**Strongyloides stercoralis:** Systematic Review of Barriers to Controlling Strongyloidiasis for Australian Indigenous Communities

Adrian Miller¹*, Michelle L. Smith¹, Jenni A. Judd², Rick Speare³,⁴

¹ Indigenous Research Unit, Griffith University, Brisbane, Australia, ² Faculty of Medicine, Health and Molecular Sciences, James Cook University, Townsville, Queensland, Australia, ³ Public Health and Tropical Medicine, James Cook University, Townsville, Queensland, Australia, ⁴ Tropical Health Solutions Pty Ltd, Townsville, Queensland, Australia

---

**Abstract**

**Background:** *Strongyloides stercoralis* infects human hosts mainly through skin contact with contaminated soil. The result is strongyloidiasis, a parasitic disease, with a unique cycle of auto-infection causing a variety of symptoms and signs, with possible fatality from hyper-infection. Australian Indigenous community members, often living in rural and remote settings, are exposed to and infected with *S. stercoralis*. The aim of this review is to determine barriers to control of strongyloidiasis. The purpose is to contribute to the development of initiatives for prevention, early detection and effective treatment of strongyloidiasis.

**Methodology/Principle Findings:** Systematic search reviewing research published 2012 and earlier was conducted. Research articles discussing aspects of strongyloidiasis, context of infection and overall health in Indigenous Australians were reviewed. Based on the PRISMA statement, the systematic search of health databases, Academic Search Premier, Informit, Medline, PubMed, AMED, CINAHL, Health Source Nursing and Academic was conducted. Key search terms included strongyloidiasis, Indigenous, Australia, health, and community. 340 articles were retrieved with 16 original research articles published between 1969 and 2006 meeting criteria. Review found barriers to control defined across three key themes, (1) health status, (2) socioeconomic status, and (3) health care literacy and procedures.

**Conclusions/Significance:** This study identifies five points of intervention: (1) develop reporting protocols between health care system and communities; (2) test all Indigenous Australian patients, immunocompromised patients and those exposed to areas with *S. stercoralis*; (3) health professionals require detailed information on strongyloidiasis and potential for exposure to Indigenous Australian people; (4) to establish testing and treatment initiatives within communities; and (5) to measure and report prevalence rates specific to communities and to act with initiatives based on these results. By defining barriers to control of strongyloidiasis in Australian Indigenous people, improved outcomes of prevention, treatment of strongyloidiasis and increased health overall are attainable.

---

**Introduction**

*Strongyloides stercoralis*, a nematode parasite, is well documented as a potentially fatal soil transmitted helminth, described as a unique and complex human parasite in Speare [1]. *S. stercoralis* is a cosmopolitan parasite, but is more prevalent in tropical regions of the world, including tropical Australia. Rural and remote regions of Australia, in particular, Queensland, Northern Territory, Western Australia, north of South Australia and northern areas of New South Wales, endemic rates [1-5]. Australia’s Indigenous communities have high prevalence of strongyloidiasis (disease resulting from *S. stercoralis*) as do immigrants from other endemic countries, travellers to these countries and military personnel who have spent time in endemic regions [6,7]. Soulsby, Hewagama and Brady [8] report four cases of strongyloidiasis in non-Indigenous people resulting from work-related exposure presenting at Alice Springs Hospital and by implication acquired indirectly from Indigenous populations. Those infected included a teacher at an Indigenous school, a child care worker, an ex-nurse and a paediatrician. Very high prevalence rates are reported for Australian Indigenous communities [3,4,6,7,9,10]. Johnston, Morris, Speare, et al. [7] describe strongyloidiasis as a clinically important condition in Australia. Kline, McCarthy, Pearson, et al. [11] discuss major neglected tropical diseases in Oceania and emphasize strongyloidiasis as an important infection despite the lack of data on overall prevalence rates and clinical impact.

Strongyloidiasis in a community is evidence that individual(s) in that community have been exposed to *S. stercoralis* from soil contaminated by human faeces [6]. Infected individuals pass first
Strongyloidiasis: Barriers to Control for Australian Indigenous People

Author Summary

*Strongyloides stercoralis*, a nematode parasite, has a well-documented history of infecting human hosts in tropical and subtropical regions mainly through skin contact with inhabited soil. The result is strongyloidiasis, a human parasitic disease, with a unique cycle of auto-infection contributing to a variety of symptoms, of which, hyperinfection causing fatality may occur. In Australia, Indigenous community members often located in rural and remote settings, are exposed to and infected with strongyloides. Previous researchers report strongyloidiasis as a recurrent health issue for Indigenous Australians. This is a systematic review to determine the barriers to control for this pernicious pathogen. Barriers to control can be defined across three key themes: (1) health status, (2) socioeconomic status, and (3) health care literacy and procedure. By conceptualizing these barriers and addressing steps to control as outlined in this study, there is potential for improvement in prevention and treatment outcomes of strongyloidiasis and subsequently, overall health for Australian Indigenous people. This study contributes to furthering prevention and treatment of strongyloidiasis, increasing exposure to the issue of strongyloidiasis in Australian Indigenous people. It is the intent of this paper to express the need to have continued research and further health policy directed specifically to eradicate strongyloidiasis in Australian Indigenous communities.

Stage larvae in the faeces; these develop on the soil to infective larvae which penetrate the skin of the next host. After a blood-lung migration, parasitic adult females (there is no parasitic male) molt and develop into adult female worms in tunnels in the small intestinal mucosa [12]. Eggs are then laid in the tunnels, hatch, and produce first stage larvae in the intestinal lumen. Most of these pass out in the feces. A small number, however, change to infective larvae in the gut. These autoinfective larvae penetrate the wall of the large intestine and re-enter the body. Hence, *S. stercoralis* is a very unusual nematode, producing infective larvae not only externally in the soil, but also internally [12].

The occurrence of the autoinfective larvae is the main reason strongyloidiasis is such a serious disease [12,13]. Infection is lifelong since adult worms are replaced by young worms and the infection does not end when the original crop of adults die. Worm numbers can rise incrementally to produce severe disease, known as the hyperinfection syndrome. Autoinfective larvae, migrating from the lumen of the large intestine, can carry enteric bacteria into the body, resulting in sepsis in any organ. Of patients with the hyperinfection syndrome, 50% present with a septic event (pneumonia, septicaemia, meningitis, peritonitis) usually caused by an enteric bacteria or polymicrobial suite of enteric bacterial [14]. Complicating this is that *S. stercoralis* has an immunosuppressive effect [15,16]. Hyperinfection occurs mainly, but not exclusively, in the people who are immunocompromised or immunodeficient with a high case fatality rate of hyperinfection, at least 60% [6,7,9,10,13,17,18].

Strongyloidiasis is usually symptomatic [14] but most signs and symptoms are non-specific. The exception is with larva currens, a rapidly moving urticarial linear rash that marks the passage of an autoinfective larvae through the skin [14,19]. This is pathognomonic of strongyloidiasis. The other non-specific signs and symptoms can include gastrointestinal (e.g., abdominal pain, nausea, diarrhoea, weight loss), respiratory (e.g., cough (productive and non-productive), haemoptysis, cutaneous (e.g., urticaria) and general malaise [7,10,14,20]. Hyperinfective strongyloidiasis, in addition to the spectrum of acute-infection symptoms, can also clinically present as paralytic ileus, pulmonary haemorrhage, pneumonia, meningitis, septicaemia or other bacterial infections [6,10,14,16,18,20–22].

Diagnostic testing includes serology and faecal examination. Once diagnosed, strongyloidiasis can be eradicated with specific anthelmintics, ivermectin being the drug of choice [6,7,12,17]. The recommended treatment for strongyloidiasis has changed with the development of more effective anthelmintic drugs. Thiabendazole was the first moderately effective anthelmintic introduced in the mid-1970s [23,24]. Albendazole, a benzimidazole like thiabendazole, was recommended as the treatment of choice for strongyloidiasis about the mid-1990s [25]. It was replaced by ivermectin as first line recommended anthelmintic in the early 2000s [10].

In Australia, ivermectin is not licensed for children <5 years or for use in pregnancy [26,27], although there is no evidence of harm in these groups [10]. Albendazole is used for >6 months and <10 kg to adults, not licensed for use during pregnancy [26–28]. Fatality from strongyloidiasis most often results from missed or late diagnosis, inadequate treatment and/or the use of immunosuppressant drug therapy in high risk groups [6,10,17]. Co-infection of strongyloidiasis with HTLV-1 is associated with more serious strongyloidiasis and potential resistance to treatment [10,15]. In addition, HTLV-1 carriers are more likely to develop T-cell leukaemia when infected with *S. stercoralis* [29–32].

There are questions about the limited information available about the prevalence, clinical picture, diagnosis and public health approaches to manage strongyloidiasis in rural and remote Indigenous communities in tropical regions of Australia [5,33]. Programs based on the treatment of stool positive individuals have also been associated with decreases in prevalence [7]. Researchers suggest that little published evidence of public health approaches to control strongyloidiasis exists [7,34] and there is a need to consider mass drug administration in Indigenous Australian communities with high prevalence of strongyloidiasis [10,11].

This systematic review attempts to answer the questions, what is the epidemiology of strongyloidiasis in Australian Indigenous people, and, what, if any, are the mentioned barriers to control? The aim of this review is to identify research focused on strongyloidiasis in this specific population and to collect and analyse available data specific to symptoms, diagnosis and treatment to determine barriers to control of strongyloidiasis. For the purpose of this paper, we respectively use the term Indigenous to represent Australian Aboriginal people and Torres Strait Islanders.

**Methods**

The outline and focus of this paper is framed on the concept of a translational research framework described by Thomson [35] within the Australian Indigenous HealthInfoNet. This systematic review was designed as a narrative review of the evidence as a way to summarise, explain and interpret evidence with thematic analysis [36].

This systematic review was based on the PRISMA statement, a tool to summarize accurate, reliable, quality evidence by way of transparent reporting (Checklist SI) [37,38]. A systematic search of health databases, Academic Search Premier, Informit, Medline, PubMed, AMED, CINAHL, Health Source Nursing and Academic was performed to search for all articles published 2012 and prior were included in the search. Articles were searched through the online academic search site, Google Scholar and
internet searches for websites containing information about strongyloidiasis. Key search terms included strongyloidiasis, Indigenous, Australia, health, and community with search strategy developed to access the broadest range of articles about strongyloidiasis are presented in Table 1. Reference lists of original articles, review articles, grey literature and websites were searched for potential articles to review for inclusion. Language restrictions were not imposed.

To meet inclusion criteria, original qualitative or quantitative research articles contained content addressing one or more of the following: symptoms, diagnosis, treatment, and barriers to control of strongyloidiasis. The location of the studies had to be Australia and include Australian Indigenous people. Exclusion criteria included, review articles and non-peer reviewed literature, original research articles with animal only studies, pharmaceutical therapy only studies and studies not differentiating *S. stercoralis* or strongyloidiasis from amongst other parasites or parasitic infections.

Based on these selection criteria, articles were reviewed in two stages. First stage, article titles and abstracts were screened to meet the requirements of strongyloidiasis as topic, Australian location and inclusion of Indigenous Australians. Second stage, articles were read as full text. Articles meeting final criteria were included in the study. Figure 1 represents the overall article search outcome.

From the original research questions, (1) what is the epidemiology of strongyloidiasis in Australian Indigenous people? and (2) what, if any, are the mentioned barriers to control? Description of studies was collected and a thematic analysis conducted [36]. Key data extracted were: purpose of study, study design, participant description, symptoms, diagnosis, treatment, barriers to control, and author’s conclusions. Articles were presented in a database with publisher details and summarized key data. The categories of symptoms, diagnosis, treatment and barriers to control were further assessed and coded using thematic analysis to determine recurring items in each. Symptoms were defined as manifestations of strongyloidiasis and included symptoms and signs due to strongyloidiasis and other existing concurrent conditions. Diagnosis was defined medical diagnoses including health status, tests performed and results.

Assessment of treatment of strongyloidiasis was based on the recommended therapy at the time of publication and defined as details on therapy provided and the comments on outcomes. Barriers to control were defined as a medical context, symptom and/or condition, or social determinant (derived from categories of symptoms, diagnosis, treatment and each author’s summary and conclusions) that inhibited overall health and/or recovery from strongyloidiasis of the individual(s). Once the barriers to control items were documented, they were then coded into barrier themes and health level. Detailing each barrier and the associating theme and level supports the translational knowledge concept by assisting to identify the relevant stakeholders [39].

## Results

Figure 1 provides an overview of the literature search results. 340 articles were retrieved with a total of 16 articles, published

| Table 1. Search strategy. |
|---------------------------|
| **Number** | **Keywords** |
| 1 | Strongyloidiasis or strongyloloides |
| 2 | Strongyloidiasis or strongyloloides and Australia |
| 3 | Strongyloidiasis or strongyloloides and Australia and Aboriginal or Indigenous |
| 4 | Strongyloïd* and Australia |
| 5 | Strongyloïd* and Indigenous |
| 6 | Strongyloïd* and Indig* |
| 7 | Strongyloïd* and Aborig* or Abor* |
| 8 | parasite infe* and Australia and Abor* |
| 9 | para* infe* and Australia and Abor* |
| 10 | para* infe* and Australia and Indig* |
| 11 | strongyloïd* and community |
| 12 | strongyloïd* and health |
| 13 | parasite and infe* and Australia and indig* |
| 14 | gastro* infe* and Australia and abor* |
| 15 | pedia* and Australia and abor* |
| 16 | infectious disease and Australia and abor* |
| 17 | 11 and 4 or 5 or 6 or 7 |
| 18 | 12 and 4 or 5 or 6 or 7 |
| 19 | 10 and 16 and 5 or 6 or 7 |
| 20 | 1 and 16 |
| 21 | 5 or 6 and 15 |
| 22 | 10 and 11 |
| 23 | 10 and 12 |

*asterisks added to root word to find all forms of word during library search.

doi:10.1371/journal.pntd.0003141.t001
between 1969 and 2006, eligible for the systematic review and are summarized in Table 2. Eleven eligible articles were from electronic library databases. Google Scholar revealed two additional eligible articles. The reference lists reviewed from published articles, grey literature and internet websites reporting on strongyloidiasis infections of Indigenous people of Australia.
Table 2. Summary of publications with original research on strongyloidiasis in Australian Indigenous people*.  

| Study | Purpose of Study | Study Location | participants* | Study Design |
|-------|-----------------|----------------|--------------|-------------|
| [4]   | To investigate the biomedical consequences of lifestyle changes among communities in order to help people understand changes and to cope with them. | Arnhem Land, Northern Territory | 403 Iac | Cross-sectional and longitudinal |
| [5]   | To report prevalence and distribution of infections with S. stercoralis in communities. | Remote communities, Queensland | 122 Ic | Retrospective |
| [21]  | To present the case of one adult with 10 episodes of meningitis due to strongyloidiasis. | Fitzroy Crossing, Western Australia | 1 Ia | Retrospective case |
| [22]  | To report a case study of a child that demonstrates how clinically unsuspected strongyloidiasis progresses to hyperinfection after increase in immunosuppression medication. | Adelaide Childrens Hospital | 1 Ic | Case |
| [16]  | To describe a case of hyperinfection. | Royal Darwin Hospital | 1 Ia | Case |
| [28]  | To explore the utility of antibody tests for confirming cure of strongyloidiasis in endemic population. | Arnhem land, Northern Territory | 508 Iac | Case control |
| [15]  | To determine whether complicated strongyloidiasis occurs in association with HTLV-1 infection. | Alice Springs Hospital | 18 Iac | Retrospective case |
| [41]  | To compare infection-related mortality rates and pathogens associated for Indigenous and non-Indigenous adults. | Alice Springs Hospital | 351 Ia; 162 Na | Retrospective comparison |
| [40]  | To compare bloodstream infection rates, pathogens and mortality among Indigenous and non-Indigenous adults. | Alice Springs Hospital | 614 Ia; 69 Na | Retrospective comparison |
| [42]  | To report biopsy findings using histological assessment and examination under dissecting microscope in intestinal mucosal biopsies from children. | Royal Alexandra Hospital for children | 30 Ic | Prospective comparison |
| [43]  | To indicate the extent or severity of diarrheal disease in children in communities. | Kimberley region, Northern Territory | 100 Ic | Prospective |
| [44]  | To show that the severity of diarrheal disease in children as a consequence of underlying small intestinal mucosal damage. | Royal Darwin Hospital, Northern Territory | 339 Ic; 36 Ic | Prospective comparison |
| [45]  | To describe clinical presentation, diagnosis and management of strongyloidiasis and to identify predisposing factors. | Townsville General Hospital | 9 Ic; 5 Ic | Retrospective |
| [46]  | To describe strongyloidiasis in children. | Darwin Hospital | 8 Ic | Case |
| [50]  | To describe clinical and laboratory features of strongyloidiasis. | Royal Darwin Hospital | 64 Ic; 4 Ic | Retrospective |
| [51]  | To present the case of an infant with meningitis and who subsequently developed complete small-intestinal obstruction. | Royal Alexandra Hospital for Children | 1 Ic | Case |

*a = Adult(s); c = child(ren), ac = adult(s) and child(ren), I = Indigenous; N = non-Indigenous;  
*For the purpose of this paper, we respectively use the term Indigenous to represent Australian Aboriginal people and Torres Strait Islanders.

doi:10.1371/journal.pntd.0003141.t002

revealed three eligible articles. Study design included case studies, retrospective and prospective comparison and non-comparison studies. Participant numbers ranged from 1 to 683. Indigenous Australian children were reported in 12/16 studies, of those 8/12 reported children only. Indigenous Australian adults were reported in 7/16 studies, of which 4/7 reported adult only. Thirteen studies were conducted in hospital and four in Indigenous communities. Eleven studies examined strongyloidiasis only with the remaining discussing the parasitic infection in the context of other infections [40,41] or while examining gastrointestinal issues [42–44]. The 16 papers included 2537 Indigenous participants and 272 non-Indigenous participants.

Eleven papers described manifestations of strongyloidiasis, including symptoms and signs due to strongyloidiasis as well as other concurrent conditions (Table 3). Studies noted strongyloidiasis symptoms such as diarrhoea, malnutrition and anorexia, abdominal pain, abdominal distension, anaemia, sepsicaemia, and fever. Other concurrent conditions including Type 2 Diabetes, Lupus, Chronic Liver Disease and Chronic Lung Disease, Alcoholism, Pneumonia, Bronchiitis, COPD, Acute Rheumatic Fever, Acute Renal Failure and/or general gastrointestinal, cardiac and respiratory problems were reported. Gunzburg, Gracey, Burke, et al. [43] reported only diarrheal symptoms as this was the scope of the study. Page, Dempsey, and McCarthy [28] and Prociv & Luke [5], although studying strongyloidiasis specifically, did not focus on symptomology. Four studies [4,15,40,42] did not discuss symptomology due to the aim of the study.

All sixteen studies provided data on diagnosis of strongyloidiasis determined by one or more tests (Table 4). Nine studies performed purposeful testing [4,5,21,28,40–43]. Five studies reported strongyloidiasis had been diagnosed when not suspected [15,22,42,45,46].

Articles were reviewed for the adequacy of treatment noting that recommended therapy has changed with time (Table 5). Eight
articles discussed the use of one or a combination of albendazole, thiabendazole and ivermectin. Three articles described a subgroup of patients receiving no therapy [28,42,45] and one article mentioned the use of pyrantel only for strongyloidiasis [5]. Pyrantel is ineffective against *S. stercoralis* [47]. In two articles, prednisolone or prednisone, a treatment which suppresses the immune system and as a result can increase the severity of strongyloidiasis, was administered to patients. Walker-Smith [42] discussed diagnoses of giardiasis and strongyloidiasis in children and provided no data on treatment. Einsiedel & Fernandes [15] detailed treatment therapies across four case studies, of which, only one case received correct strongyloidiasis treatment with ivermectin. Overall, adequate treatment was documented in publications in only 5.2% of cases.

Barriers to control of strongyloidiasis were summarized in terms of item, theme and health access level (Table 6). Three barriers themes emerged as items contributing to adequate management of strongyloidiasis: (1) health status; (2) socioeconomic status; (3) health care literacy and procedures. Theme 1, health status was defined patients’ health prior to and at the time of diagnosis of strongyloidiasis. This included concurrent infections (e.g., meningitis, pneumonia), concurrent chronic health conditions (e.g., Lupus, Chronic Liver Disease, Chronic Lung Disease, Acute Rheumatic Fever, HTLV-1, Hepatitis B, alcoholism, immunocompromised, immunosuppressed) and the phenomenon of compromised, immunosuppressed) and the phenomenon of compromised, immunosuppressed) and the phenomenon of compromise, chronic diarrhoea, septicaemia). Theme 2, socioeconomic status included living conditions, racial disparities, communication (e.g., interaction between community, patients, health professionals/institutions). Theme 3, health care literacy and procedures involved barriers that influence the diagnosis and treatment outcomes (e.g., delayed diagnosis, difficult to detect, failure to recognize symptoms, inadequate knowledge/treatment/treatment dose, serology test cut off, lack of communication, lack of screening, lack of follow-up, treatment non-compliance).

**Table 3. Manifestations of strongyloidiasis in Indigenous Australian patients**.

| Study | Participant details | Other condition | Symptoms/signs due to strongyloidiasis |
|-------|---------------------|-----------------|---------------------------------------|
| [4]   | 403: 10 yr and older | hepatitis B     | not listed                            |
| [5]   | 122: under 15 yr    | not listed      | not listed                            |
| [15]  | 513: 351 Ind; 162 Non | not listed      | not listed                            |
| [16]  | 1 female 18 yr      | Grade IV lupus glomerulonephritis (LG) with nephrotic syndrome, hypertension, febrile neutropenia, chronic gastric erosions, non-insulin dependent diabetes, poor cardiovascular and respiratory function | diarrhea, abdominal pain, anorexia |
| [21]  | 1 male adult        | recurring meningitis, alcoholism | *E. coli* septicaemia |
| [22]  | 1 female 12 yr      | Systemic lupus erythematosus, paralytic ileus, candidiasis, pneumonia | anemia, headache, back pain, fever, confusion, bacterial septicaemia |
| [28]  | 508: 13 yr and older | not listed      | not listed                            |
| [40]  | 614 Ind; 69 Non: under 15 yr | not listed      | not listed                            |
| [41]  | 18 Case series (C) (4 detailed): C1 female 39 yr; C2 male 29 yr; C3 male 32 yr; C4 male 41 yr | C1 chronic liver disease, alcoholism, shoulder pain, epigastric pain, cachectic; C2 peripheral neuropathy, chronic liver disease, alcoholism, HTLV-1, hepatitis B, pleuritic chest pain, productive cough, dyspnea; C3 chronic liver disease, alcoholism, bilateral crakale, wheeze, dyspnea, hypotensive; C4 Type 2 diabetes, chronic liver disease, alcoholism, hypotensive, crakale, wheeze, acute renal failure, intravascular coagulopathy | C1 abdominal pain, severe pruritis, diarrhea, faecel incontience; C2 abdominal pain, diarrhea; vomiting, septic shock; C3 abdominal pain, pruritis, diarrhea; C4 Fever, diarrhea, abdominal pain |
| [42]  | 3: 1–5 yr           | not listed      | partial villous atrophy of third degree |
| [43]  | 100: 0–5 yr         | not listed      | Diarrhea                              |
| [44]  | 338 Ind; 37 Non: children | hypokalemia; cryptosporidium | diarrhoea; malnutrition |
| [45]  | 9 Case series: C1 17mos; C2 42 yr; C3 49 yr; C4 11yr; C5 7mo; C6 17 yr; C7 30 yr; C8 1 yr; C9 26 yr | C1 croup; C2 alcoholism, COPD, trichuriasis; C3 no details; C4 nil; C5 bronchitis, cryptosporidiosis; C6 alcoholism, trichuriasis; C7 systemic lupus erythematous, alcoholism, giardiasis; C8 Giardiasis; C9 Alcoholism, trichuriasis, toxic epidermal necrolysis, allergies | C1 diarrhoea, rash; C2 abdominal pain; C3 no details; C4 diarrhoea; C5 diarrhoea; C6 abdominal pain, diarrhoea, nausea, vomiting/C7 pruritis, death; C8 diarrhoea, vomiting, rash; C9 diarrhoea, septicaemia, recurrent infections |
| [46]  | 3 Case series: C1 1 yr; C2 2 yr; C3 4 yr | C1 anaemia; C2 bronchitis, otitis media; C3 acute rheumatic fever | C1 diarrhoea, failure to thrive, hypokalemia, hypotremia, partial intestinal obstruction; C2 gastroentritis, hypokalemia, partial intestinal obstruction; C3 gastroentritis, intestinal obstruction |
| [50]  | 68: 64 Ind; 3 Non | Alcoholism, scabies (and “other” parasites), pulmonary disease, congestive cardiac failure | anaemia, diarrhea, gastrointestinal symptoms, malnutrition |
| [51]  | 1 female 6mo        | Pneumonia, *H. influenza*, meningitis | Intestinal obstruction with granulomata around larvae, vomiting, abdominal distension |

Total 2537 Ind; 272 Non

*Participant details: Indigenous Australian unless otherwise specified, Ind = Indigenous, Non = non Indigenous.
*For the purpose of this paper, we respectively use the term Indigenous to represent Australian Aboriginal people and Torres Strait Islanders.

doi:10.1371/journal.pntd.0003141.t003
Periods lead to this outcome. Adams, Page and Speare [6] and hyperinfection and fatality may be prevented the earlier strongyloidiasis is diagnosed as undetected strongyloidiasis over longer periods without symptoms. Specific cases of hyperinfection occurred in two of these studies [15,22]. Keulenaer [16] report specific cases of hyperinfection. Of these 4 specific cases fatality is particularly important for patients from populations in S. stercoralis endemic areas. Rural and remote Indigenous communities (more specifically northern Australia) and including immunocompromised patients are at particular risk for hyperinfection before administering immunosuppressive medication [22]. Protocol including clinical screening index, stool microscopy and culture, full blood count, immunoglobulin levels, and serological testing is recommended [22].

Majority of studies reported Indigenous Australian children with strongyloidiasis suggesting a diagnosis of strongyloidiasis should be considered when Indigenous children presenting with even non-suspecting general gastro-intestinal symptoms. Mucosal damage in Indigenous Australian children is possibly a result of damage produced by repeated episodes of gastroenteritis and/or parasitic infection, including strongyloidiasis [42]. Reduction in

### Discussion

This study reviewed original articles on strongyloidiasis in Indigenous Australian people. Articles were analyzed for symptoms, diagnosis and treatment and barriers to control of Strongyloidiasis. Overall outcomes are presented as symptomology, diagnosis and treatment protocols, community research and action and addressing barriers to control.

### Symptomology

The broad spectrum of symptoms, as represented in manifestations of strongyloidiasis in Table 3, illustrates the complex nature of Strongyloidiasis that is so often misdiagnosed. Many of these manifestations, such as diarrhoea, stomach pain, malnutrition, dehydration and vomiting are common to many illnesses and diseases. As described by researchers [6,15,16,20,43,45,46], strongyloidiasis can present many varying symptoms or be asymptomatic [43,46]. It is important to recognize that strongyloidiasis can potentially exist for years presenting often with non-specific symptoms and signs (e.g., diarrhoea) as well as at times with periods without symptoms.

**Hyperinfection.** Einsiedel and Fernandes [15], Byard, Bourne, Matthews et al. [22] and Potter, Stephens and De Keulenaer [16] report specific cases of hyperinfection. Of these 4 specific cases fatality occurred in two of these studies [15,22]. Results support previous research indicating that cases of hyperinfection and fatality may be prevented the earlier strongyloidiasis is diagnosed as undetected strongyloidiasis over longer periods lead to this outcome. Adams, Page and Speare [6] and Speare and Durrheim [12] report attention must be paid to those who are immunocompromised and, in all cases, steroid medication should not be administered until a diagnosis of strongyloidiasis is confirmed or ruled out. Early diagnosis increases probability of recovery. The possibility of hyperinfection or disseminated strongyloidiasis in immunocompromised patients, particularly in endemic areas, needs consideration [48]. The current protocol in place is to give the first dose of ivermectin when strongyloidiasis is suspected (i.e., when blood or faeces is taken) and then to give follow-up doses when test are positive. For those from a high prevalence area taking an immunosuppressive treatment (and until finished) are to continue with follow up strongyloidiasis treatment every three months [26,27,49].

### Diagnosis and treatment protocols

Delayed diagnosis, inadequate knowledge/treatment/treatment dose, lack of communication and lack of follow up by health professionals were described as particular issues in the majority of studies [3,15,16,22,29,40,44,45,50,51]. Infection should be suspected in every person with unexplained abdominal pain, diarrhoea, cutaneous symptoms or eosinophilia and the laboratory alerted of a provisional diagnosis [45]. Testing for strongyloidiasis is particularly important for patients from populations in S. stercoralis endemic areas. Rural and remote Indigenous communities (more specifically northern Australia) and including immunocompromised patients are at particular risk for hyperinfection before administering immunosuppressive medication [22]. Protocol including clinical screening index, stool microscopy and culture, full blood count, immunoglobulin levels, and serological testing is recommended [22].

### Table 4. Tests performed to diagnosis patients’ condition not necessarily specifically related to strongyloidiasis diagnosis.

| Study          | Tests Performed                                      |
|----------------|------------------------------------------------------|
| [4]            | Blood; Stool                                         |
| [5]            | Stool                                                |
| [15]           | Abdominal scan; Chest x-ray; Serology; Stool         |
| [16]           | Abdominal scan; Brain scan; Chest x-ray; Blood; Stool|
| [21]           | Cerebral spinal fluid protein level/neutrophil count; CT scan; Blood; Stool |
| [22]           | Cytology; Gastric aspirate; Lung biopsy              |
| [28]           | Serology                                             |
| [40]           | Blood                                                |
| [41]           | Serology                                             |
| [42]           | Intestinal biopsy                                    |
| [43]           | Stool                                                |
| [44]           | Blood; Stool                                         |
| [45]           | Stool                                                |
| [46]           | Abdominal x-ray; Chest x-ray; Gastric aspirate       |
| [50]           | Stool                                                |
| [51]           | Abdominal x-ray; Abdominal x-ray/barium enema; Gastric aspirate; Laparotomy; Lumbar puncture; Stool |

doi:10.1371/journal.pntd.0003141.t004

Einsiedel & Fernandes [15], Byard, Bourne, Matthews et al., [22] and Potter, Stephens and De Keulenaer [16] report specific cases of hyperinfection of these 4 specific cases fatality occurred in two of these studies [15,22]. Results support previous research indicating that cases of hyperinfection and fatality may be prevented the earlier strongyloidiasis is diagnosed as undetected strongyloidiasis over longer periods lead to this outcome. Adams, Page and Speare [6] and Speare and Durrheim [12] report attention must be paid to those who are immunocompromised and, in all cases, steroid medication should not be administered until a diagnosis of strongyloidiasis is confirmed or ruled out. Early diagnosis increases probability of recovery. The possibility of hyperinfection or disseminated strongyloidiasis in immunocompromised patients, particularly in endemic areas, needs consideration [48]. The current protocol in place is to give the first dose of ivermectin when strongyloidiasis is suspected (i.e., when blood or faeces is taken) and then to give follow-up doses when test are positive. For those from a high prevalence area taking an immunosuppressive treatment (and until finished) are to continue with follow up strongyloidiasis treatment every three months [26,27,49].

### Diagnosis and treatment protocols

Delayed diagnosis, inadequate knowledge/treatment/treatment dose, lack of communication and lack of follow up by health professionals were described as particular issues in the majority of studies [3,15,16,22,29,40,44,45,50,51]. Infection should be suspected in every person with unexplained abdominal pain, diarrhoea, cutaneous symptoms or eosinophilia and the laboratory alerted of a provisional diagnosis [45]. Testing for strongyloidiasis is particularly important for patients from populations in S. stercoralis endemic areas. Rural and remote Indigenous communities (more specifically northern Australia) and including immunocompromised patients are at particular risk for hyperinfection before administering immunosuppressive medication [22]. Protocol including clinical screening index, stool microscopy and culture, full blood count, immunoglobulin levels, and serological testing is recommended [22].

Majority of studies reported Indigenous Australian children with strongyloidiasis suggesting a diagnosis of strongyloidiasis should be considered when Indigenous children presenting with even non-suspecting general gastro-intestinal symptoms. Mucosal damage in Indigenous Australian children is possibly a result of damage produced by repeated episodes of gastroenteritis and/or parasitic infection, including strongyloidiasis [42]. Reduction in
the frequency of gastroenteritis and parasitic infection in Indigenous children should greatly reduce incidence of small intestinal mucosal damage [42]. Working to eradicate or reduce strongyloidiasis infection in children with early detection and immediate treatment could decrease strongyloidiasis and mucosal damage. Given the challenges of diagnosing infection, standardizing treatment in communities for an extended period could potentially decrease infections rates [5].

Lack of follow-up. There was a repeated lack of follow-up within and across cases of strongyloidiasis [15,45,50]. It is quite possible that patients treated for strongyloidiasis may continue to carry the infection as has been presented in cases with people suffering from strongyloidiasis infection for years after initial exposure [16,21]. This is problematic for a number of reasons. There is increased health risk to the patient as a result of continued infection including hyperinfection and fatality. The lack of awareness of continued infection in patient leads to increased risk for infection in the patients’ community and decreases awareness by health professionals and community for need to eradicate the infection within community and finally. This leads to inadequate reporting of strongyloidiasis in communities and under-representation of strongyloidiasis prevalence rates. Diagnosis and treatment of strongyloidiasis is challenging and requires specific knowledge. This knowledge must be acquired and maintained by health professionals in Australia and in particular, when assisting Indigenous Australian community members [6]. Assistance begins not only at the point of care in the hospital but also at the community level.

Table 5. Assessment of whether cases reported in papers were adequately treated according to the recommended anthelmintic for that time.

| Study | Anthelmintic used | Comment | Total | Evidence* | % |
|-------|------------------|---------|-------|-----------|---|
| [4]   | No comment on treatment | Total 411 (positive: 60% serology; 41% faeces) | 246   | 0         | 0 |
| [5]   | Pyrantel used as a routine de-wormer in Queensland Aboriginal health program – does not treat strongyloidiasis; thiabendazole given for strongyloidiasis (sometimes) but usually for 2 days not 3; so arguably none received adequate treatment | Multiple cases in children (<16yr) – 1971–1991: thiabendazole used, but probably not for most cases; comment made that children often refused drug due to unpleasant side effects | 632   | 0         | 0 |
| [15]  | Albendazole = 1 (single dose); Ivermectin = 3; No treatment = 14 | In 18 patients treatment was inadequate since 14 no treatment; 1 single dose albendazole; 3 single dose of ivermectin. (15/18 patients died) | 18    | 0         | 0 |
| [16]  | Albendazole and ivermectin (sequence) | Treatment successful | 1     | 1         | 100 |
| [21]  | No comment on therapy | 1 adult male | 1     | 0         | 0 |
| [22]  | No comment | Indigenous female child with hyperinfection | 1     | 0         | 0 |
| [28]  | Albendazole single = 10 (inadequate); Albendazole multiple = 10 (adequate); Ivermectin single = 19 (inadequate); Ivermectin multiple = 42 (adequate) | Was a critical paper in that demonstrated albendazole was less effective than ivermectin; hence, both albendazole and ivermectin considered adequate | 79    | 52        | 66 |
| [40]  | No comment | Study on blood stream infection | 73    | 0         | 0 |
| [41]  | No comment | Study on deaths in hospitalized patients | 2     | 0         | 0 |
| [42]  | None described | Not stated how many children had S. stercoralis | | | |
| [43]  | No comment on treatment | 12 children with S. stercoralis in faeces | 12    | 0         | 0 |
| [44]  | No comment | Study on diarrhoea in children admitted to Royal Darwin Hospital | 23    | 0         | 0 |
| [45]  | Thiabendazole | Of 6 adults, 4 adequately treated; Of 3 children, 2 adequately treated | 9     | 6         | 67 |
| [46]  | Thiabendazole | Case 1: 1 course of unstated length; eosinophilia on discharge; Case 2: No details; eosinophilia on discharge; Case 3: No details | 3     | 0         | 0 |
| [50]  | Thiabendazole | Details for Indigenous patients not given; comment made that 57% of all (not just Indigenous) patients received adequate treatment | 64    | 57 (54–61) | |
| [51]  | Thiabendazole multiple doses and courses | No larvae found at end and eosinophil count normal | 1     | 1         | 100 |
| Total |                          |                                  | 1165  | 60        | 5.2 |

*Evidence of adequate treatment.

doi:10.1371/journal.pntd.0003141.t005

Community research and action
Parasitic diseases have significant health risk and morbidity for Australian Indigenous people [11,20]. Rural and remote communities are the most affected [3,18]; mainly in children; and those
Table 6. Barriers to control of strongyloidiasis.

| Item described in one or more studies | Barrier Theme | Level* | [4] | [5] | [15] | [16] | [21] | [22] | [28] | [40] | [41] | [42] | [43] | [44] | [45] | [46] | [50] | [51] |
|---------------------------------------|--------------|--------|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Antibiotic prior treatment            | (1)(3)       | (1)(2)(3)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Chronic Diarrhoea                    | (1)(3)       | (1)    |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Concurrent Chronic infections        | (1)(2)(3)    | (1)(2)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Concurrent Health Conditions/Disease | (1)(3)       | (1)(2)(3) | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      |      |
| HTLV-1                               | (1)(2)       | (1)(2)(3)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Immunocompromised                    | (1)(3)       | (1)(3)  |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Immunosuppression                    | (1)(3)       | (1)(3)  | Y   | Y   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Sepsis                               | (1)(3)       | (1)(3)  | Y   | Y   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Malignancy                           | (1)          | (1)    |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Malnutrition                         | (1)(2)       | (1)(2)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Hypokalemia                          | (1)          | (1)(3)  |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Re-infection                         | (1)(2)(3)    | (1)(2)(3)(4) | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Asymptomatic                         | (1)(3)       | (1)    |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Delayed Diagnosis                    | (2)(3)       | (3)(4)  | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Difficult to detect                  | (1)(2)(3)    | (3)(4)  |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Failure to Recognize Symptoms        | (3)          | (3)(4)  | Y   | Y   |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Inadequate Knowledge                 | (3)          | (3)(4)  | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Inadequate Treatment                 | (3)          | (3)(4)  | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Inadequate treatment dose            | (3)          | (3)(4)  | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Serology test cut off                | (3)          | (3)(4)  | Y   | Y   |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Lack of Communication                | (2)(3)       | (2)(3)(4) | Y   | Y   |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Lack of screening                    | (3)          | (2)(3)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Lack of inadequate Follow-up         | (2)(3)       | (1)(2)(3)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Treatment Non-compliance             | (1)(2)(3)    | (1)(2)(3)(4) | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Racial Disparities                   | (2)(3)       | (1)(2)(3)(4) |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Lower SES                            | (1)(2)(3)    | (1)(2)(4) | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |
| Living conditions                    | (1)(2)       | (1)(2)(4) | Y   | Y   | Y    |      |      |      |      |      |      |      |      |      |      |      |      | Y    |

Y = at least one incident of symptom or condition or determinant reported in one or more patients.

*(1) Prior/current health status; (2) Overall SES status; (3) Health care knowledge and procedures.

*1) Individual; (2) Public/Community; (3) Organization; (4) Healthcare system.
immunocompromised with a number of cases of fatality reported [15,22,40,41]. Studies in 2002 and 2005 report there are limited published examples of community interventions in Australia to control strongyloidiasis [7,52]. Johnston, Morris, Speare, et al. [7] found no evidence of studies examining roles of environmental interventions, and expressed the need to do so. The need for initiatives for housing and sanitation are imperative [15]. Issues of environmental health must be addressed concurrently with health service initiatives to develop long term and sustainable improvements in control of infectious parasitic and non-parasitic diseases in rural and remote Indigenous communities in Australia [10,11,20]. There may be increased risks associated with a casual approach to management and may be significantly higher for Indigenous Australian people living in HTLV-1 endemic Central Australia [10,40]. Einsiedel and Woodman [40] further state the risk of strongyloidiasis in Indigenous communities and HTLV-1 infection may further predispose people to complicated strongyloidiasis.

Addressing barriers to control
Steps to address the barriers to control should include: (1) development of S. stercoralis and strongyloidiasis reporting protocols across health care system and communities (e.g., consistent case study reporting methods, documentation of current infection sites) [6,40]; (2) testing all Indigenous Australian patients, immunocompromised patients and those exposed to or living in areas of strongyloidiasis (e.g., rural/remote communities) present- ing with gastrointestinal or respiratory symptoms (take particular notice of individuals from these groups with repeated visits to hospital) [7,15,16,48]; (3) requirement of health professionals to have detailed information and education regarding strongyloidiasis and the potential for exposure in Indigenous Australian communities (e.g., understanding of the expanse of symptoms and potential for asymptomology, difficulty in diagnosis, need for variety of tests and retesting, accurate follow-up to confirm patient cleared of infection) [5,15,21,42]; (4) establishment of testing and treatment initiatives in the community (e.g., over extended periods and periodically and treat symptomatic and asymptomatic strongyloidiasis carriers) [6,10,12,15,45]; (5) measure and report prevalence specific to Indigenous Australian communities and to act with initiatives based on these results [6,12,40].

References
1. Speare R. (1989) Identification of species of strongyloides. In: Grove D, editor. Strongyloidiasis: a major roundworm infection of man. London: Taylor and Francis Ltd. pp.11–83.
2. Kakarovicz R, Robino-Browne RM, Austen NM, Bresster DR. (2002) Enteric pathogens, intestinal permeability and nitric oxide production in acute gastroenteritis. Pediatr Infect Dis J 21: 730–739.
3. Aland K, Prociv P, Currie B, Jones H. (1996) Worm project at Galiwin’ku. Working Together 6: 10.
4. Flannery G, White N. (1993) Immunological parameters in northeast Arnhem Land aborigines: Consequences of changing settlement patterns and lifestyles. Urban Ecology and Health in the Third World.Cambridge University Press, Cambridge: 202–220.
5. Prociv P, Luke R. (1993) Observations on strongyloidiasis in Queensland aboriginal communities. Med J Aust 158: 160–163.
6. Adams M, Page W, Speare R. (2003) Strongyloidiasis: an issue in aboriginal communities. Rural and remote health 3: 152.
7. Johnston FH, Morris PS, Speare R, McCarthy J, Currie B, et al. (2005) Strongyloidiasis: a review of the evidence for Australian practitioners. Aust J Rural Health 13: 247–254.
8. Goodyear EM, Hegawa S, Brady S. (2012) Case series of four patients with strongyloides after occupational exposure. Med J Aust 196: 444.
9. Speare R, White S. (2001) Strongyloidiasis-a social determinant of health. Outback Flyer 50: 4–5.
10. Sheld JM, Page W. (2008) Effective diagnostic tests and anthelmintic treatment for Strongyloides stercoralis make community control feasible. Papua New Guinea Medical Journal 51: 103–119.
11. Kline K, McCarthy JS, Pearson M, Loukas A, Hotez PJ. (2013) Neglected tropical diseases of Oceania: review of their prevalence, distribution, and opportunities for control. Plos neglected tropical diseases 7: e1755.
12. Speare R, Durheim D. (2004) Strongyloides serology-useful for diagnosis and management of strongyloidiasis in rural indigenous populations, but important gaps in knowledge remain. Rural Remote Health 4: 264.
13. Stowden EGBD, Schaffner WMD, Stone WHMD. (1978) Overwhelming strongyloidiasis: An unappreciated opportunistic infection. Medicine 57: 527–544.
14. Grove DI. (1989) Clinical manifestations. In: Grove DI, editor. Strongyloidiasis: a major roundworm infection of man. London: Taylor and Francis Ltd. pp.155–173.
15. Einsiedel L, Fernandes L. (2008) Strongyloides stercoralis: A cause of morbidity and mortality for indigenous people in Central Australia. Intern Med J 38: 697–703.
16. Potter A, Stephens D, De Keulenaer B. (2003) Strongyloides hyper-infection: A case for awareness. Aust Trop Med Parasitol 97: 353–409.
17. Page W, Sheld J. (2005) Strongyloidiasis-an update on best practice. Journal for Community Nurses 10: 15.
18. Hansman D. (1995) Public health information. A rapidly progressive fatal illness associated with strongyloidiasis. Communicable Disease Report. Adelaide: Women’s and Children’s Hospital.
19. Gill GV, Welch E, Bailey JW, Bell DR, Beeching NJ. (2004) Chronic strongyloides stercoralis infection in former British Far East prisoners of war. QJM 97: 769–795.
20. Holt DC, McCarthy JS, Carapetis JR. (2010) Parasitic diseases of remote indigenous communities in Australia. Int J Parasitol 40: 1119–1126.
21. Mak D. (1993) Recurrent bacterial meningitis associated with strongyloides hyperinfection. Med J Aust 159: 354–354.
22. Byard R, Bourne A, Matthews N, Hennig P, Robertson D, et al. (1993) Pulmonary strongyloidiasis in a child diagnosed on open lung biopsy. Surgical Pathology 5: 53–62.

Limitations. Studies analyzed for this review had an overall lack of detailed information on prevalence rates, diagnosis and treatment outcomes. Repeated lack of follow-up made it difficult to determine outcomes for those reported infected with strongyloides in studies. In addition, a number of articles [5,15,50] conducted retrospective studies of hospital records with reported missing data, missing records and inconsistent reports. Case studies did not have a consistent reporting protocol to facilitate analysis within and across cases. It was unfortunate that a number of studies had to be excluded from this review as they had gathered overall parasite infection data in Indigenous Australian communities but had not further represented data by parasite (e.g., hookworm, S. stercoralis). This data would have been potentially valuable for increasing both the evidence and support to further define strongyloidiasis a problem for Indigenous Australians.

Conclusions. If barriers are managed, current research and the health care system can report accurately and provide the data required to support initiatives to eradicate strongyloidiasis in Indigenous Australian communities. Addressing these barriers would support conclusions of researchers that health education and public health interventions and guidelines for mass treatment with follow-up for effective treatment are essential [6,10,11]. As Einsiedel and Woodman [40] state sustainable improvements require a coordinated approach based on dialogue, cultural understanding and development of locally specific solutions by Indigenous people themselves. This comprehensive focus with Indigenous Australian people and their communities on strongyloidiasis is imperative. Community initiatives to eradicate endemic parasite infection such as hookworm have had success and there is potential to do the same with S. stercoralis [10].

Supporting Information

Checklist SI PRISMA 2009 checklist [30] utilized in systematic review with referring page numbers, tables and figures represented in manuscript.
(DOC)

Author Contributions

Analized the data: AM MLS JAJ RS. Wrote the paper: AM MLS JAJ RS.
27. NPS Medicinewise (2010) Albendazole (zental) listing extended to treat.

28. Page WA, Dempsey K, McCarthy JS. (2006) Utility of serological follow-up of chronic strongyloidiasis after anthelminthic chemotherapy. Trans R Soc Trop Med Hyg 100: 1056–1062.

29. Stewart DM, Ramanathan R, Mahanty S, Fedorko DP, Janik JE, et al. (2011) Disseminated Strongyloides stercoralis infection in HTLV-1-associated adult T-cell leukemia/lymphoma. Acta Haeomatol 126: 63–67.

30. Plumelle Y, Guinin C, Edouard A, Bacher BJ, Thomas L, et al. (1997) Effect of strongyloides stercoralis infection and eosinophilia on age at onset and prognosis of adult T-cell leukemia. Am J Clin Pathol 107: 81–87.

31. Satoh M, Toma H, Sugahara K, Etoh K, Shiroma Y, et al. (2002) Involvement of IL-2/IL-2R system activation by parasite antigen in polyclonal expansion of CD4(+)/CD25 (+) HTLV-1-infected T-cells in human carriers of both HTLV-1 and S. stercoralis. Oncogene 21: 2466–2475.

32. Keiser PB, Nutman TB. (2004) Strongyloides stercoralis in the immunocompromised population. Clin Microbiol Rev 17: 209–217.

33. Thompson R. (2001) The future impact of societal and cultural factors on parasitic disease—some emerging issues. Int J Parasitol 31: 949-959.

34. Conway DJ, Lindo JF, Robinson RD, Bundy DA. (1995) Towards effective control of Strongyloides stercoralis. Parasitology Today 11: 420–424.

35. Thomson N. (2012) Translational research and the Australian indigenous HealthInfoNet. health 7: 211.

36. Mays N, Pope C, Popay J. (2005) Systematically reviewing qualitative and quantitative evidence to inform management and policy-making in the health field. J Health Serv Res Policy 10 Suppl 1: 6–20.

37. Moher D, Liberati A, Tetzlaff J, Altman DG. (2009) Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann Intern Med 151: 264–269.

38. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, et al. (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. J Clin Epidemiol 62: e1–34. doi: 10.1016/j.jclinep.2009.06.006.

39. Tugwell P, Robinson V, Grimshaw J, Santes N. (2006) Systematic reviews and knowledge translation. Bull World Health Organ 84: 643–651.

40. Einsiedel LJ, Woodman RJ. (2010) Two nations: Racial disparities in bloodstream infections recorded at Alice Springs hospital, Central Australia, 2001–2005. Med J Aust 192: 567.

41. Einsiedel LJ, Fernandes LA, Woodman RJ. (2008) Racial disparities in infection-related mortality at Alice Springs hospital, Central Australia, 2000–2005. Med J Aust 188: 568–571.

42. Walker-Smith J, Reye R. (1971) Small intestinal morphology in aboriginal children. Aust N Z Med J 1: 377–381.

43. Gunzburg S, Gracey M, Burke V, Chang B. (1992) Epidemiology and microbiology of diarrhoea in young aboriginal children in the Kimberley region of Western Australia. Epidemiol Infect 108: 67–76.

44. Kukuruzovic RH, Beverot DR. (2002) Small bowel intestinal permeability in Australian aboriginal children. J Pediatr Gastroenterol Nutr 35: 205–212.

45. Yiannakou J, Croese J, Ashdown LR, Prociv P. (1992) Strongyloidesis in north Queensland: Re-emergence of a forgotten risk group? Med J Aust 136: 24–27.

46. Walker A, Blake G, Downing D. (1976) Syndrome of partial intestinal-obstruction due to Strongyloides stercoralis. Med J Aust 1: 47–48.

47. Desowitz RS, Bell T, Williams J, Gardines R, Tammaru M. (1970) Anthelmintic activity of pyrantel pamoate. Am J Trop Med Hyg 19: 775–778.

48. Davis JS, Currie BJ, Fisher DA, Huffam SE, Anstey NM, et al. (2003) Prevention of opportunistic infections in immunosuppressed patients in the tropical top end of the Northern Territory. Commun Dis Intell Q Rep 27: 526–532.

49. CARPA. (2009) CARPA standard treatment manual: A clinical manual for primary health care practitioners in remote and rural communities in Central and Northern Australia. Alice Springs: Central Australian Rural Practitioners Association Inc. 432 p.

50. Fisher D, McCarr F, Currie B. (1993) Strongyloides in the Northern Territory. under-recognised and under-treated? Med J Aust 159: 89–90.

51. Walker-Smith JA, McMillan B, Middleton AW, Hopcroft A. (1969) Strongyloidesis causing small-bowel obstruction in an aboriginal infant. Med J Aust 2: 1263–1265.

52. McCarthy JS, Garrow SC. (2002) Parasite elimination programs: at home and away. Med J Aust 176: 456–457.