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VIEWPOINT

Childhood pneumonia in New Zealand

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While deaths from pneumonia during childhood in New Zealand (NZ) are now infrequent, childhood pneumonia remains a significant cause of morbidity. In this viewpoint, we describe pneumonia epidemiology in NZ and identify modifiable risk factors. During recent decades, pneumonia hospitalisation rates decreased, attributable in part to inclusion of pneumococcal conjugate vaccine in NZ's immunisation schedule. Irrespective of these decreases, pneumonia hospitalisation rates are four times higher for Pacific and 60% higher for Māori compared with children of other ethnic groups. Consistent with other developed countries, hospitalisation rates for pneumonia with pleural empyema increased in NZ during the 2000s. Numerous factors contribute to childhood pneumonia acquisition, hospitalisation and morbidity in NZ include poor quality living environments, malnutrition during pregnancy and early childhood, incomplete and delayed vaccination during pregnancy and childhood and variable primary and secondary care management. To reduce childhood pneumonia disease burden, interventions should focus on addressing modifiable risk factors for pneumonia. These include using non-polluting forms of household heating; decreasing cigarette smoke exposure; reducing household acute respiratory infection transmission; improving dietary nutritional content and nutrition during pregnancy and early childhood; breastfeeding promotion; vaccination during pregnancy and childhood and improving the quality of and decreasing the variance in primary and secondary care management of pneumonia.

Globally, pneumonia remains a major cause of childhood death and disease, being the leading infectious disease cause of death in children <5 years old.[1] In New Zealand (NZ), pneumonia is an infrequent cause of childhood death,[2] but remains a frequent cause of hospital admission.

In this viewpoint, childhood pneumonia mortality and morbidity in NZ is reviewed, modifiable factors associated with pneumonia acquisition and hospitalisation in NZ described and challenges to best practise care for childhood pneumonia summarised. A literature search was conducted in Medline using the search strategies shown in Table 1. An agenda of research about early childhood acute respiratory infections (ARIs) is proposed to address current deficits in our knowledge and care (Table 2).

Childhood Pneumonia Mortality

In 2018, there were approximately ≈800 000 pneumonia deaths among children <5 years old.[3] Most occurred in developing countries.[1] Globally since 2000, pneumonia deaths in children <5 years old declined by >50%.[3,4]

In NZ, there were only ≈10 deaths/year from pneumonia in the 0- to 24-year age group from 2000 to 2012.[2] However, the NZ childhood pneumonia mortality rate is not decreasing.[2]

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Within NZ, pneumonia mortality rates and proportion of deaths from pneumonia are higher for Pacific children.[5] In the 1- to 14-year age group from 2008 to 2012, the pneumonia mortality rate (1.29/100 000) and percentage of all deaths (4.9%) was higher for Pacific children compared with all NZ children (0.43/100 000, 2.5%).[5]

Childhood Pneumonia Morbidity

The <5-year-old childhood pneumonia hospitalisation rate in developing countries in 2015 was 20.9/1000,[6] four times higher than the NZ average annual rate (2012–2016, 4.82/1000).[7] The <2-year-old annual childhood pneumonia hospitalisation rate in NZ (2006–2010) is twice that for the United States (2007–2009).[8,9]

Pneumonia hospitalisation rates in NZ in the 0- to 24-year age group decreased by ≈15% from 2000 to 2014 (2.81/1000 to 2.42/1000).[2] The decreases were specific to the 0- to 14-year age group and were larger for Pacific and Māori compared with European.[2] Despite this, pneumonia hospitalisation rates among children 0–14 years old from 2010 to 2014 for Pacific children (9.04/1000) were four times higher and for Māori children (3.82/1000) ≈60% higher than for other ethnic groups (2.36/1000).[5,10]

Globally, ≈29% of pneumonia deaths are vaccine preventable (pneumococcal conjugate vaccine (PCV) 19%, *Haemophilus influenza* type b (Hib) vaccine 10%). From 1990 to 2017, increased PCV and Hib vaccine coverage, alongside reductions in household air pollution, accounted for most of the decreases in preventable pneumonia deaths among children <5 years old.[11]

Decreased pneumonia hospitalisations, following introduction of PCV into NZ's Immunisation Schedule in 2008,[12] were

Table 1 Childhood pneumonia in New Zealand literature search

References for this review were identified through searches of Medline for articles published with the following search strategies for childhood pneumonia and then for childhood pneumonia in New Zealand
1 Pneumonia/
2 pneumonia.ti,ab,kw,kf
3 1 or 2
4 child, preschool/ or infant/
5 (child or children or infant? or preschool* or pre-school* or toddler? or paediatric* or paediatric*).ti,ab,kw,kf
6 4 or 5
Then this search with
7 New Zealand/ 40 154
8 new zealand*.ti,ab,kw,kf
9 (maori or maaori).mp
10 pasifika.mp
11 7 or 8 or 9 or 10
12 3 and 6 and 11
Articles identified from these searches and relevant references cited in those articles were reviewed. We only included article with full text available in English

Table 2 Potential research question agenda for early childhood acute respiratory infections

1 How can we improve prevention of acute respiratory infections?
   - Designing and testing interventions for tractable risk factors and novel interventions.
2 How can we prevent transmission of acute respiratory infections to young children?
3 What contribution does malnutrition make to childhood pneumonia in NZ?
4 Can interventions that seek to improve nutritional status during pregnancy and early childhood prevent childhood pneumonia in NZ?
5 What are the key barriers to access to quality care and how do we overcome them?
   - Understanding pathways of care from home to hospital.
   - Knowledge, attitude and practise for respiratory infections – both in the health system and in whānau.
6 How do we address inequities in respiratory infection prevention and treatment?
   - How can childhood vaccines be delivered on time to the children most at risk of vaccine preventable pneumonia?
7 How can we improve management of acute respiratory infections in NZ to avoid both undertreatment and overtreatment?
   - Designing and evaluating diagnostics to guide treatment and referral – identifying cases with higher risk of severe disease and/or complications.
8 What is the aetiology of acute respiratory infections in NZ?
   - Better understanding of aetiology in NZ using the best methods now available.
   - Understanding the dynamics of respiratory disease progression and complication.
9 What impact does early identification and intervention for acute illness have on downstream outcomes such as recurrence and bronchiectasis?
10 How does acute respiratory infection in NZ relate to acute respiratory infection elsewhere in the Pacific and beyond?
   - How can they inform one another and link to enhance intervention impact?

NZ, New Zealand.

reported from Counties-Manukau District Health Board (CMDHB) from 2001 to 2011 for children <2 years old.[12,13] In addition to the gradual decrease over this interval (age <2 years ≈25/1000 to 20/1000 (2001/2002–2007/2008), an additional decline in pneumonia hospitalisation rates occurred from 2009 to 2011 (to ≈12/1000 in 2010–2011). That this occurred for pneumonia but not bronchiolitis is consistent with prevention of pneumococcal infections.[13] Decreases were largest for Pacific children. Despite this, pneumonia hospitalisation rates remained several times higher for Pacific vs. European children.[13]

Over the same interval that childhood pneumonia hospitalisation rates have decreased, rates for pneumonia complicated by pleural empyema have increased (age 0–14 years: 1/100 000 to 10/100 000 (1998–2012)).[14] Increased incidence of pleural empyema was also reported from Canada (2008),[15] the United States (2010),[16] Denmark (2014)[17] and Germany (2019).[18]

Risk Factors for Childhood Pneumonia and Pneumonia Hospitalisation in NZ

Observational studies have identified multiple factors associated with pneumonia and pneumonia hospitalisation. Studies have used case definitions from those specific to pneumonia,[19] to others including a broader range of ARIs.[20–23]

A case–control study in Auckland which enrolled children <5 years old from 2002 to 2004 identified factors associated with community-acquired pneumonia (CAP) and pneumonia requiring hospital admission.[23] Factors independently associated with CAP were lower weight-for-height, spending less time outside,[24] previous chest infections and mould in the child's bedroom.[23] Factors independently associated with the risk of CAP hospitalisation were maternal history of pneumonia, crowded households, household cigarette smokers and mould in the child's bedroom.[23]

A case series of children <2 years old hospitalised from August to December 2007 at Kidz First Children's Hospital in CMDHB with a lower respiratory infection (LRI) documented the prevalent adverse living circumstances.[20] Admissions with an International Classification of Diseases (ICD-10) LRI primary discharge code were included. The 465 children enrolled had 580 LRI admissions during the 5-month study interval, 132 (26%) for pneumonia.[20] Household characteristics were described for 394 children. Caregivers described highly prevalent crowding (25% of children in households with ≥7 other people and 33% with ≥4 children); household cigarette smoking (65% of children exposed) and inadequate heating.[20] Twenty-seven percent of households had no heating and 17% used bottled gas.[20]

Within NZ's contemporary child cohort study, *Growing Up in New Zealand* (GUiNZ) (www.growingup.co.nz), three studies have investigated the epidemiology of ARIs resulting in early childhood hospital presentations.[21,23,25] The GUiNZ cohort was established by the recruitment of 6843 pregnant women living in the Auckland, Counties-Manukau and Waikato DHB regions.[26] The child cohort included the 6853 children born in 2009–2010 to these women. At birth, the cohort aligned closely with all NZ births from 2007 to 2010.[27]

The first of these studies investigated the relationship of internal living environments with ARI hospital admissions from 0 to 4 years of age.[21] Household crowding (22%) and dampness (20%) and, in the child's bedroom, heavy condensation (20%) or mould/mildew (13%) were prevalent, as were maternal smoking (14%) and household smoking (30%).[21] When all internal living environment and socio-demographic factors were considered, the risk of ARI hospitalisation was increased for children living in households where a gas heater was used in the child's bedroom and where it was the sole form of household heating.[21] The risk of ARI hospitalisation was decreased for children living in households that used electric heaters or wood burners for household heating.[21]

A subsequent study showed adverse effects of wood burners on the health of children in neighbouring households.[22] As density of wood or coal-smoke producing households/ha increased, the odds of <3-year-old children having a non–accident-related emergency department (ED) visit increased,[22] and of being prescribed respiratory medications increased.[23]

Priority Areas for Management of Childhood Pneumonia in NZ

Frameworks developed to prevent childhood pneumonia deaths in developing countries are applicable to preventing childhood pneumonia in NZ (Table 3).[1] Some interventions will decrease ARI morbidity, some are pneumonia specific. Ongoing evaluation of tractable risk factors and novel interventions is required.

Table 3 Potential strategies to reduce childhood pneumonia morbidity in New Zealand

Prevention	Diagnosis and management
• Improve the quality of indoor living environments. • Reduce risk of household person-to-person transmission of acute respiratory infections. • Improve dietary nutritional content during pregnancy and early childhood. • Maternal pregnancy immunisation. • Timely immunisation of children most at risk of vaccine preventable pneumonia.	• Improve clinical diagnosis and management of community acquired childhood pneumonia. • Establishing definable endpoints for secondary care management of childhood pneumonia.

Improve the quality of indoor living environments

Developing strategies to prevent within household transmission of ARIs to young children remain an important area of research focus.

At the 2018 NZ census, >280 000 children lived in damp housing and >230 000 in mouldy houses. Installing non-polluting, more effective heating into NZ homes where asthmatic children live, reduces LRI symptoms, school absence and health-care utilisation.[28]

Forms of household heating having the most adverse environmental effects (coal, wood, gas) are also associated with increased odds of early childhood ARI.[21,23] Replacing these with electrical heating potentially reduces global warming and childhood ARI morbidity, but only if the electricity is generated using environmentally safer means, such as hydro-, solar and wind generation.[29]

Smoke-free legislation reduces children's exposure to tobacco smoke,[30] and prevents ARI-related health-care visits.[31] Smoking remains prevalent among NZ women of child bearing age. GUiNZ data show that 20% of such women were cigarette smokers, with almost half ceasing smoking once becoming pregnant.[32] For smoking cessation to occur during pregnancy and be sustained during infancy requires focus on the households rather than just the mothers smoking habits.[32]

Crowding is a recognised NZ housing issue and contributor to ARI morbidity.[33] In GUiNZ, at age 2 years, 20% of children lived in households with ≥2 people/bedroom.[34] Strategies can be used in overcrowded households to reduce ARI transmission risk to young children. Bed sharing with a coughing adult is a risk factor for severe pneumonia among children in Africa.[35] Implementation of non-bed sharing or room sharing practises when household members have ARIs should be evaluated in NZ.

Improve the nutritional content of pregnancy and early childhood diets

Malnutrition underlies 50% of <5-year-old childhood pneumonia deaths globally.[36] Malnutrition includes macro- and micronutrient deficiency and excess.[37] These are interrelated, for example, micronutrient deficiency is more prevalent in children with either macronutrient deficiency or excess.[38]

In the developing world, risk of fatal or severe childhood pneumonia increases as weight-for-height decreases.[35,37] In NZ, risk of pneumonia hospitalisation increases as weight-for-height decreases.[19] In NZ, to be in the lowest risk group for pneumonia hospitalisation, weight-for-height *z*-score is ≥ +1 standard deviation, implying a nutrient poor diet relative to its energy content.[19]

NZ needs to acknowledge malnutrition is prevalent, that dietary nutritional content is poor and that these reflect and contribute to current child health inequities, and specifically to risk of childhood pneumonia hospitalisation.[38,39] Policy is required that addresses pregnancy and early childhood nutrition. Examples, successfully implemented in other countries, include free nutritious food and micronutrient supplements during pregnancy and childhood,[40–42] and micronutrient food fortification.[43]

Breastfeeding halves early childhood ARI hospitalisation risk.[44,45] In NZ, 16% of infants are exclusively breastfed for 6 months.[46] The odds of exclusively breastfeeding for ≥4 months are lower for Māori, Pacific or Asian vs. European infants.[46] Strategies specific to each ethnic group enabling longer breastfeeding duration are required. For example, determinants

of exclusive breastfeeding duration among Māori women include breastfeeding knowledge, return-to-work issues, motherhood experiences, Māori worldview connection, antenatal depression and vaccine hesitancy.[47]

Greater emphasis needs to be placed on understanding the contributions that malnutrition makes to childhood pneumonia in NZ and the evaluation of interventions that seek to improve nutritional status during pregnancy and early childhood.

Pregnancy vaccination and timely childhood vaccination for those most at risk of vaccine preventable pneumonia

It is estimated that of global deaths from LRIs in children <5 years old, 19% are attributable to low PCV and 9.6% to low Hib vaccine coverage.[11] Approximately 14% of severe pneumonia cases in developing countries requiring hospital admission are attributable to pathogens targeted by available vaccines (Hib, PCV and pertussis, tuberculosis and influenza vaccines).[48,49] Both viral and bacterial pneumonia hospitalisation rates decreased following PCV introduction, for example, in Australia,[50] consistent with more than one respiratory pathogen frequently being identified in children hospitalised with pneumonia.[51]

Childhood vaccination programmes now start during pregnancy. Pregnancy influenza vaccination halves the risk of influenza hospitalisation in <6-month-old infants.[52] Pregnancy pertussis vaccination prevents early infancy pertussis hospitalisation and intensive care unit admission.[53] Despite being fully funded, NZ coverage for pregnancy influenza and pertussis vaccine in NZ from 2013 to 2018 was ≈22% for influenza and 26% for pertussis vaccine.[54] Pregnant women of Māori or Pacific ethnicity are at decreased odds of being vaccinated.[54]

NZ has never achieved on-time childhood vaccination delivery to children most at risk of vaccine preventable pneumonia. Inequities in vaccination timeliness persist, for children in households in poorer neighbourhoods, and Māori children.[55] Children with delayed vaccinations are frequent health-care service users, but have repeated missed vaccination opportunities.[56] COVID-19–related disruptions to vaccination have been larger for Māori and Pacific children.[57,58]

NZ's approach to childhood vaccine delivery requires a refocus. Priority should be on-time delivery of pregnancy and childhood vaccinations for children most at risk of vaccine preventable diseases. Alternative vaccination systems are needed. Potential examples include pharmacy vaccination,[59] and vaccination programmes aligned with cultural structures such as those developed by Southseas Healthcare (https://www.southseas.org.nz) for COVID-19 vaccine delivery. Every pregnancy and childhood health-care interaction should be considered a potential vaccination event.

Improve community-acquired childhood pneumonia diagnosis and management

Consistent use of key clinical symptoms and signs to diagnose pneumonia and decide upon hospital referral has dramatically reduced early childhood pneumonia mortality rates globally.[60] In developing countries, this approach has reduced <5-year-old pneumonia mortality by one-third.[61]

In NZ, primary care factors associated with pneumonia ED presentation and hospitalisation were described in an Auckland study in the 2000s.[62] Among <5-year-old children, pneumonia ED presentation was more likely for children without a regular GP, if their GP worked ≤20 h/week or the practise lacked immunisation-recall.[62] Lower parental rating for continuity, communication and satisfaction increased the likelihood of pneumonia ED presentations.[6263] Parents of Pacific children reported greater dissatisfaction with primary care aspects including continuity, communication, interpersonal care and knowledge.[64] For Pacific children hospitalised with pneumonia, mistrust of primary care was the primary parental reason for hospital presentation.[65]

The importance of communication and primary care childhood pneumonia management in NZ was shown by a study investigating why children hospitalised with pneumonia had not received antibiotics in primary care.[66] While some illnesses progressed too rapidly, pneumonia was sometimes not diagnosed despite indicative symptoms and antibiotics sometimes were not prescribed despite diagnosed pneumonia.[66]

Development of a simplified approach in NZ to improve precision and accuracy of childhood pneumonia diagnosis and management is required. This approach could utilise device-based clinical decision support tools. For example, use of these to aid febrile infant management is associated with improved guideline adherence.[67]

Establishing endpoints for hospital childhood pneumonia management

Currently, the Starship Clinical Guidelines recommend follow-up for childhood pneumonia hospitalisations if cough for >6 weeks, and follow-up chest radiograph for complicated pneumonia or chronic/recurrent symptoms.[68]

Are these endpoints robust? When <2-year-old children, hospitalised with pneumonia or severe bronchiolitis, are followed, persisting respiratory abnormalities are evident. Follow-up of 237 <2-year-old children admitted to Kidz First Children's Hospital with pneumonia showed that 1-year post-admission chronic moist cough was present in 30%, moist cough and/or crackles in 32% and chest radiograph abnormalities in 62%.[69] Although current international guidelines do not recommend follow-up radiography for most childhood pneumonia,[70] a symptom- and sign-based algorithm may need development. The Koira4Rukahukahu: Lungs4Life programme which seeks to reduce inequity in respiratory health outcomes for children across the Northern region of NZ is a new initiative which has the potential to address this issue.[71]

Conclusion

Pneumonia is an infrequent cause of childhood death in NZ, but accounts for ≈2 times more deaths among Pacific children.

Irrespective of the decreases in pneumonia hospitalisation rates that have occurred in NZ in recent decades, pneumonia hospitalisation rates are ≈4 times higher for Pacific and 60% higher for Māori children compared with other ethnic groups.

NZ internal living environments are poor and contribute to the high ARI burden. Contemporary data highlight the contribution of poor air quality, secondary to the use of coal, wood or gas for household heating. Specific policy could address the contributions of overcrowding to pneumonia risk.

Malnutrition is an important risk factor for pneumonia in NZ. Policy which improves dietary quality and nutritional status during pregnancy and childhood is needed.

NZ has never achieved equitable access to vaccines which can prevent childhood pneumonia. Our national vaccine strategy needs focus on timely protection of children most at risk of vaccine preventable pneumonia.

Pneumonia is a disease that examines health-care systems and tests how well a country cares for its more vulnerable populations. From this perspective, NZ does not currently fare well. Deficits are evident in primary and secondary care of childhood pneumonia and result in children receiving suboptimal care for pneumonia.

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