence interval; $COEF_{adj}$, adjusted regression coefficient; HI, hearing impairment; HL, hearing loss; OR_{adj}, adjusted odds ratio.

Confounding variables

The selection of other variables, including potential confounding variables, controlled for in the analysis was based on previous studies. From the Perinatal Data Register the selected variables for children were; sex, twin birth, low birthweight and preterm birth; and for mothers were: teenage pregnancy, diabetes, hypertension, smoking or drinking alcohol during pregnancy and fewer than seven antenatal visits.[16] Community level variables selected were the Index of Relative Socio-Economic Disadvantage (IRSD, representing socio-economic disadvantage, expressed as quintiles),[17] the level of relative remoteness (ARIA+) and housing crowdedness indicators (including 'average household size>5 persons' and 'average persons per bedroom >2'),[17] all of which were linked to the combined dataset by a child's school location at time of AEDC assessment.

Statistical analysis

A z-test was used to compare children with and without hearing assessment data. Logistic regression was used to analyse the associations with dichotomous outcome variables, drawing reference from a similar published study.[16] Linear regression was used for continuous outcome variables. Multivariate regression models were built by first including all covariates with unadjusted $P < 0.25$ and then removing covariates with an adjusted $P \geq 0.05$ from the model until a stable and parsimonious model was achieved. A number of confounding variables (low birthweight, sex, IRSD, relative remoteness and household size >5) were retained throughout the model building process. The normality of residuals was checked after each multivariate linear regression to ensure the domain scale score data for the study cohort were suitable for analysis with linear regression. This was important as previous studies have found the national AEDC data for domain scale scores to be heavily skewed and not responsive to transformation.[18] In the linear regression results for individual domains, as the scale scores ranged from 0 to 10, a 1-unit difference in the regression coefficient is equivalent to a 10% score difference. A two-tailed $P < 0.05$ or a 95% confidence interval (CI) not including the null value was considered to indicate a significant difference. All statistical analyses were conducted using Stata for Windows, version 15 (Stata Corporation, College Station, TX, USA).

Ethical approval

The study was approved by the Human Research Ethics Committee of the NT Department of Health and Menzies School of Health Research (HREC-2016-2708).

Results

Descriptive statistics

After the selection process (Fig. 1), the study cohort consisted of 1037 children (550 being boys, or 53.0%) aged 4.0–7.3 years at time of AEDC assessment (median 5.4 years). Their mean age at the time of their first audiometric assessment (as recorded in the RHA) was 5.4 years (95% CI, 5.3–5.6, see Table A2). Just over half (52.4%) of all children received their first hearing assessment when aged 5 years or older, and 15.5% received their first assessment before the age of 3 years. There was evidence of some difference between the study cohort and the 1484 Aboriginal children also living in remote NT communities who completed the AEDC but who did not receive hearing assessment, in 7 of the 14 confounding variables (Table A3).

Summary measures of developmental outcomes

The confounding variables retained in the final multivariate models for both the summary measures and domain-specific outcomes were 'sex (male)', 'low birthweight', 'antenatal visit<7 times', 'child's age at AEDC', 'community average household size>5', the IRSD, and 'living in very remote areas'.

In univariate analysis there was no evidence of an association between any of the HI categories and the dichotomous measure of vulnerability (DV2) (Table 1). In multivariate analysis 'moderate or worse HI' was associated with an adjusted odds ratio (OR_{adj}) of 1.69 (95% CI, 1.03–2.77).

The analysis of the continuous variable 'domain score sum' demonstrated a negative correlation, in univariate analysis, with 'mild HI'. In the multivariate model, there was evidence for a negative correlation with both 'mild HI' and 'moderate or worse HI' (Table 1). Additionally, in multivariate analysis there was suggestion of an increasing negative effect on outcome with increasing level of HI, with no evidence of an association with UHL (adjusted coefficient ($COEF_{adj}$), 0.07, 95% CI: −1.58 to 1.73) and increased negative correlation for mild HI ($COEF_{adj}$ − 1.60, 95% CI: −3.02 to −0.18) and moderate or worse HI ($COEF_{adj}$ − 2.40, 95% CI: −4.50 to −0.30).

Domain-specific outcomes

In analyses across the five domains, using the dichotomous variables for vulnerability, there was strong evidence for an association between 'moderate or worse HI' and developmental vulnerability in the 'communication skills and general knowledge' domain only (OR_{adj} 2.41; 95% CI, 1.49–3.92, Table 2). The analysis using the continuous variables of domain scores provided some evidence of a negative correlation between 'mild HI' and the 'language and cognitive skills' ($COEF_{adj}$ −0.41; 95% CI, −0.76 to −0.06) and 'physical health & wellbeing' ($COEF_{adj}$ −0.36; 95% CI, −0.65 to −0.08) domains. There was also evidence for a negative correlation between 'moderate or worse HI' and domain scores for the 'communication skills and general knowledge' ($COEF_{adj}$ −0.89; 95% CI, −1.56 to −0.23) and 'physical health and wellbeing' ($COEF_{adj}$ −0.48; 95% CI, −0.90 to −0.07) domains.

There was no evidence of an association between the UHL category and any of the outcome measures.

Discussion

Our study has provided evidence for an association between HI and early childhood development in NT Aboriginal children. Our analysis showed that 'moderate or worse HI' was associated with a 1.69-fold increased odds of being developmentally vulnerable in two or more AEDC domains, after controlling for a range of factors at both individual and community levels. In the analysis using the domain score sum as a continuous variable, both 'mild HI' and 'moderate or worse HI' categories provided evidence of an association with lower 'domain score sum.' In addition, the magnitude of adjusted regression coefficients increased progressively from the UHL category to the 'moderate or worse HI', which suggests that the risk of poorer developmental outcomes increases with the severity of HI.

There is also evidence that HI is more strongly associated with specific areas of development, particularly those domains involving language and communication skills, where even mild HI may have an impact. This finding is consistent with children's development of language and communications skills depending heavily on their ability to hear. It is also consistent with past research investigating the association between HI and language and communication development.[19,20] Both 'mild HI' and 'moderate or worse HI' categories were also associated with poorer developmental outcomes in the domain of 'physical health &

wellbeing.' Literature investigating the impact of OM on the physical health and motor ability is limited; however previous studies have found evidence for an association between OM with effusion in children and abnormal balance and motor functions.[21] Aboriginal students' participation in school sport has been found to support attendance and wellbeing.[22] These results suggest the need to evaluate the potential benefits and harms of supporting school sport participation by children with a history of ear disease.

However, the major educational implication of our findings is to provide local evidence that Aboriginal children with conductive HI have a need for greater pre-school and school based support than normal hearing children. There is evidence, including studies with Aboriginal children, for the use of sound field amplification in classrooms and greater local engagement,[8,23] but research is needed on other school-based intervention programmes. On the health front, given the findings of this study, public health interventions implemented for the prevention (such as pneumococcal conjugate vaccines[1]), early detection and effective treatment (such as the NT Healthy Under Five Kids programme)[24] of OM and the associated HI can also contribute to reducing the impact of OM-related HI on early childhood development. Routine hearing screening at school entry can also help to detect children with HI and inform suitable support to reduce further impact.[8]

Our study applied AEDC scale scores as a continuous outcome variable, finding evidence for associations in more categories of HI and in more domains than when using the standard dichotomous outcome variables. Compared with a continuous variable, a dichotomous outcome variable results in considerable loss of power and does not adjust for residual confounding.[25] Furthermore dichotomous results for individual AEDC domains are determined using cut-off points of the 10th percentile of the scores of a national AEDC cohort.[14] Given the proportion of NT Aboriginal children below the cut-off point was about eight times higher than the national AEDC cohort (40.2 vs. 5.1% in 2012) and that they on average achieved substantially lower scores across all five domains,[14] using dichotomised outcome variables and national benchmarks for this study cohort would have diminished variation making it less likely to detect evidence for associations.

A strength of this study is that it used population-level linked data for hearing assessment and early childhood development, for which there has been no comparable Australian studies. The size of our study cohort was large, compared with similar studies using special survey methods.[19,20] This and the comprehensive coverage of the administrative datasets provide adequate statistical power and representativeness of the data of the targeted population to make useful inferences. The ability these linked datasets provided to control for potential confounding and moderating factors enabled the study to investigate the independent impact of HI. A second strength was the direct use of audiometrically determined degree of HI as explanatory variables, which eliminated the uncertainty associated with using the clinical diagnosis of OM as the explanatory variable.

Our study also has limitations. More than half of the children in the study cohort received their first hearing assessment when aged 5 years or older including after the AEDC assessment. However, an argument for a causal relationship between HI and AEDC outcomes is supported by the early onset and persistence of OM in this high prevalence population. A related constraint is the use of each child's first audiometry result for analysis under the assumption that the result was indicative of the long-term HI status of a child. As the severity of HI may change with time there may be some misclassification; though if this is the case then our results will be an underestimate of the strength of association between HI and the various measures of developmental vulnerability. A further limitation is that hearing assessment data in the RHA dataset may not be representative of all NT Aboriginal children.[11] Although the outreach service that provided ear health assessment was free and delivered to the communities, access was not universal. Comparison between remote dwelling Aboriginal children in the AEDC dataset with and without hearing assessment data found the two groups to differ significantly in half of the selected variables. It is likely that some degree of selection bias existed in the study. Finally, while we have included a number of potential confounding variables in the analysis, there may be other factors, such as level of parental education, which were not available for the study.

Conclusions

Our study provides evidence that HI, associated with OM, increases the risk for poorer outcome in early childhood development and school readiness for Aboriginal children living in remote NT communities, and that risk may increase with the severity of HI. These findings highlight the importance of vigorous public health prevention and intervention programmes to manage OM and the related HI from early in a child's life, which will not only reduce disease but also mitigate the negative impacts of HI on early childhood development, especially the development of language, cognitive and communication skills and physical health and wellbeing.

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APPENDIX

Table A1 Hospital diagnoses and surgical procedures related to otitis media, with the related International Classification, 10th Revision – Australian Modification (ICD-10AM) codes, used in the exclusion criteria

ICD-10AM CODE	Diagnosis/Procedure
Diagnosis	
H65	Nonsuppurative otitis media
H66	Suppurative and unspecified otitis media
H72	Perforation of tympanic membrane
Procedure	
41527-00	Myringoplasty, transcanal approach
41530-00	Myringoplasty postaural or endaural approach
41533-01	Myringoplasty with atticotomy
41542-00	Myringoplasty with ossicular chain reconstruction
41551-00	Mastoidectomy by intact canal wall technique with myringoplasty
41554-00	Mastoidectomy by intact canal wall technique with myringoplasty and ossicular chain reconstruction
41560-00	Modified radical mastoidectomy with myringoplasty
41560-01	Radical mastoidectomy with myringoplasty
41563-00	Modified radical mastoidectomy with myringoplasty and ossicular chain reconstruction
41563-01	Radical mastoidectomy with myringoplasty and ossicular chain reconstruction
41626-00	Myringotomy, unilateral
41626-01	Myringotomy, bilateral
41632-00	Myringotomy with insertion of tube, unilateral
41632-01	Myringotomy with insertion of tube, bilateral
41635-01	Excision of lesion of middle ear with myringoplasty
41638-01	Excision of lesion of middle ear with myringoplasty and ossicular chain reconstruction
41789-00	Tonsillectomy without adenoidectomy
41789-01	Tonsillectomy with adenoidectomy
41801-00	Adenoidectomy without tonsillectomy
90114-00	Other procedures on eardrum or middle ear

Table A2 Descriptive statistics of the study cohort

Category	Study cohort			
	Female	Male	Total	%
Number of children	487	550	1037	
%	47.0	53.0		
Median age†	5.0	5.2	5.1	
Mean age†	5.3	5.5	5.4	
(95% CI)	5.1–5.6	5.3–5.7	5.3–5.6	
AEDC year				
2009	245	276	521	50.2
2012	138	143	281	27.1
2015	104	131	235	22.7
Year of birth				
2002	<10	<10	12	1.2
2003	78	108	186	17.9
2004	114	122	236	22.8
2005	48	41	89	8.6
2006	80	84	164	15.8
2007	58	56	114	11.0
2008	<10	<10	12	1.2
2009	52	61	113	10.9
2010	49	62	111	10.7
Year of hearing assessment†				
2007	<10	<10	<10	0.5
2008	106	102	208	20.1
2009	77	81	158	15.2
2010	42	50	92	8.9
2011	34	63	97	9.4
2012	53	52	105	10.1
2013	58	72	130	12.5
2014	68	69	137	13.2
2015	45	60	105	10.1
Age at first hearing assessment				
<1	<10	<10	<10	0.6
1–2	70	84	154	14.9
3–4	173	161	334	32.2
5–8	211	271	482	46.5
9–14	30	31	61	5.9

†Statistics for the children at their first recorded hearing assessment. CI, confidence interval.

Table A3 Comparison of selected characteristics of children, with or without hearing assessment data

Variable	% missing data	Group without hearing assessment data (n = 1484)		Group with hearing assessment data (n = 1037)		P value
		%	95% CI	%	95% CI	
Sex (male)	0.0	49.4	46.8–51.9	53.0	50.0–56.1	0.072
Maternal factors						
Teenage mother	0.0	24.9	22.7–27.1	28.8	26.1–31.6	0.026
Diabetes	0.0	9.8	8.3–11.4	10.3	8.5–12.2	0.693
Hypertension	0.0	4.4	3.4–5.5	4.1	2.9–5.2	0.628
Antenatal visits <7	1.4	31.8	29.4–34.2	36.2	33.3–39.2	0.022
Alcohol in pregnancy	22.0	16.3	14.2–18.4	12.3	10.0–14.6	0.015
Smoking in pregnancy	19.1	54.4	51.6–57.2	49.0	45.6–52.4	0.015
Perinatal factors						
APGAR score < 7	0.1	2.4	1.6–3.1	2.0	1.2–2.9	0.579
Resuscitation at birth	0.0	54.9	52.3–57.4	55.5	52.5–58.6	0.731
Emergency caesarean section	0.0	15.1	13.3–16.9	18.7	16.3–21.1	0.016
Low birthweight	0.0	13.1	11.4–14.8	14.3	12.1–16.4	0.387
Preterm birth	<0.1	12.6	10.9–14.3	16.6	14.3–18.9	0.005
Admitted to special care nursery	0.8	20.4	18.3–22.4	25.6	22.9–28.3	0.002
Twin birth	0.0	2.0	1.3–2.7	2.5	1.6–3.5	0.416

All children were born in the NT, lived in remote communities and completed the AEDC in 2009, 2012 or 2015. AEDC, Australian Early Development Censuses; CI, confidence interval.

The Dreamtime by Aliyah Saldanna (age 13) from the SHINE Art Competition 2019