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REVIEW ARTICLE

Otitis media in Indigenous Australian children: review of epidemiology and risk factors

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Abstract

Background: Otitis media represents a major health concern in Australian Indigenous children ('Indigenous children'), which has persisted, despite public health measures, for over 30 years.

Methods: Global searches were performed to retrieve peer-reviewed and 'grey' literature investigating the epidemiology of and risk factors for otitis media in Indigenous children, published between 1985 and 2012.

Results: In Indigenous children, the prevalence of otitis media subtypes is 7.1–12.8 per cent for acute otitis media, 10.5–30.3 per cent for active chronic otitis media and 31–50 per cent for tympanic membrane perforation. The initial onset of otitis media in Indigenous children occurs earlier and persists for longer after the first year of life, compared with non-Indigenous children. Indigenous children are colonised by otopathogens more frequently, at younger ages and with a higher bacterial load. Poor community and domestic infrastructure, overcrowding and exposure to tobacco smoke increase the risk of otitis media in Indigenous children; however, the availability of swimming pools plays no role in the prevention or management of otitis media.

Conclusion: Despite awareness of the epidemiological burden of otitis media and its risk factors in Indigenous children, studies undertaken since 1985 demonstrate that otitis media remains a significant public health concern in this population.

Key words: Otitis Media; Health Services, Indigenous; Review; Risk Factors; Prevalence; Incidence; Epidemiology

Introduction

Otitis media represents a major public health concern in Australian Indigenous children ('Indigenous children'), resulting in significant social, educational and economic harm. Accordingly, the burden of and risk factors for otitis media have been the focus of substantial research for well over 30 years. Review articles published in the last decade have focused on general research findings, without seeking to present a complete overview of the literature.[1–3] The current paper seeks to present a comprehensive review of the literature investigating the epidemiology of and risk factors for otitis media in Indigenous children, published since 1985, including Moran and colleagues' overview of the largest screening programme ever undertaken in Indigenous Australians (the National Trachoma and Eye Health Program).[4] Studies investigating epidemiological trends have been of longitudinal, cross-sectional and survey types, with cohorts ranging in size from 17 to 22 000 children and ranging in age from birth to 18 years. The reviewed risk factors for otitis media in Indigenous children include age, bacterial colonisation, living conditions, swimming pool use, breastfeeding and passive smoking.

This review focuses on the clinical signs of otitis media. It is acknowledged that while physical examination can diagnose ear disease, it is the sequelae of middle-ear disorders, primarily in relation to consequent conductive hearing loss, that result in the significant educational, social and financial burden seen in Indigenous Australians. Accordingly, there is a wide body of literature investigating hearing loss in Indigenous populations; however, these studies are beyond the scope of this review.

Methods

Searches of the PubMed, CINAHL and Cochrane Library databases, and of papers accessed via the Google Scholar search engine, were performed. References cited in relevant articles were also searched. Search terms included a combination of 'otitis media', 'middle ear disease', 'indigenous', 'aboriginal', 'review', 'risk factors', 'prevalence', 'incidence' and 'epidemiology'. The authors included all peer-reviewed

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TABLE I
ACUTE OTITIS MEDIA: TERMINOLOGY AND DEFINITIONS

Subtype	Definition
Acute otitis media without perforation	Presence of middle-ear fluid with symptoms or signs of infection, which may include otalgia, fever, irritability, vomiting or diarrhoea
Acute otitis media with perforation	Acute infection with recent discharge from middle ear
Recurrent acute otitis media	Recurrent bouts of acute otitis media: 3 episodes in 6 months or 4–5 in 12 months
Otitis media with effusion	Presence of middle-ear fluid without symptoms or signs of suppurative infection

and 'grey' literature investigating the epidemiology of and risk factors for otitis media in Indigenous children, published between 1985 and 2012.

Definitions

In order to compare studies accurately, precise definitions of the subtypes of otitis media must be used. These definitions have changed over time, making earlier studies difficult to interpret. Tables I and II outline the current terminology for and understanding of the acute[5,6] and chronic forms of otitis media.[6]

Results and analysis: epidemiology

Longitudinal studies

A number of ear health studies have followed Indigenous children over time (Table III). Children were followed for defined periods of time ranging from eight weeks to nine years. A number of these studies involved control groups of non-Indigenous subjects.

McCafferty *et al.*[7] and Boswell and Nienhuys[12] followed subjects for 9 years and 12 months, respectively, and categorised subjects into 1 of 5 similar patterns of otitis media, pattern 1 being the most severe and pattern 5 indicating 'always or almost always normal ears'. McCafferty *et al.* classified 63 per cent of their child subjects followed for 9 years as presenting with 'persistent closed ear disease, occasional perforation' (pattern 4) or worse, with only 37 per cent recorded as having 'always or almost always normal ears' (pattern 5). Boswell and Nienhuys performed a similar study, and found that 96 per cent of their Indigenous infant subjects followed during the first year of life demonstrated 'persistent otitis media with effusion with or without episodes of acute otitis media' (pattern 3) or worse. All of the latter authors' non-Indigenous infant subjects had an otitis media pattern better than pattern 3 (i.e. they had healthier ears), demonstrating an alarming longitudinal disparity in ear health at a very young age.

In other longitudinal studies, Lehmann *et al.*[14] and Boswell and Nienhuys[11] also reported significant differences between cohorts. Overall, Boswell and Nienhuys[11] found otitis media with effusion or acute otitis media in 58 per cent more Indigenous neonates (i.e. 0–8 weeks of age), compared with non-Indigenous neonates. Lehmann *et al.* found evidence of otitis media in 29 per cent more examinations, comparing Indigenous versus non-Indigenous children (0–2 years of age). These latter authors confirmed previous findings[12] that peak prevalence occurs in Indigenous populations earlier,[14,15] at 5–9 months, compared with 10–14 months in non-Indigenous subjects.

These studies provide important insight into the nature of otitis media in Indigenous populations. Persistent, severe otitis media appears to be a major feature in Indigenous populations throughout childhood, compared with non-Indigenous populations, in which otitis media is less severe and less persistent.

Cross-sectional studies

Cross-sectional studies undertaken since 1979 provide the most comprehensive analysis of the burden of otitis media in Indigenous populations (Table IV).

TABLE II
CHRONIC OTITIS MEDIA: TERMINOLOGY AND DEFINITIONS

Subtype	Synonym	Definition
Healed chronic otitis media		Thinning and/or local or generalised opacification of pars tensa without perforation or retraction
Inactive (mucosal) chronic otitis media	Tympanic membrane perforation	Permanent perforation of pars tensa but no middle-ear inflammation
Inactive (squamous) chronic otitis media		Retraction of pars flaccida or pars tensa (usually posterior-superior) which has potential to become active with retained debris
Active chronic otitis media	Chronic suppurative otitis media	Permanent defect of pars tensa with inflamed middle-ear mucosa which produces mucopus that may discharge
Active (squamous) chronic otitis media		Retraction of pars flaccida or pars tensa with retained squamous epithelial debris ('cholesteatoma')

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TABLE III
LONGITUDINAL STUDIES

Study	Overview	Location	Sample	Age	Results
McCafferty *et al.*[7]	9-yr study of middle-ear state, i.e.: – Perforation always or usually (pattern 1) – Perforation on most evaluations, occasionally intact (pattern 2) – Perforation in 1st 2 yr, normal thereafter (pattern 3) – Persistent closed ear disease, occasional perforation (pattern 4) – Always or almost always normal ears (pattern 5)	Qld	449 Indigenous	0–9 yr	Pattern 1 = 7.6% Pattern 2 = 6.5% Pattern 3 = 5.6% Pattern 4 = 43.3% Pattern 5 = 37%
Rebgetz *et al.*[8]	Incidence of perforation in infants followed fortnightly for 1st 6 mth of life, then monthly to 1 yr	NT	75 Indigenous	0–6 mth	Perforation in 2/3 children by 12 mth
Douglas[9]	Perforation in Indigenous children followed from 6–8 wk to 2 yr, with 2–4 mth examinations	NT	206 Indigenous	6–8 wks to 2 yr	≥1 perforation in 91/206 (44.2%) children
Boswell *et al.*[10]	TM assessment in Indigenous neonates from 2–5 wk to 29–32 wk	NT	17 Indigenous	2–5 wk to 29–32 wk	Most TMs normal at 1st examination (2–5 wk) Abnormal TM mobility (indicating otitis media) in all subjects by 3rd examination (13–16 wk)
Boswell & Nienhuys[11]	Otitis media in Indigenous & Non-Indigenous neonates from birth to 8 wk	NT	22 Indigenous (remote) 10 non-Indigenous (urban)	0–8 weeks	Prevalence at 15–56 days: – Indigenous grp: otitis media with effusion or acute otitis media in 76% – Non-Indigenous grp: otitis media with effusion in 18% (none with acute otitis media)
Boswell & Nienhuys[12]	Middle-ear state in 1st year of life, i.e.: – Persistent perforation (pattern 1) – Persistent otitis media with effusion or acute otitis media with occasional perforation (pattern 2) – Persistent otitis media with effusion with or without episodes of acute otitis media (pattern 3) – Persistent otitis media with effusion or acute otitis media with occasional normal ears (pattern 4) – Always or almost always normal ears (pattern 5)	NT	36 Indigenous (remote) 10 non-Indigenous (urban)	0–1 year	Indigenous grp: – Pattern 1 = 35% – Pattern 2 = 19% – Pattern 3 = 42% Non-Indigenous grp: – Pattern 4 = 10% – Pattern 5 = 90%
Boswell[13]	(Follow up from 8 wk longitudinal study of Indigenous infants); monthly examinations to 15 mth	NT	41 Indigenous	8 wk to 15 mth	By 3 mth: – Acute otitis media in 28% – Otitis media with effusion in 72% Perforation in 15/41 in 15 mth
Lehmann *et al.*[14,15]	280 Indigenous & non-Indigenous children from 0–2 yr; 3 clinical examinations per child	WA	100 Indigenous 180 non-Indigenous	0–2 yr	Indigenous grp: otitis media* in 55% of examinations; peak prevalence 72% at 5–9 mth examination Non-Indigenous grp: otitis media* in 26% of examinations; peak prevalence 40% at 10–14 mth examination
Dept of Health & Ageing[16]	2-yr study of 4 communities with 4 × 6-mthly examinations, 2007–2009	SA	262 Indigenous	1–19 yr	Prevalence of middle-ear conditions across 4 visits: – Chronic suppurative otitis media: 12.5%, 30%, 28.4%, 30.3% – Dry perforation: 31.3%, 14%, 15.7%, 14.6%

Mackenzie *et al.*[17]	2 cohorts of vaccinated & non-vaccinated Indigenous children; monthly examinations to 12 mth, then at 18 & 24 mth	Tiwi Islands, NT	99 vaccinated 103 non-vaccinated (Indigenous)	0–24 mth	By 6 mths, otitis media with effusion in 96% of vaccinated grp & 100% of non-vaccinated grp By 12 mths, documented episode of acute otitis media in 89% of vaccinated grp & 88% of non-vaccinated grp By 24 mth, chronic suppurative otitis media in 30% of vaccinated grp & 39% of non-vaccinated grp
Sanchez *et al.*[18]	4 pool & 4 non-pool communities visited twice annually 2009–2011 for clinical assessment of ear health & hearing	SA	813 Indigenous	5–18 yr[†]	Prevalence of middle-ear conditions across 6 visits: – Active chronic otitis media: 21.0%, 12.8%, 25.1%, 10.5%, 26.6%, 13.6% – Dry perforation: 21.6%, 25.9%, 16.4%, 24.6%, 17.7%, 21.5%

[*]Otitis media defined as eustachian tube dysfunction, otitis media with effusion, acute otitis media without perforation, acute otitis media with perforation, dry perforation, or perforation with purulent discharge.
[†]2.4% of subjects were <5 or >18 years. Yr = years; Qld = Queensland; mth = months; NS = not specified; wk = weeks; NT = Northern Territory; TM = tympanic membrane; grp = group; WA = Western Australia; Dept = department; SA = South Australia

The National Trachoma and Eye Health Program of 1976–1979 involved over 90 000 subjects. In the 0–9 year age group (n = 21 988 Indigenous children), 16.6 per cent of Indigenous children were diagnosed with otitis media (defined as dry tympanic perforation, wet or suppurative perforation, or glue ear (otitis media with effusion)), compared with 1.3 per cent of the non-Indigenous cohort.[4,28]

New data from the Australian Federal Government's 2012 Northern Territory Emergency Response Child Health Check Initiative[27] demonstrated no improvement in the prevalence of otitis media since the 1976–1979 National Trachoma and Eye Health Program.[4] The Child Health Check Initiative report stated that the prevalence of acute otitis media and chronic suppurative otitis media (excluding otitis media with effusion) was 19.2 per cent. This figure was higher than the combined prevalence of dry tympanic perforation, wet or suppurative perforation, and glue ear (otitis media with effusion) found by the National Trachoma and Eye Health program.

The literature provides specific data on the burden of otitis media subtypes. In relation to tympanic membrane perforation, Watson and Clapin,[22] Foreman *et al.*,[23] Kelly and Weeks,[21] and Foreman[19] found tympanic membrane perforation prevalence rates in Indigenous children as high as 37, 31, 50 and 36 per cent (of ears examined), respectively. By way of comparison, longitudinal studies have found prevalences of 'persistent perforation' and 'perforation always or usually' of 35 per cent[12] and 34 per cent[7], respectively, in Indigenous populations. Tympanic membrane perforation rates have also been shown to be significantly higher in Indigenous children from remote communities compared with those in urban settings. Sanchez *et al.*[26] found that the tympanic membrane perforation prevalence in 5–12 year old metropolitan Indigenous children (n = 3058 ears) was 1.17 per cent, compared with 32.0 per cent in the same age group of Indigenous children from the Anangu Pitjantjatjara Yankunytjatjara Lands (n = 1454 ears). These figures far exceed those reported in other populations (i.e. 0–4 per cent), including at-risk groups such as Indigenous North American communities.[29,30]

Acute otitis media is an extremely common disease. By 3 years of age, over 80–90 per cent of all children will have developed an episode of acute otitis media.[17,31] While there is a high incidence of acute otitis media in the general paediatric population, the prevalence (i.e. children in a cohort presenting with acute otitis media at the same point in time) is low. In a large international epidemiological study of children aged 3–8 years, the prevalence of acute otitis media was less than 2 per cent.[32]

In 2012, the Northern Territory Emergency Response Child Health Check Initiative found the prevalence of acute otitis media in Indigenous children to be 12.8 per cent in the 0–5 year age group.[27] In a 2005 study of 709 Indigenous children aged 6–30

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TABLE IV
CROSS-SECTIONAL STUDIES

Study	Overview	Location	Sample	Age	Results
Moran *et al.*[4]	Screening results from National Trachoma & Eye Health Program 1976–1979 (465 remote Indigenous communities; 60 273 Indigenous & 37 713 non-Indigenous subjects)	Australia	21 988 Indigenous 15 450 non-Indigenous	0–9 yr	Indigenous grp: otitis media* in 16.6% Non-Indigenous grp: otitis media* in 1.3%
Foreman[19]	Evidence of eye & ear disease in 3 Indigenous communities	NT	224 Indigenous	0–72 mth	Prevalence of otitis media in ears examined, by community: – Perforation with discharge: 33%, 30%, 21% – Dry perforation: 36%, 34%, 25% – TM inflammation: 26%, 34%, 34%
Roberts *et al.*[20]	Impact assessment project re health state of children up to 12 yr	NT	80 Indigenous	10 mth to 12.4 yr	Chronic suppurative otitis media signs in 19%
Kelly & Weeks[21]	Prevalence of perforations, hearing loss & 'glue ear' in 3 communities	WA	125 Indigenous	0–4 yr	At 0–4 yr, perforation prevalence† by community: 50% (remote), 32.5% (remote), 6% (urban)
Watson & Clapin[22]	Ear health & hearing in Kalgoorlie & Boulder area, WA	WA	642 Indigenous	3–15 yr	Perforation in 37% Otitis media with effusion in 5% Perforation by age: –5–8 yr, 43% – ≥9 yr, 34%
Foreman *et al.*[23]	Ear state in Indigenous children 3 mth to 5 years	NT	218 Indigenous	3 mths to 5 yr	Perforation in 31.2% Inflamed TM in 32.2% Normal TM mobility in 1.6%
Morris *et al.*[24]	Large-scale study of Indigenous children from 29 remote Indigenous communities	NT	709 Indigenous	6–30 mth	Otitis media in 91% Unilateral otitis media with effusion in 10% Bilateral otitis media with effusion in 31% Acute otitis media without perforation in 26% Acute otitis media with perforation in 7% Chronic suppurative otitis media in 15%
Williams *et al.*[25]	Indigenous middle school children 4–12 yr in metropolitan school in Perth, WA	WA	119 Indigenous	4–12 yr	Otitis media‡ in 40%
Sanchez *et al.*[26]	Ear health & hearing in remote & urban, Indigenous, school-age children, SA	SA	1454 ears, Indigenous (remote) 3058 ears, Indigenous (urban)	5–12 yr	In children 5–12 yr: – Active chronic otitis media in 0.49% (urban) & 17.6% (remote) – Dry perforation in 0.69% (urban) & 14.4% (remote)
Aust Inst Health & Welfare 2012[27]	Indigenous children in NT receiving ENT & Audiology services as part of NT Emergency Response Child Health Check Initiative	NT	5474 Indigenous	0–5 yr 6–11 yr ≥12 yr	Middle-ear condition in 66.7% Otitis media with effusion in 26.1% Chronic suppurative otitis media in 12.3% Acute otitis media in 6.9% (12.8% in 0–5 yr grp)

*Otitis media defined as dry tympanic membrane perforation, wet or supporting perforation, or glue ear (otitis media with effusion). †Approximate, from published graph. ‡Appearance suggestive of eustachian tube dysfunction, otitis media with effusion, or chronic suppurative otitis media, in one or both ears. Yr = years; grp = group; NT = Northern Territory; mth = months; TM = tympanic membrane; WA = Western Australia; SA = South Australia; Aust Inst = Australian Institute

months, the prevalence of acute otitis media was 33 per cent.[24] By way of comparison with these cross-sectional study results, Lehmann and colleagues' longitudinal study[14] found a lower prevalence of acute otitis media (with and without perforation) in Indigenous children, at 7.1 per cent in the first 2 years of life. Nevertheless, this figure was much higher than the prevalence in the non-Indigenous study cohort, at 2.8 per cent. Boswell's longitudinal study[13] found an acute otitis media prevalence of 28 per cent in 41 Indigenous infants at 2–15 months of age. These figures demonstrate that, although all childhood populations encounter high incidence rates of acute otitis media (80–90 per cent), there remains an unacceptably high prevalence of acute otitis media in Indigenous early childhood populations.

The World Health Organization (WHO) defines a prevalence of chronic suppurative otitis media (i.e. active chronic otitis media) of greater than 4 per cent as 'a massive public health problem'.[33] In the literature reviewed, the point prevalence of active chronic otitis media in Indigenous populations has been reported to range from 10.5 per cent[18] and 12.5 per cent[16] to as high as 15 per cent,[24] 19 per cent,[20] 30.3 per cent,[16] 15.9 per cent[18] and 17.6 per cent.[26] In addition, a 2009 study by Mackenzie *et al.*[17] found that, by 24 months of age, 30 per cent of vaccinated (pneumococcal vaccine) Indigenous children and 39 per cent of non-vaccinated Indigenous children had chronic suppurative otitis media. These figures, predominately shown to be above 15 per cent in a range of study populations, far exceed the WHO's accepted prevalence rates, and therefore demonstrate the alarming extent of active chronic otitis media in Indigenous children.

Survey-based population studies

A number of large-scale surveys have provided further information on the burden of otitis media in Indigenous children (Table V). Studies by Zubrick *et al.*[34] and the Australian Bureau of Statistics[36] involved respondents completing questionnaires about children in their care, regarding recurring ear infections and middle-ear infections, respectively. In Zubrick and colleagues' study,[34] carers reported that 18.1 per cent of Indigenous children aged 0–17 years had recurring ear infections (20.4 per cent of 0–3 year olds, 19.9 per cent of 4–11 year olds and 13.6 per cent of 12–17 year olds), while in the Australian Bureau of Statistics study[36] carers reported that 4 per cent of Indigenous children aged 0–14 years had middle-ear infections. These prevalence rates are clearly much lower than those reported in the studies reviewed above. This inconsistency in prevalence rates suggests many underlying middle-ear conditions are not detected in large-scale surveys which ask carers about the ear health of children in their care.

The remaining surveys compared the burden of otitis media in Indigenous and non-Indigenous children presenting to primary healthcare services. Rothstein

TABLE V
LARGE-SCALE SURVEY STUDIES

Study	Overview	Location	Sample	Age	Results
Zubrick *et al.*[34]	Indigenous children in metropolitan, rural & remote regions of WA, May 2000 to June 2002; survey completed by child's carer	WA	5289 Indigenous	0–17 yr	Recurring ear infections in 18.1%: – 0–3 yr, 20.4% – 4–11 yr, 19.9% – 4–11 yr, 18.1%
Gunasekera *et al.*[35]	Surveyed primary healthcare consultation records for children 0–18 yr*	Australia	2856 Indigenous 116 647 non-Indigenous	0–18 yr	Indigenous grp: – Otitis media (any kind) in 9.8% consultations – 9.9% of otitis media cases severe† Non-Indigenous grp: – Otitis media (any kind) in 9.8% consultations – 1.7% of otitis media cases severe†
Aust Bureau Statistics[36]	National health survey of 10 439 Indigenous Australians, 2004–05, including otitis media and ear disease questions	Australia	10 439 Indigenous	0–14 yr	Reported otitis media (0–14 yr): – 4% in Indigenous grp – 2 % in non-Indigenous grp
Rothstein *et al.*[37]	Retrospective review of Far North Qld Paediatric Outreach Service database to establish patterns of otitis media	Qld	1553 Indigenous 1367 non-Indigenous	0–18 yr	Chronic suppurative otitis media: – 24.6% in Indigenous grp – <5% in non-Indigenous grp

*Children must have presented to a primary service provider. †Non-severe otitis media comprised otitis media with effusion, and acute otitis media; severe otitis media comprised chronic suppurative otitis media, chronic otitis media, and perforated tympanic membrane. WA = Western Australia; yr = years; grp = group; Qld = Queensland

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et al.[37] assessed presentations of chronic suppurative otitis media, and found a prevalence of 24.6 per cent in Indigenous children compared with less than 5 per cent in non-Indigenous children. Gunasekera *et al.*[35] found the prevalence of severe otitis media presentations (defined as chronic suppurative otitis media, chronic otitis media or perforated tympanic membrane) to be 9.9 per cent in Indigenous children versus 1.7 per cent in non-Indigenous children. These figures show that serious otitis media not only imposes a greater health burden on Indigenous children, but also results in more frequent presentation of Indigenous children to medical services.

Results and analysis: risk factors

The risk of otitis media in paediatric populations depends upon many host-related and environmental factors. Risk factors specifically studied in Indigenous populations include age, bacterial colonisation, living conditions, swimming pool use, breastfeeding and passive smoking.

The general literature on otitis media includes studies of many other risk factors which have not been investigated in Indigenous populations. Host-related risk factors include premature birth,[38] allergies,[39] immunological deficiency,[40] genetic predisposition,[41] craniofacial abnormalities[42] and adenoids.[43] Examples of environmental factors increasing the risk of otitis media include childcare attendance,[44] seasonality,[45] socioeconomic status[46] and pacifier use.[47] As these risk factors have not been studied in Indigenous children, they are beyond the scope of this review.

Age

Otitis media is a disease of early childhood, with peak prevalence in the first year of life.[48] Earlier onset of otitis media has been shown to increase the risk of additional and more frequent episodes of otitis media.[31,49]

Studies of Indigenous populations have demonstrated that bacterial colonisation[50,51] and initial onset of otitis media occur earlier[11] in Indigenous groups compared with control cohorts. Additionally, while the prevalence of otitis media in control groups peaks in the first year of life and then sharply drops, the condition persists at higher rates in Indigenous populations. For example, Morris *et al.*[24] found that acute otitis media was as common in Indigenous children in the 18–30-month age range as in the first 6–18 months of life. This is inconsistent with worldwide prevalences of acute otitis media, which sharply drop following the first months of life (globally, 45 per cent of new acute otitis media episodes occur in the first year of life).[48]

Bacterial colonisation

Nasopharyngeal colonisation by otopathogens predicts early onset and frequency of otitis media in all children.[52] Bacterial carriage has been well researched in Indigenous groups (Table VI), with studies suggesting

TABLE VI
BACTERIAL COLONISATION STUDIES

Study	Overview	Location	Sample	Age	Results
Leach *et al.*[50]	Relationship between time of otitis media onset & bacterial colonisation in Indigenous infants	NT	41 Indigenous 12 Non-Indigenous	0–38 wk	Bacterial colonisation occurs earlier in Indigenous infants, & predicts earlier onset of otitis media
Smith-Vaughan *et al.*[53]	Real-time PCR used to identify respiratory pathogens (*S pneumoniae*, *H influenzae* & *M catarrhalis*) & total bacterial load, from nasal swabs from Indigenous children from remote communities, & non-Indigenous children attending urban childcare centres	NT	59 Indigenous 52 non-Indigenous	18–36 mth	Significantly greater *S pneumoniae* & *M catarrhalis* nasal load & proportion of total load in Indigenous grp
Watson *et al.*[51]	Cross-sectional study of upper respiratory tract bacterial carriage in Indigenous & non-Indigenous children in Kalgoorlie & Boulder area, WA	WA	100 Indigenous 180 non-Indigenous	0–2 yr	Indigenous child* carriage rates: – *S pneumoniae* & *M catarrhalis*, 51–67% – *H influenzae*, 42–62% Non-Indigenous child* carriage rates: – *S pneumoniae* & *M catarrhalis*, 26–37% – *H influenzae*, 11–18%
Moore *et al.*[54]	Longitudinal study of respiratory viruses & pathogenic otitis media bacteria in 1006 nasopharyngeal aspirates from asymptomatic Indigenous & non-Indigenous children	WA	436 Indigenous 570 non-Indigenous	0–2 yr	Viruses identified in: – 42% of Indigenous samples – 32% of non-Indigenous samples

*From 3 months onwards. NT = Northern Territory; wk = weeks; PCR = polymerase chain reaction; mth = months; grp = group; WA = Western Australia; yr = years

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Indigenous children are colonised by otopathogens more frequently, at younger ages and with higher bacterial loads.[50,51,53,54]

Living conditions

The risk of otitis media is increased by contact with other children (e.g. during childcare),[55] an overcrowded family home,[56,57] and interaction with individuals with acute otitis media.[47]

Several studies have investigated adverse living conditions as a risk factor for otitis media in Indigenous populations (Table VII). Overcrowding has been widely recognised as a major problem in remote Indigenous communities.[62] The incidence of otitis media[60] and tympanic membrane perforation[8] increases in Indigenous children with siblings, and in homes with two or more people per room.[60] Additionally, nasopharyngeal bacterial carriage of the major otopathogens has been shown to increase in Indigenous children with fewer rooms in the family home and an increased number of siblings (with a stronger effect in Indigenous than non-Indigenous groups).[59]

Studies focusing on housing improvement programmes in the Northern Territory have also shown specific correlation between otitis media and factors such as toilet infrastructure and bedding.[58] However, improvement in housing infrastructure does not necessarily address community-wide overcrowding and levels of otitis media.[61]

Swimming

Although bathing in contaminated water is a known risk factor for chronic suppurative otitis media,[63] some studies have that found clean swimming pool facilities play a role in clearing middle-ear discharge.[64] However, consensus on this issue has not been reached, with recent meta-analyses suggesting that swimming pools provide no benefit.[65,66] The international literature provides no evidence that swimming facilities provide protection against other subtypes of otitis media (e.g. acute otitis media), through improved hygiene.[67,68]

Studies of the effect of swimming pools in Australian Indigenous communities (Table VIII) initially appeared to contradict the international literature, since results from the National Trachoma and Eye Health Program revealed lower rates of chronic otitis media in remote communities located near swimming areas (i.e. swimming pools, water holes or the ocean).[28] Studies in 2003 and 2008 supported these findings in remote communities with new swimming facilities, finding reductions in tympanic membrane perforations in two communities, from 32 per cent to 13–18 per cent,[69] and an apparent reduction of 61 per cent in middle-ear presentations to medical clinics.[70]

However, these promising results have been contradicted by more recent literature reporting that swimming pools provide no benefit to middle-ear health

TABLE VII
LIVING CONDITION STUDIES

Study	Overview	Location	Sample	Age	Results
Rebgetz *et al.*[8]	Incidence of perforation in infants followed fortnightly for 1st 6 mth then monthly to 1 yr	NS	75 Indigenous	0–1 yr	Perforation more likely in infants with ≥5 siblings
Bailie *et al.*[58]	Survey of NT community households with ≥1 children aged <7 yr, 2003–2004	NT	618 children	<7 yr	Reported ear infection* in 28% Ear infections associated with poor toilet infrastructure, poor housing infrastructure, & poor hygiene of sleeping & bedding area
Jacoby *et al.*[59,60]	Longitudinal study of 280 children 0–2 yr; 3 clinical examinations per child	WA	100 Indigenous 180 non-Indigenous	0–3 yr	Carriage of *S pneumoniae*, *M catarrhalis* & *H Influenzae* increases with more siblings & adults Carriage declines with increasing number of rooms in house Otitis media† in: – 72% of children in house with ≥2 persons per room – 29% of children in house with ≤1 persons per room
Bailie *et al.*[61]	Prospective carer interviews for Indigenous children moving into new houses; average analysis 6 mth prior to & 10 mth after occupation	NT	418 Indigenous children	<7 yr	No reduction in reported ear infections after infrastructure improvement

*In preceding 2 weeks. †Otitis media defined as acute otitis media, otitis media with effusion, or tympanic membrane perforation with or without purulent discharge. Mth = months; yr = years; NS = not specified; NT = Northern Territory; WA = Western Australia

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TABLE VIII
SWIMMING POOL STUDIES

Study	Method	Location	Sample	Age	Results
Lehmann *et al.*[69]	Ear disease before & after introduction of swimming pools in 2 Indigenous communities	WA	162 Indigenous (remote)	<17 yr	Perforation decreased from 32% (both communities) to 13% & 18% (variously)
Silva *et al.*[70]	Retrospective analysis of medical clinic records, 1998–2005, in 2 communities with swimming facilities installed in 2000	WA	259 Indigenous (remote)	<17 yr	61% reduction in clinic attendance for middle-ear infections
Dept Health & Ageing[16]	Longitudinal study of 4 communities with 4 × 6-monthly examinations, 2007–2009; 3 of 4 communities received swimming pool facilities after baseline	SA	262 Indigenous (remote)	1–19 yr	Middle-ear conditions across 4 visits: – Chronic suppurative otitis media: 12.5%, 30%, 28.4%, 30.3% – Dry perforation: 31.3%, 14%, 15.7%, 14.6%
Stephen *et al.*[71]	89 Indigenous children (baseline ear discharge, 65%) randomised to swimming & non-swimming grps for 4 wk	NT	89 Indigenous (remote)	5–12 yr	After 4 weeks, ear discharge in: – 59% of swim grp – 67% of non-swim grp
Sanchez *et al.*[18]	Clinical assessment of ear health & hearing in 4 pool & 4 non-pool communities visited twice annually, 2009–2011	SA	813 Indigenous (remote)	5–18 yr*	No difference in ear disease severity in pool *vs* non-pool communities

*2.4% of subjects were aged <5 years or >18 years. WA = Western Australia; yr = years; SA = South Australia; grp = group; NT = Northern Territory

and hearing in populations of school-age children.[16,18,71] A 2009 study of 262 children in 4 Anangu Pitjantjatjara Yankunytjatjara Lands communities showed no significant change in rates of chronic suppurative otitis media and dry tympanic membrane perforation over a 3-year period.[16] These findings were confirmed by Sanchez *et al.*[18] in a large longitudinal study of 813 Indigenous children from Anangu Pitjantjatjara Yankunytjatjara Lands communities with and without well maintained, chlorinated saltwater swimming pools. Similar results have also been demonstrated in a recent randomised, controlled trial undertaken in the Northern Territory.[71] A further study of trachoma prevalence following the introduction of a swimming pool in a remote South Australian Indigenous community also found no benefit.[72]

Consequently, while promising results were reported in swimming pool studies leading up to 2009, three more recent, large scale studies have contradicted these findings. The recent literature appears to be more rigorous and comprehensive than the initial studies (i.e. Lehmann *et al.*[69] and Silva *et al.*[70]), and indicates that swimming pools are not protective, as the broader body of literature suggests.

Breastfeeding

International literature suggests that lack of exclusive breastfeeding in the first six months of life increases the risk of acute otitis media in infants.[47,73] Evidence on the risk of bottle-feeding as regards acute otitis media (or other types of otitis media) in Indigenous populations is limited. However, Jacoby and colleagues' longitudinal study[59,60] of 280 Indigenous children followed from birth to 24 months showed that lack of breastfeeding does not increase the risk of otitis media in the first 6 months of life.

Smoking

Passive smoking has consistently been shown to be a significant risk factor for otitis media in children.[47,74–76] This association has been demonstrated in Indigenous populations by Jacoby *et al.*[60] who found that environmental tobacco smoke was a significant predictor of otitis media in the first 24 months of life.

Discussion

In Australia, Indigenous status is a significant risk factor for all types of otitis media. The two largest studies reviewed (the 2012 Northern Territory Emergency Response Child Health Check Initiative[27] and the 1979 National Trachoma and Eye Health Program[4]) indicate that there has been no improvement in the prevalence of otitis media in Indigenous children in more than 30 years.

The literature reveals important insights into the nature of otitis media in Indigenous children. Specific research findings demonstrate that otitis media starts earlier, persists for longer and is more severe in Indigenous children than other paediatric

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populations.[7,12,14] The literature shows a significantly higher prevalence of tympanic membrane perforation in Indigenous populations than other cohorts.[19,21–23] Perforation rates are also much higher in Indigenous children from remote versus urban communities.[26] In studies investigating acute otitis media, it is clear that while almost all children, irrespective of ethnic background, suffer acute otitis media during childhood (with reported incidences of 80–90 per cent), there remains an unacceptably high prevalence of acute otitis media in Indigenous children. The reported prevalence of active chronic otitis media in Indigenous children ranges from 10.5 per cent[27] to 30.3 per cent.[16] These figures are far in excess of the 4 per cent prevalence rate which the WHO specifies as constituting a 'massive public health problem'. The results of Australian Indigenous household surveys assessing middle-ear health suggest that otitis media is both under-recognised and under-reported by carers of Indigenous children. Other large-scale surveys show that otitis media not only imposes a greater health burden on Indigenous children, but also results in more frequent presentation to medical services, compared with non-Indigenous children.

The reviewed studies on otitis media risk factors in Indigenous children show greater bacterial colonisation[50,51] and earlier initial onset of otitis media[11] in this population. Furthermore, otitis media persists at higher rates in Indigenous populations after the first year of life.[24] Indigenous children are also colonised by otopathogens more frequently, at younger ages and with higher bacterial loads.[50,51,53,54] Adverse living conditions, including poor infrastructure[58] and domestic overcrowding,[60] have been shown to increase the risk of otitis media in Indigenous children, as has exposure to tobacco smoke.[60] The impact of these risk factors appears to be accepted; however, recent research into the effect of swimming pools on otitis media in Indigenous children negates the results of earlier studies, which had suggested that swimming pool use was beneficial to ear health.

Despite awareness of the epidemiological burden of and risk factors for otitis media in Indigenous children, studies undertaken since 1985 demonstrate that otitis media remains a public health concern and a chronic disease which has significant and persistent effects on many individuals. The prevention and treatment of otitis media should therefore be a major policy consideration in efforts to close the gap between the health of Indigenous and non-Indigenous Australians.

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