MANAGEMENT PERSPECTIVE

Diabetes Management

Diabetic foot disease in Indigenous people

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Practice points

Background

- Indigenous people in any country are more likely than non-Indigenous people to be disadvantaged and marginalized, and have a higher incidence of chronic disease such as diabetes.

Risk factors for diabetic foot disease in Indigenous people

- In addition to biomedical risk factors, complex social and political factors such as geographical isolation, inferior infrastructure, educational and employment disadvantage, and both cultural and linguistic differences are all potential barriers to optimal healthcare for Indigenous people.
- Lower limb complications of diabetes, including peripheral neuropathy and peripheral artery disease, are more common in Indigenous people compared with non-Indigenous people.

Lower extremity amputations in Indigenous people with diabetes

- Foot ulceration and amputation are about two- to three-times more common, and occur at a younger age, in Indigenous people compared with non-Indigenous people.

Interventions for diabetic foot disease in Indigenous people

- Successful intervention strategies for managing diabetic foot disease in Indigenous people include: the use of evidence-based guidelines, risk stratification and screening, and the introduction of multidisciplinary teams that include Indigenous health workers.
- Despite the evidence for these strategies, their funding and implementation remains inadequate and the disparity in outcomes persist.

SUMMARY This article will examine what is known about the epidemiology of diabetic foot disease in Indigenous people and what strategies have been used to manage the problem. The prevalence of diabetes is several-fold higher in Indigenous people compared with non-Indigenous people. The prevalence of diabetic peripheral neuropathy varies but in general it appears to be more common and start at a younger age in Indigenous compared with non-Indigenous people. Peripheral artery disease is also more prevalent and the incidence of lower extremity amputation is higher. Various strategies have been shown to be effective in the delivery healthcare for diabetic foot disease in Indigenous people. There are, however, social and political barriers to the implementation and success of these interventions.

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Future Medicine part of fsg

10.2217/DMT.14.43 © 2014 Future Medicine Ltd

ISSN 1758-1907

KEYWORDS
• diabetes • diabetic foot disease • diabetic foot ulcer • diabetic peripheral neuropathy • health access • Indigenous • lower extremity amputation • peripheral artery disease

Diabetes & Indigenous people

There is no strict definition of Indigenous people and instead, the United Nations emphasizes the importance of self-identification and determination [1]. It is estimated that there are at least 370 million Indigenous people living in some 90 countries, constituting almost 5% of the world's population. Indigenous people are over-represented among the most disadvantaged and dispossessed people, and have the worst health statistics. Diabetes is a global problem, but it is a particularly bad one for Indigenous people because of a combination of new environmental exposures and a high genetic predisposition to the disease. The prevalence of Type 2 diabetes is several-fold higher in most Indigenous people compared with local non-Indigenous people [2]. For example, Australian Aboriginal and Torres Strait Islander people are three times as likely as non-Indigenous people to have diabetes, although there is some variation between different Indigenous groups [3,4]. Worldwide, it is estimated that more than 50% of adults over the age of 35 years in Indigenous communities have diabetes [5]. In addition to having a higher prevalence and worse risk factor profiles, there is evidence that some Indigenous people are diagnosed with diabetes at a younger age than non-Indigenous people [6].

This review will examine what is known about the epidemiology of diabetic foot disease in Indigenous people and what strategies have been used in attempts to manage the problem. Although the concept of Indigenous identity is not exclusive to regions that have been affected by white settlers and colonialists [1], most of the contemporary literature about diabetes and its complications in Indigenous people is from ex-colonial countries so the focus will necessarily be on these regions. There are published reports from four regions (USA, Australia, Canada and New Zealand); unfortunately, there is a lack of data from less economically developed countries.

Methods

The English language literature since 1980 was searched using PubMed, EMBASE, Medline and Google Scholar. Search terminology included combinations of (A) one of the following: Indigenous people(s), Australian Aborigine(s), Torres Strait Islanders, Polynesian Oceanic Ancestry Group, First Nations, Maori(s), Pacific Islander(s), Inuit, Native American(s), American Indian(s), American Native Continental Ancestry Group, Amerid, Alaskan, Eskimo(s), Native Hawaiian(s), Metis, Native Canadian(s), Canadian Indian(s); with (B) one of the following: diabetes mellitus complications, peripheral neuropathy, diabetic foot, diabetic angiopathy, diabetic vasculopathy, peripheral artery (vascular) disease, podiatry, foot ulceration, diabetic foot or lower extremity amputation. Wherever possible the most recent or comprehensive paper has been selected for inclusion. Government Health and Indigenous Affairs Department websites in the USA, Australia, Canada, New Zealand were also searched using a similar strategy.

The lack of agreement about the definition of 'Indigenous' presents challenges to the comprehensive identification of both relevant literature [7] and data within administrative databases [8]. The appropriate terminology for specific Indigenous peoples in various countries has changed over time; we have used the most contemporary descriptor applied to any given Indigenous people.

Diabetic complications in Indigenous people: nephropathy & retinopathy

The rates of most diabetes-related complications appear to be higher in Indigenous people than non-Indigenous people regardless of history, geography and genetic heterogeneity. Despite similarities in diabetic risk factors in Indigenous populations, there is evidence that cardiovascular risk factors and some diabetic complications may differ among groups [9,10].

In Type 2 diabetes, the prevalence of microalbuminuria, nephropathy and end-stage renal disease (ESRD) is about two- to four-times greater in Indigenous compared with non-Indigenous people in any given geographical region. Among Australian Aboriginal and Torres Strait Islander people the prevalence of kidney disease ranged from <1% in those aged <45 years, to >6% in those aged ≥45 years [4]. Compared with the general Australian population after adjusting for other risk factors, urban Indigenous Australians had two- to three-fold increased risk of albuminuria [11]. Among people with Type 2 diabetes in New Zealand, the proportion of Maori (55%) and Pacific Islanders (50%) with microalbuminuria is greater than Europeans (27%) [12]. There is a 3.5-fold higher relative incidence of commencing renal replacement therapy in Maori and Pacific Islanders [13]. Similarly, the Pacific Islanders of New Zealand (3.3%), and the Maori of New Zealand (4.7%) had higher rates of the population diagnosed with renal failure, compared with 0.3% of the general population with diabetes in New Zealand [7]. Among Canadian First Nations people with diabetes, the prevalence of ESRD was 56% compared with 24% in non-Indigenous people with diabetes [7]. A recent health service data analysis from the USA found the prevalence of renal failure to be 1.7-times greater in Native Americans compared with commercially insured US adults [14].

The prevalence of various manifestations of diabetic retinopathy in Indigenous people varies considerably but overall is similar to that of non-Indigenous people [7,15]. Worldwide the prevalence of any diabetic retinopathy is approximately 35%, while among Indigenous people it ranges from 17% in Canadian First Nation and Metis to approximately 50% in New Zealand Maori [7]. Maori were over-represented in patients with retinopathy and maculopathy, but under-represented within the screening population [16]. In New Zealand, moderate or more severe retinopathy is more common in Polynesians than Europeans [17].

Risk factors for diabetic foot disease in Indigenous people

• Diabetic peripheral neuropathy

Diabetic symmetrical sensorimotor polyneuropathy (DSPN) is a common and important complication of diabetes that is thought to be due to microvascular disease secondary to chronic hyperglycemia [18]. Studies reporting the prevalence of DSPN in various Indigenous peoples are summarized in **Table 1**. Methodological factors such as the number and type of tests used to diagnose DSPN and the nature of the cohort influence the reported prevalence, making assessment and comparison of true prevalence difficult. Cohort studies which include dedicated clinical testing for DSPN, suggest the prevalence is in the range of 30–50% [19–22]. However, when identified by chart audit, the prevalence of reported DSPN is much lower (generally <30%) than for dedicated clinical testing [14,23–25]. When only one physical test for DSPN (the 10-gram monofilament) was combined with a symptom questionnaire, the prevalence in one remote Canadian community was only 7% [26].

In general, Indigenous diabetic people appear to be at higher risk of peripheral neuropathy than non-Indigenous diabetic people. In the DRUID study, Australian Indigenous people had a 1.7-fold greater risk of DSPN than non-Indigenous Australian people in the AusDiab study [11]. Similarly, Native Americans had a 2.2 ratio of prevalence of DSPN compared with the US adult population with diabetes [14]. Indigenous people also appear to develop DSPN at a younger age: 50–53 years in Indigenous Australians versus 64 years in non-Indigenous Australians [11,14,22]. Compared with insured non-Indigenous American 18–34-year-olds with diabetes, the prevalence of DSPN is 50% higher in Native Americans [14].

The presence of DSPN at the time of diabetes diagnosis is relatively common in Indigenous people [11,26]. A pediatric clinic in Canada reported 12% of Indigenous children (mean age: 15 years) with diabetes had symptoms but no signs of DSPN [27]. In Indigenous people with newly diagnosed diabetes, DSPN was found in 2% in an observational cohort study (using a combination of instruments), and (using monofilament only) in 8% of people in a remote Canadian First Nation community [26]. As with most people with diabetes, the presence of concomitant peripheral artery disease (PAD) or cardiovascular disease increases the prevalence of DSPN in Indigenous people – for example from 25.1 to 56.5% in Navajo Indians [25].

• Peripheral artery disease

The proportion of Indigenous people with cardiovascular disease is reported to be in the 30–35% range although may be as high as 50% in Indigenous Australians [7,28]. In a recent study from Western Australia, the Indigenous age-standardized case fatality was 1.5-times higher than those of the non-Indigenous population aged 55–74 years [29]. In New Zealand, Maoris were significantly more likely to be at high cardiovascular risk than non-Maori (odds ratio: 2.07; 95% CI: 1.51–2.84) [30]. Indigenous people, particularly in Australia, tend to have lower life expectancies and higher age-standardized mortality rates for cardiovascular (and other) disease than non-Indigenous people [31].

Peripheral artery disease (PAD) is common in people with diabetes and is an independent risk factor for foot ulceration, amputations and cardiac death [32]. As with DSPN, the prevalence of PAD is influenced by the methods of detection and the type of cohort. Three Australian studies compared the prevalence of PAD in Indigenous and non-Indigenous people. The Fremantle

Table 1. Observational studies reporting the prevalence of diabetic sensorimotor polyneuropathy in Indigenous people.

Study (year)	Participants and setting	Diagnostic test	Sample (n)	Prevalence (%)	Ref.
Hoy *et al.* (1995)	NA (Navajo): hospital	Not stated (record review)	777	28.4	[25]
Schulz *et al.* (1997)	NA (Oneida): community	Not stated (record review)	358	16.0	[24]
Jones *et al.* (2001)	IA: community: urban	Biothesiometer	97	50.0	[45]
Simmons (2003)	IA: community: urban	Not stated (record review)	47	50.0	[92]
Maple-Brown *et al.* (2004)	IA: community: remote	>1 abnormal: MF/vibration/temp/reflex	381	28.0	[20]
Hanley *et al.* (2004)	CI: community: remote	>2/8 on modified MNSI and MF	189	46.0	[19]
Reid *et al.* (2006)	CI: community: remote	MF + vibration	169	29.0 vibration, 40.0 MF	[21]
Chuback *et al.* (2007)	CI: tertiary hospital pediatric	MF + vibration + temp	110	0.0	[27]
Rose *et al.* (2008)	CI: tertiary hospital MDFUC	MF + vibration + temp + pinprick + proprioception	101	87.0	[81]
Bruce *et al.* (2008)	CI: community: rural	>1 MF + PN symptoms	483	7.0	[26]
Maple-Brown *et al.* (2008)	IA: community: urban	Modified NDS + NSS + pressure	135	9.0	[11]
O'Connell *et al.* (2010)	NA and all insured US adults national data	Not stated (ICD-9-CM coding)	30,121	16.8	[14]
Harris *et al.* (2011)	CI: 19 communities: mixed	Not stated (record review)	825	10.8	[23]
Davis *et al.* (2012)	IA and Anglo–Celts: community: urban	>2/8 MNSI clinical portion	196	48.5	[22]

CI: Canadian Indigenous; IA: Indigenous Australian; ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification; NA: Native American; MDFUC: Multidisciplinary foot ulcer clinic; MF: Monofilament; MNSI: Michigan Neuropathy Screening Instrument; NDS: Neuropathy Disability Score; NSS: Neuropathy Symptom Score; Temp: Temperature.

Diabetes Study [22] reported a significant difference in the prevalence of PAD – 30.7% in Indigenous people and 21.5% in Anglo–Celtic people (p = 0.04). Of particular concern was that the prevalence of PAD increased in Indigenous participants but decreased in Anglo–Celtic people between 1993–96 and 2008–11. In urban Indigenous Australians (DRUID participants), the prevalence of PAD was 12% – about two- to three-fold increased risk compared with that seen in non-Indigenous Australians (AusDiab participants) after adjusting for other factors [11]. In a study of people with diabetes in northern Australia (Queensland) undergoing major LEA, the prevalence of PAD was significantly higher in Indigenous (38%) compared with non-Indigenous people (12%) [33].

Studies directly comparing the prevalence of PAD in Native Americans, Canadian First Nation and Maori diabetic people with diabetes with local non-Indigenous diabetic people with diabetes appear to be lacking. Cross-sectional data from 1333 Chippewa and Menominee Indians found approximately 6.9% of men and 6.1% of women had PAD in the general population [34], compared with approximately 5% in the general US population [35]. While lower rates of PAD have been reported in general Maori populations from primary healthcare data (3% in Maori vs 1% in non-Maori) this nevertheless this represents a threefold greater risk [36].

In Canada, two cross-sectional community-based studies report a large range in the prevalence of PAD. Standardized foot assessment in one remote community found clinical evidence of PAD was common: one or both pedal pulses were absent in 41% of 169 participants, 8% had rest pain or intermittent claudication and 5% had undergone lower extremity bypass [21]. Retrospective auditing of a representative sample of 19/20 First Nation communities' medical charts (21% non-isolated, 34% semi-isolated and 45% remote) reported a prevalence of PAD of 2.4% (range: 0.0–13.7%) [23]. Maple-Brown *et al.* compared PAD in a remote Australian Indigenous community, a remote First Nation Community and the urban Indigenous community of the DRUID study, and found there were no significant differences in rates of PAD between the three groups of Indigenous people [9].

Canadian Indigenous people had worse outcomes of lower limb revascularization than non-Indigenous people, attributed to renal disease and more advanced clinical stage of PAD at the time of the intervention [37]. Late presentation with more severe disease is a common pattern in many studies of Indigenous people, and relates in part to access to services (see below). The presence of PAD is also a marker of other cardiovascular disease. The Fremantle Diabetes Study reported a hazard ratio of 1.55

(95% CI: 1.18–2.03) for PAD as a predictor of all-cause mortality between Indigenous people in Western Australia and Anglo–Celtic people [38]. The higher prevalence of PAD in Indigenous people is therefore relevant in terms of the lower life expectancy of Indigenous people [31].

Both DSPN and PAD alone, and especially the combination, are dominant risk factors for the trajectory of foot ulceration, mechanical deformity and ultimately amputation. The approximate doubling of the prevalence of both in many Indigenous people with diabetes is an important factor in the poorer outcomes.

• Foot ulceration & deformity

There is a paucity of data about diabetic foot ulceration in general, and even less in Indigenous people. The only study comparing the prevalence of foot ulceration in different Indigenous communities found no significant difference between a remote Australian Indigenous community (3%), urban Indigenous Australians (6%) and a remote Canadian First Nation people (5%) [9]. These are all higher than the prevalence of, for example, 1.7% seen in a typical non-Indigenous community in the UK [39]. In one remote Australian Indigenous community the history of previous foot ulceration was 12% [20]. This is much higher than the prevalence of 2.1% seen in non-Indigenous Australians (AusDiab) [40]. In a primary healthcare study of New Zealand Maori people, 8% had current foot ulceration but 53% had pre-ulcerative lesions [41]. In Canada, 5% of Indigenous people with diabetes had foot ulceration and 15% had a history of prior ulceration in one remote community [21]. In the USA, the prevalence of foot ulceration was as high as 50% in Navajo Indians but only 7.7% in the general adult diabetic population [25,42].

There are also little data about prevalence and relevance of foot shape, deformity and joint mobility in Indigenous people with diabetes [26,41,43,44]. There is some evidence that limited access to, and possibly use of, appropriate footwear may contribute foot problems in Australian Indigenous people with diabetes [45,46]. It is possible that some Indigenous peoples have wider feet that non-Indigenous people, which may be of relevance to use of footwear [Singh A, Pers. Comm.]. The initiative by Nike™ to produce a shoe specifically designed for Native Americans is an interesting development in this area [47].

Lower extremity amputations in Indigenous people with diabetes

Although rates of foot ulceration and subsequent wound healing are the best indicators of disease severity and quality of foot care, rates of lower extremity amputation (LEA) are easier to measure and therefore more commonly reported [48]. Comparing the rates of amputations is complex and results need to be interpreted carefully. The average incidence and its trend over time may be influenced by type and definition of diabetes, the level and type of amputation and whether the denominator used for the calculation of rates is the diabetic population at risk or the whole population [49].

The age-adjusted rate of LEA among Indigenous people is undoubtedly much higher than for non-Indigenous people. Compared with non-Indigenous people, this ranges from 4.7-times greater in Maori people in New Zealand [50], 30-times greater in First Nation people in Canada [26], up to 38-times in Western Australia [51]. Even within one country there are significant differences in the rates of LEA. For example, within the Manitoba province of Canada, rates of LEA in one First Nation community is 6.2 per 1000, twice that of other First Nations provinces (3.1 per 1000) [26]. Yet, others report 24.1 per 1000 in population linked data studies comparing the Metis people to all other residents in Manitoba [52]. Some of these disparities can probably be attributed to methodological differences between studies [49]. Over the last 25 years there have been numerous reports of the higher incidence and prevalence of LEA in numerous Native American people with rates at least three times that of non-Indigenous people [53,54]. Most recently, O'Connell *et al.* found that LEA in Native Americans in central Arizona was 14.4-times greater than that of commercially insured non-Indigenous people [14]. It is worth noting that this was much greater than the approximate doubling of risk for other complications of diabetes.

Common to all publications, is the observation that Indigenous people have LEA at a younger age than non-Indigenous people [33,51,55]. For example, in one Australian study, Indigenous people's mean age at first LEA at 56.3 years was 14 years younger than non-Indigenous people [33], while Canadian Indigenous people's first LEA at 58 years was approximately 7 years younger [55]. Interestingly, for all Alaskan Native people with diabetes there was a significant downward trend in LEA rates in people over 55 years of age over the 21-year period 1986–2006. However, no similar trend was seen in those aged less than 55 years of age [56]. This trend may be influenced by lower Indigenous life expectancy.

Most of the well-recognized clinical risk factors for LEA in non-Indigenous people with diabetes have also been identified in Indigenous people. There is an overall greater frequency of prior amputation or ulceration, DSPN, PAD and foot deformity in most Indigenous populations [41,57]. The higher rate of LEA in males with diabetes is reported in most Indigenous populations [50,53,56,58–62]. Similarly, ESRD is frequently associated with LEA in Indigenous people with diabetes. In northern Australia, Indigenous people with prior diabetes-related amputations were significantly more likely to suffer from chronic kidney disease than comparable non-Indigenous people [33]. Indigenous Canadians with diabetes and ESRD were, on average, 7 years younger than non-Indigenous, and had a higher frequency of previous amputation, ulceration, osteomyelitis and mean number of foot ulcers, and risk of future ulceration [57].

The magnitude of the increased incidence of LEA in Indigenous people is far greater than the magnitude of increase in the prevalence of DSPN and PAD. As such, the gap cannot be attributed to increased DSPN and PAD alone. The likely contribution of barriers to effective and equitable healthcare delivery to the poor outcomes are discussed below.

Interventions for diabetic foot disease in Indigenous people

A robust evidence base regarding the effectiveness of interventions is needed to reduce the high rates of diabetes and diabetes complications in Indigenous people. A review of the number and quality of published interventional studies in Type 2 diabetes in Indigenous populations of Australia, Canada, New Zealand and the USA revealed the total number of publications about diabetic Indigenous health has increased from 1998 to 2008; however, the research is predominantly descriptive [63]. The proportion of research involving interventions increased from 3 to 12% in the 20 years but only seven out of 28 intervention studies met the Cochrane Effective Practice and Organization of Care standard [64]. Of these seven studies, only one in Australian Indigenous people included foot measures [65].

The elements of any prevention program are:

- Identification of individuals at potential risk;
- Screening for disease precursors and signs and symptoms;
- Provision of a risk score;
- Timely and appropriate referral based on risk score.

The diabetic foot requires the same prevention steps and this should be integrated within any system of diabetes care. A review of the literature from Indigenous health services demonstrates that a range of strategies have been successful in a number of settings **(Box 1)**. All these strategies are appropriate for any population and certainly have been developed, and initially implemented, in Indigenous health services in the USA and Alaska.

Access to culturally appropriate services – or the more dynamic term, culturally safe services – has been addressed in a number of settings. It has been successful in urban areas of Perth, Western Australia with the Moorditj Djena program, a mobile service at multiple locations with ‘walk-in’ appointments offered [66]. Similarly in Canada, a mobile diabetes clinic in Indigenous communities in British Columbia has proven successful [67]. Traveling foot care services were part of the Sioux Lookout Diabetes program in north western Ontario [68]. The mobile ‘SLICK vans’ that traveled to Alberta’s 44 First Nations commenced in 2001, staffed by First Nation health professionals, were successful and improved access to foot services [10,69]. Key to the success of all these programs is improved access, community acceptance and Indigenous health workers.

Indigenous people have generally not had the same opportunity for health education and literacy within health systems and this has failed to create the conditions that enable people to take control of their lives [70]. While the benefit of patient education remains to be established [71], access to culturally appropriate health education has not been universal for Indigenous people. As part of the Special Diabetes Program for Native Americans, culturally appropriate education materials were developed [72]. In Australia, culturally appropriate education has been developed separately in different states in consultation with Indigenous communities as there were no nationally available resources [73–76]. Community consultation, engagement

Box 1. Examples of successful intervention strategies for diabetic foot disease undertaken by Indigenous health services.

- Introduction and implementation of evidence-based guidelines for the diabetic foot in a well-supported health service [65,72,85,93–95]
- Development and maintenance of diabetes databases, to identify those at risk of diabetic foot complications [56,65,72,84,95–98]
- Quality improvement activities, audit and feedback to providers, or continuous quality improvement cycle [65,72,93,95,99–102]
- Risk stratification of the diabetic foot, to identify those at high risk of diabetic foot ulceration or those that need further assessment, treatment or education has targeted care [61,85,103,104]
- Team management of diabetes utilizing chronic disease coordinators, physicians, nurses, allied health practitioners and Indigenous health workers [72,92,95]
- Introduction of specialty foot services or podiatry care in Indian and Alaskan health services [84,85]

and participation in the development of these local diabetes foot care education resources is essential, as it allows Indigenous people to be involved in making decisions about the suitability of resources, and encourages community ownership resources.

Barriers to prevention & intervention

There are many recognized barriers to the prevention of diabetic foot disease and its complications, common to all populations. However, the reasons for the consistent and persistent disparity in diabetic foot complications in Indigenous people compared with non-Indigenous people needs to be examined. As reviewed above, some of the disparity is due to Indigenous people having longer duration of diabetes, worse risk factor profiles with more prevalent and severe DSPN and PAD. These biomedical factors are greatly influenced by complex social and political factors that are relevant to all aspects of the increased morbidity and mortality faced by Indigenous peoples [77]. Social disadvantage and poverty has a marked impact on the incidence of both foot ulceration and LEA in all populations including Indigenous ones [35,78]. In many regions there are significant barriers to optimal healthcare such as geographical isolation, inferior infrastructure including food supply, and disadvantages in both educational and employment opportunities [7]. Language differences, cultural understanding and social context of the basis of health and illness may further complicate how Indigenous people experience and respond to conditions such as diabetes [79]. The fact that some, possibly most, Indigenous peoples' languages lack a word for diabetes epitomises this predicament [49].

Shared causes of higher rates of LEA among Indigenous people have been related to access to healthcare, continuity of care, socioeconomic status and rural residence [52]. Many Indigenous people live in remote regions where access to services are inherently limited. For example, in Western Australia, multidisciplinary foot ulcer clinics are only located in urban tertiary hospitals, and regions with the highest Indigenous amputation rates do not have such clinics [80]. Rural or remote residence of Indigenous people is associated with LEA and shorter average length of time from first visit to amputation [33,81].

Access is influenced by approachability, acceptability, availability, affordability and appropriateness [82]. Here we will consider three issues that impact on access – cultural appropriateness, community engagement and funding. Accessibility is central to the performance of healthcare systems and is a critical component of equity [83]. Access is complex, and involves a dynamic interaction between health systems, organizations and services providers, and individual and community factors. Levesque *et al.* argue that utilization and access to healthcare are key measures of the performance of health systems [82]. Marginalization of Indigenous people, particularly in terms of access to allied health and medical care, is a serious problem [2,7]. If access to basic primary healthcare services is limited, then access and timely referral to specialty services, such as multidisciplinary foot ulcer clinics, are likely to be compromised. For example, the timeliness of the referral may contribute to Indigenous people progressing more quickly to major amputation than non-Indigenous people within a multidisciplinary clinic setting [81].

Access to horizontal (broad-based) services are needed as they provide the full range of services and enable vertical funding (disease-specific) effects to be realized by the creation of a comprehensive healthcare system. The benefits of targeted funding of podiatry, allied health services and Indigenous health workers is likely to be prompt and durable. For example, care by podiatrists in the year preceding a diabetic foot ulcer was associated with a lower hazard of LEA and hospitalization in US Medicare and non-Medicare populations [83]. Tribal corporations in Alaska used a portion of their Special Diabetes Program for Native American funding to implement a high-risk foot program that enabled diabetic foot clinics to be delivered routinely in urban and remote settings – and this resulted in reduced amputations [84]. Similarly, initiation of a high-risk foot-care service in a rural primary healthcare setting of the Indian Health Service also resulted in reduced amputations [85]. Patient education was emphasized in both of these studies. The availability of these culturally appropriate resources enable podiatrists, diabetes educators and Indigenous health workers to provide education in respect to symptoms and prevention was by enabled by the additional funding.

A recent update from the Indigenous and Rural Health Division of the Australian Department for Health [86] reported that Indigenous health services involved in continuous quality improvement had better outcomes than those that did not. Additionally, organizations in the two states where the Department for Health has supported implementation of systematic continuous quality improvement programs performed better than those in other states. Despite this evidence, and high rates of LEA [51], a national framework to support continuous quality improvement of Indigenous health services has yet to be introduced in Australia.

Unfortunately, many of these otherwise successful programs suffer from ongoing uncertainty of funding that jeopardizes improvement in Indigenous diabetic foot outcomes. For example, the Special Diabetes Program for Native Americans was mandated in 1997. However, even taking these new funds into account, the per capita expenditure for American Indian health remains well below those of other US citizens and in constant dollars, the per person expenditure has remained relatively flat for well over a decade [87]. Additional funding, when there is increasing prevalence of diabetes and diabetic complications in Native American populations, also has limited effect when the funding is inequitably shared. For example, in 1993 per capita expenditure ranged from US$575 in Oklahoma to US$1906 in Alaska. In Australia, a recent study identified a 44% margin, or an average shortfall of A$1733 (~US$1630) per Indigenous person with diabetes or ESRD to provide optimal management, as defined by Australian diabetes standards of care [88].

Conclusion & future perspective

The available evidence consistently shows that diabetic foot disease is a major public health problem among Indigenous people. Every aspect, from risk factors through to LEA, is worse for Indigenous people, irrespective of geographical location. The problem is part of the burden of diabetes and other related chronic diseases, which occur as a result of complex historical legacy, leading to disadvantage and social determinants of poor health that lie outside the health sector. It is important to not blame the individuals or label them as ‘non-compliant’, but instead, ask how systems can help them achieve their goals, offer hope and continue to empower Indigenous people to achieve health as defined by the WHO, as a state of complete physical, mental and social well-being, not merely the absence of disease.

Nevertheless, much can be achieved by proactive strategies within the clinical sector. The recruitment and involvement of Indigenous health workers in all stages of diabetic foot care can be implemented immediately, without further research as this is safe, relatively inexpensive and culturally secure. This includes involvement in screening, education, prevention, support within the hospital system and coordination of care after discharge from hospital. Communication between all team members involved in diabetic foot management needs to be timelier and a priority for the Indigenous diabetic foot. The clinical complexity of care for Indigenous people, with the presence of multiple comorbidities requires consistent communication and respect for all team members to ensure continuity and coordination of care. The communication process must start earlier and engage information technology to enable real-time communications between all providers.

Strategies to deal with the problem need to occur at a health service level with a mechanism to incentivize equity and quality rather than just productivity [89]. Primary healthcare, delivered by Indigenous health services, is clearly identified as the best setting for implementing successful diabetic foot care interventions (see **Box 1**), as their intention is to address health, access to health services and the social determinants of health.

At a policy level, organizations and workers need to be supported with funding and technology. For example, the use of information technology tools such as electronic clinical decision support tools integrated into current medical software programs to calculate foot risks can improve communication and risk score validity by Indigenous health workers [89,90] or the use Telehealth for remote expert consultations with multidisciplinary teams to improve earlier assessment, as is being trialed in Western Australia. There is evidence that factors such as organizational (and political) commitment, patient-centered care and community health focus are determinants of success and these factors need to be underpinned by independent assessment of outcomes stratified by ethnicity [91]. Finally, all clinicians and policy-makers involved in the care of diabetic foot disease in Indigenous people need to be active 'foot advocates' – just as clinicians responsible for other complications of diabetes are.

Financial & competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

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