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EDITORIAL

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Summaries

Comprehensive cancer centres for Aotearoa New Zealand: from aspiration to necessity

Frank Frizelle

Cancer is Aotearoa New Zealand's leading cause of death, responsible for almost one-third of all mortality, with incidence projected to nearly double by 2040. Despite successive cancer strategies, survival outcomes lag behind comparable countries, and inequities remain entrenched, particularly for Māori and Pacific populations. Current services are fragmented, specialist workforces are overstretched and research capacity is constrained. A business case that has been recently produced for comprehensive cancer centres in Auckland and Christchurch offers a transformative solution: centralised hubs of multidisciplinary care integrated with research, training and regional networks. International evidence demonstrates that comprehensive centres improve survival, enhance access to clinical trials and attract and retain skilled clinicians. Their establishment would also reduce inequities by embedding Kaupapa Māori leadership and extending quality care through hub-and-spoke models. Although investment is required, economic analysis indicates substantial long-term gains through reduced productivity losses, philanthropic engagement and workforce stability. Comprehensive cancer centres are not aspirational luxuries; they are essential if Aotearoa New Zealand is to confront its escalating cancer burden and deliver equitable, sustainable outcomes.

Reimagining health in Porirua: a community-led approach to hauora

Nethmi Kearns, Jennifer Randle, Anita Taggart, Silvana Tizzoni, Antonia Quinn, Jodi Watene

Te Wāhi Tiaki Tātou is working with the Porirua community to shape and improve local health and wellbeing services through "reimagining sessions". These are community (and provider) engagement sessions where people share their real-life experiences with the health system and imagine how it could be better. Lived experience is treated as powerful evidence and communities are treated as experts in their own lives. The sessions follow principles from participatory research and service design to support genuine community-led decision making. Key learnings from this process include the importance of building trusted relationships, showing manaakitanga (care and hospitality), supporting emotional transitions, and centering Māori and community values throughout engagement. The ideas gathered are turned into practical recommendations, many of which have already led to new or improved services. The approach shows that real change is possible when communities are treated as experts in their own lives.

Epidemiology of bone and joint infection in Pacific children from the Auckland Region, 2018–2023

Sarah Hunter, Elsie Brown, Corina Grey

Childhood bone and joint infections are a serious problem in New Zealand, with Pacific children experiencing the second highest rate of disease in the world. This study reports on bone and joint infections for a cohort of children treated in Auckland between 2018 and 2023. Compared with New Zealand European children with bone infections, Pacific children were more likely to need surgery and have longer hospital stays. Eczema diagnosis was associated with more severe infections, needing multiple surgeries or admission to intensive care.

CTPA and pulmonary embolism rates between Māori and European populations in Hauora a Toi Bay of Plenty, New Zealand

Thomas H E Clark, Catherine Song, Matthew B Wheeler, Chris Frampton

This study looked at the rate of pulmonary emboli (blood clots in the lungs) and computed tomography pulmonary angiography (the scans used to detect them) in the Bay of Plenty. It found that the rate of pulmonary emboli is equivalent in Māori and European patients, when factoring in the different age structures of the populations. It also found that the rate of scans to detect pulmonary emboli was higher in Māori patients than European patients, demonstrating an equitable approach by clinicians in the region. Finally, it reinforced previously observed patterns linking an increased rate of pulmonary emboli to increasing age and female sex.

Trends in thoracic spine injury rates in New Zealand: an eleven-year (2013–2023) analysis of ACC claims

Kesava Kovanur Sampath, Tyler Nitschke

This study looked at patterns of thoracic spine injuries (TSIs)—injuries to the middle part of the back—in New Zealand over an 11-year period. We analysed data from the country's accident compensation system to see how common these injuries were in different age groups, ethnic communities and between men and women. Most of the injuries were muscle strains or soft tissue problems, while only a small number were bone fractures. Overall, these injuries became slightly more common over time, especially in elderly. The findings can help health services and policymakers plan better prevention programmes and make sure support is available for the groups most affected.

COVID-19 is a living example of Darwinian natural selection, and SARS-CoV-2 evolution is occurring under (and in) our noses

Rohan Ameratunga, Euphemia Y Leung, See-Tarn Woon, Edward Lea, Lydia Chan, James AH Mehrtens, Hilary J Longhurst, Richard Steele, Klaus Lehnert

COVID-19 has been mitigated but not eliminated. There is a risk of ongoing waves of infection with waning immunity. Vaccination protects against severe disease. Recurrent infection with SARS-CoV-2 may increase the risk of long-term disability. Vaccination reduces the risk of death and other serious disabilities from COVID-19.

Nurse endoscopists: a rational response to rising rates of young-onset colorectal cancer in Aotearoa New Zealand

Phil Bagshaw, John D Potter, Nicola Griffiths, Andrew Hornblow, Brian Cox, Karen Gower

There is an epidemic of bowel cancer in young people here and in other countries. No one knows why, and the only known way to get on top of it is to offer a limited bowel inspection (sigmoidoscopy) to everyone at age 50. We don't have enough trained people to do this, so we propose training nurses in order to increase the workforce. This has been shown in the United Kingdom to be the most effective and cheapest way it can be done. This increased workforce can also respond to those under 50 years with bleeding and bowel habit changes.

Paediatric ingestion of one hundred small high-power magnets—the dangers of the online marketplace

Binura Buwaneka Wijesinghe Lekamalage, Lucinda Jane Duncan-Were, Nicola Mary Davis

This case report is of a 13-year-old boy who ingested 80–100 small neodymium magnets, which were purchased on an online marketplace (Temu™). This, unfortunately, required a major surgery to remove all magnets, including removal of part of the bowel. This case highlights that while product safety laws

exist in New Zealand that prohibit the sale of high-powered magnets, there is significant challenge in enforcing these laws on products sold on online marketplaces. This is especially concerning for our tamariki as these platforms are easily accessible. We believe this case highlights the dangers of online marketplaces in our paediatric population.

Klebsiella pneumoniae liver abscess following screening colonoscopy: a case report

Seong Shin, Maggie Chapman-Ow

Our report describes a rare case where a 72-year-old man from Sri Lanka developed a serious liver infection, called a pyogenic liver abscess, just 5 days after a routine colonoscopy, which is a test to check the colon for cancer or other issues. The infection was caused by a bacteria called *Klebsiella pneumoniae*, and the man had risk factors like diabetes and diverticulosis (small pouches in the colon) that likely made him more vulnerable. He was treated successfully with antibiotics and a procedure to drain the abscess, recovering fully. This case suggests that even a simple colonoscopy might, in rare cases, lead to such infections, especially in people with certain health conditions. More research is needed to understand how often this happens and how to prevent it.

Now you see it, now you don't—the use of dual energy chest radiography to differentiate lung nodules from pleural plaques

Thomas May, Bobby S Bhartia, Martyn Kennedy

This is a case report describing the utility of dual exposure dual energy chest radiography. This is an important and effective tool in chest radiology assessment to differentiate indeterminate findings on plain chest radiographs. Compared to computed tomography (CT) imaging the test is quicker to arrange, lower radiation, lower cost and quicker to report.

Comprehensive cancer centres for Aotearoa New Zealand: from aspiration to necessity

Frank Frizelle

Cancer is now the leading cause of death in Aotearoa New Zealand, responsible for nearly one-third of all mortality.¹ More than 27,000 people receive a diagnosis each year, a number forecast to double by 2040 as the population grows and ages.¹ This rising burden coincides with chronic workforce shortages, fragmented service delivery and widening inequities in outcomes between Māori, Pacific and non-Māori New Zealanders. Absent decisive reform, the system will fail patients.

The [business case for comprehensive cancer centres](#) in Auckland and Christchurch, commissioned by the Christchurch Cancer Foundation and authored by Sir William Young, sets out a pragmatic and evidence-based response.¹ Its premise is simple: Aotearoa New Zealand must now adopt the internationally recognised model of comprehensive cancer centres—institutions that integrate multidisciplinary clinical care with research, education and regional networks—to deliver equitable and sustainable improvements in cancer outcomes.

A system under strain

Cancer services in Aotearoa New Zealand are dispersed across more than two dozen hospitals, with complex procedures frequently delivered in low-volume centres. There is as a result often considerable variation in treatment with both over- and under-treatment. Outcomes are predictably worse: survival rates for cancers such as pancreas and lung remain below those achieved in Australia and other high-income countries.

Workforce pressures are acute. Radiation oncology is already beyond capacity, with all public centres operating above 100% load.¹ Fewer than 70 radiation oncologists serve the country, and modelling predicts that by 2031 demand will outstrip supply by almost half.¹ Surgery faces similar strain: while case volumes requiring operative intervention are projected to rise by nearly

30% by 2040, the surgical workforce is projected to contract.¹ Medical oncology and haematology are likewise stretched, with infrastructure dating back decades and with limited space for expansion.

These shortages are compounded by inequity. Māori experience cancer mortality rates almost 80% higher than non-Māori.¹ Pacific communities, rural patients and those living in deprived areas also face barriers to early diagnosis and best-practice treatment. Despite successive cancer action plans, disparities have widened over the past three decades.

The comprehensive cancer centre model

Comprehensive cancer centres are not novel experiments; they are established best practice. In the United States of America, National Cancer Institute-designated centres have, for decades, demonstrated the benefits of concentrated expertise, critical patient volumes and seamless integration of laboratory science, clinical trials and patient care. Similar centres in Europe and Australia, particularly Victoria's successful adaptation of the model, provide further evidence that centralisation of complex care improves survival while extending access through hub-and-spoke networks.

Key features define the model:

- **Centralisation of expertise** in high-volume hubs where complex surgery, radiotherapy and systemic therapies are delivered by subspecialists.
- **Integration of research and care**, with clinical trials and translational science embedded in routine practice.
- **Regional extension** through linked hospitals, ensuring patients receive accessible care locally where safe, and specialised care centrally where needed.
- **Education and workforce development**,

providing attractive training environments to recruit and retain skilled clinicians.

Evidence consistently shows that patients treated in research-active hospitals have lower mortality, and that participation in trials accelerates adoption of effective innovations. The research effect benefits even those not directly enrolled.¹

Addressing inequity

The inequities that characterise cancer in Aotearoa New Zealand are profound. Māori and Pacific patients are diagnosed later, have less access to radiation oncology and experience lower survival across nearly all tumour types. Rural patients confront prohibitive travel barriers, while deprived populations face delayed detection and poorer treatment pathways.¹

Comprehensive cancer centres provide a structural mechanism to reduce these inequities. By anchoring national referral pathways, comprehensive cancer centres ensure consistency of multidisciplinary decision making, quality surveillance and equitable access to advanced treatments. Hub-and-spoke models minimise unnecessary travel while concentrating complex care where outcomes are best. Importantly, comprehensive cancer centres offer a framework for embedding Kaupapa Māori leadership and research at all levels, aligning service delivery with Te Tiriti obligations and equity imperatives.

Research and education

Despite unique national assets—a cancer registry, data-linkage capacity and willing patient participation—Aotearoa New Zealand underperforms in research. Funding is modest, trial enrolment rates are low and fewer than 10% of oncologists hold academic appointments.¹ The result is a persistent “brain drain” of clinicians and researchers to Australia and beyond.

Comprehensive cancer centres would reverse this trend by embedding research in care pathways, providing infrastructure for multi-centre trials, and offering sustainable career structures that integrate clinical and academic work. Partnerships with the universities of Auckland and Otago would consolidate a pipeline of cancer-specific postgraduate education, enhancing recruitment and retention of clinicians.

Economic rationale

Investment in comprehensive cancer centres is not merely a moral imperative but an economic one. Cancer imposes immense productivity losses: premature mortality, prolonged morbidity and high treatment costs. High-level analysis appended to the business case suggests billions of dollars in potential gains from reduced productivity losses alone.¹

Initial construction costs will be substantial, but returns will accrue across multiple domains: fewer complications and duplications, more efficient use of expensive technologies, retention of expensively trained specialists and attraction of philanthropic funding.

A national network anchored in Auckland and Christchurch

The proposed centres in Auckland and Christchurch would serve complementary populations, together covering the entire country. Each would function as a hub, linked to regional spokes through telemedicine, shared protocols and streamlined referral systems. Patients would access care locally whenever safe but would be referred to hubs for complex interventions.

This dual-centre model avoids overconcentration while ensuring scale and balance. It aligns with the country's geography and health infrastructure, offering national coverage with regional sensitivity.

The imperative of action

The arguments against inertia are overwhelming. Cancer incidence will almost double within two decades.¹ Current workforce trajectories are unsustainable. Survival gaps between New Zealand and comparator countries persist or may well expand with the increased workload and variation in resourcing. Inequities are already entrenched and will likely worsen for the same reasons.

Comprehensive cancer centres are not a luxury. They are a necessity if Aotearoa New Zealand is to deliver equitable, sustainable and internationally competitive cancer care. The costs of inaction—measured in lives lost, families impoverished, clinicians emigrated and trust eroded—will dwarf the costs of investment.

Conclusion

Comprehensive cancer centres would represent a turning point for Aotearoa New Zealand. By uniting clinical care, research, education and equity under one roof, they offer a path to reduce avoidable deaths, attract and retain clinicians and restore public confidence.

The business case is compelling. The evidence is unequivocal. What remains is political courage. Establishing comprehensive cancer centres in Auckland and Christchurch is the viable route to address Aotearoa New Zealand's looming cancer crisis. Anything less will be remembered as a failure of vision and will.

COMPETING INTERESTS

Frank Frizelle is the Editor in Chief of the *New Zealand Medical Journal*.

Frank Frizelle is Chair of the Christchurch Cancer Foundation, who funded and facilitated the business case.

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Reimagining health in Porirua: a community-led approach to hauora

Nethmi Kearns, Jennifer Randle, Anita Taggart, Silvana Tizzoni, Antonia Quinn, Jodi Watene

ABSTRACT

BACKGROUND: Meaningful community engagement is essential when designing health services and initiatives. Te Wāhi Tiaki Tātou was established as the Porirua locality under the *Pae Ora Act 2022* to support place-based approaches to hauora. Our community engagement takes the form of “reimagining sessions”: facilitated hui that elevate lived experience as a powerful and essential form of evidence in health service design.

METHODS: Reimagining sessions blend principles from participatory action research (PAR) and service design, grounded in Te Tiriti o Waitangi. From PAR, they draw on honouring lived experience as expertise. Service design contributes sequencing and holistic thinking principles. Shared principles across both PAR and service design are community-centred approaches, where whānau are positioned as co-creators (from service design) or co-researchers (from PAR), and power sharing with the community to create space for true community-led decision making. Whānau and providers are invited separately to map their experiences of current health services and envision an ideal future state. Sessions are guided by relational engagement and reflexive practice.

RESULTS: Reimagining sessions are more than a consultation mechanism, and serve to share power and elevate community voice. Outputs are synthesised into action-oriented reports validated by participants. Our learnings highlight the importance of trusted relationships, culturally safe environments and emotional anchoring to support aspirational thinking.

CONCLUSION: Reimagining sessions demonstrate that whānau-led change is possible when communities are treated as experts in their own lives. They reflect a shift from consultation to collaboration, from systems-centred to whānau-centred and from generic services to community-informed services.

Our whakapapa

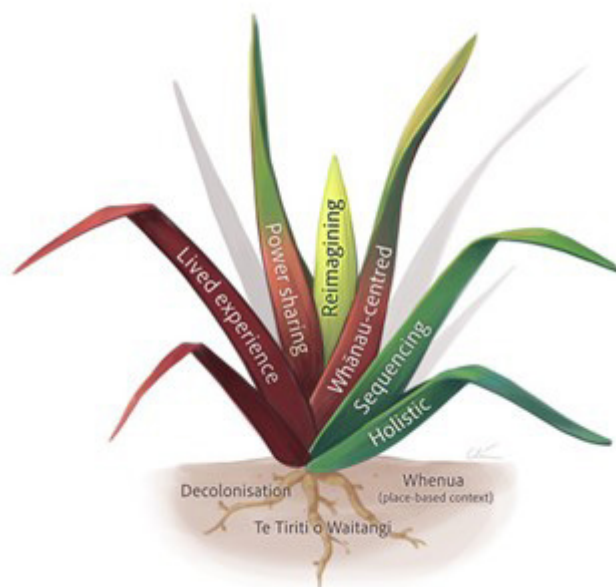
Te Wāhi Tiaki Tātou¹ (Porirua locality) was one of 12 prototype localities originally set up following the health reforms under the *Pae Ora (Healthy Futures) Act 2022*.² As previously laid out in section 54 of the *Act*,² Health New Zealand – Te Whatu Ora and Te Aka Whai Ora – Māori Health Authority must jointly determine “geographically defined areas (localities) for the purpose of arranging services”. Te Wāhi Tiaki Tātou was the name gifted to the Porirua locality by mana whenua Ngāti Toa Rangatira and operates under Te Rūnanga o Toa Rangatira as an iwi-led locality prototype (see Appendix Table 2 for te reo glossary). Although the concept of localities has now been disestablished, Te Wāhi Tiaki Tātou continues to operate as an entity, championing place-based approaches to health and wellbeing service delivery in Porirua.

Porirua is a city of approximately 60,000 residents located in the Wellington Region of Te Ika-a-Māui (North Island), Aotearoa New Zealand. It is characterised by a youthful and

diverse population, with 23.0% identifying as Māori (compared to 17.8% nationally) and 26.5% as Pacific peoples (compared to 8.9% nationally).³ The city’s population distribution is concentrated at both ends of the socio-economic deprivation spectrum, with many whānau living in areas classified within the highest and lowest deprivation quintiles.³ This socio-economic divide is reflected in disparities across a range of indicators, including income, employment, housing tenure and quality and access to telecommunication.³ However, Porirua also demonstrates strong resilience, culture and community leadership, with 84% of Porirua residents reporting a positive overall quality of life and 77% considering it a great place to live.⁴

Since the inception of Te Wāhi Tiaki Tātou, there has been a strong focus on the Porirua community and community engagement, with whānau voice considered a vital form of evidence in shaping our approach to improving health outcomes in Porirua. While quantitative data remain critical, we know that numbers alone do not tell the full story. Lived experience is a powerful and often overlooked form of evidence,

Figure 1: The principles behind reimagining sessions.



The process of reimagining sessions draws on principles from participatory action research (PAR) and service design. The green harakeke leaves represent service design principles, while the red leaves represent those from PAR. Blended leaves reflect principles shared by both. Together, these principles nurture the growth of the rito—the reimagining sessions. Grounded in a place-based approach, the sessions are by, with and for the Porirua community. Everything discussed relates to Porirua, sessions are held in Porirua and participants are from Porirua. At the foundation, like the roots of the harakeke, sits Te Tiriti o Waitangi, anchoring this mahi in a decolonial, Tiriti-honouring approach.

especially in current decision-making systems. Even when efforts are made to engage with communities, they often serve as symbolic or “tick-box” exercises. Community members report that these have felt superficial and extractive, with unclear outcomes from their input. Moreover, entrenched forms of domination embedded within social practices, rules and prevailing “norms” can significantly constrain the ability of marginalised communities to participate and engage meaningfully.^{5–8}

To address these issues, our core approach to community engagement has been through “reimagining sessions”: intentional, facilitated spaces where we invite those with lived experience to share their insights, visualise a better health service and guide future action. We have conducted reimagining sessions across a wide range of kaupapa, including dental health, mental health, support for young hapū māmā, family harm, resilience to organised crime, cardiovascular health, diabetes, cancer, neurodivergent learners and tāngata whaikaha.¹ Each of these sessions has offered valuable insights grounded in lived experience, contributing to a deeper under-

standing of the systemic barriers and aspirations within our communities. The reflections and ideas shared during these sessions have directly informed the design of locally led initiatives and service enhancements that aim to improve health and wellbeing in Porirua.

Our reimagining sessions draw on principles from both participatory research action⁹ (PAR) and service design^{10,11} (Figure 1). The often unacknowledged theory and practice of PAR, in fact, comes from Indigenous decolonial community capacity building practices and principles that were documented in the “developing world” during the 1970s.^{12–15} PAR is an approach to inquiry that challenges traditional paradigms of research by placing those most affected by social inequities at the centre of the knowledge-production process.^{9,16,17} It recognises that experiential knowledge, particularly from communities who have historically been marginalised or harmed by institutional systems, is not only valid but essential for understanding and transforming those systems. The methodology disrupts the assumption that expertise resides solely within formal institutions or “experts”. It recognises community members

as holders of deep, legitimate and contextualised knowledge, and affirms their role in contributing meaningfully to improving the status quo.

PAR also aims to challenge and reconfigure power dynamics at the individual, collective and systemic levels.^{9,16} Rather than viewing participants as passive subjects of study, PAR seeks to redistribute power by positioning communities as “co-researchers”. In our reimagining sessions, facilitators are intentional about creating spaces that promote power sharing. Our facilitators actively reflect on their positionality and are intentional in using language and tone that avoids unintended power dynamics. We aim for a genuine devolution of power to whānau, recognising them as experts in their own lives and health journeys.

Reimagining sessions also strongly reflect the principles of service design, particularly user-centredness, co-creation, sequencing and a holistic perspective.^{10,11} Some of these principles overlap with those of PAR—for example, both user-centredness and co-creation align closely with the emphasis on placing whānau experience at the centre of the process and creating conditions for shared decision making. Our approach to co-creation involves extensive collaboration with both community members and service providers, fostering collective ownership over the process and recognising that meaningful, enduring solutions require contributions across organisational and sectoral boundaries.

The principle of sequencing is applied through the use of tools such as journey mapping, touch points and dot voting.¹⁰ Journey mapping visually outlines the steps whānau take when interacting with a service, highlighting key moments, emotions, barriers and opportunities across their experience. Touchpoints are the moments where

whānau interact with the service. These interactions can be physical, digital, relational or environmental and collectively shape the user experience and outcomes. Dot voting is a simple technique that allows whānau to prioritise ideas or challenges by voting on what matters most. This sequencing allows abstract ideas to become more concrete and supports participants to articulate what a better experience might look and feel like.

A holistic lens ensures that the reimagining sessions consider the full ecosystem of care across tangible and intangible elements. Participants are encouraged to reflect not only on individual services but also on broader aspects of the system such as cultural safety, relationships, communication, policies and physical environments. This helps uncover how various parts of the system intersect and affect one another, and what might be required for a more integrated, equitable experience of care.

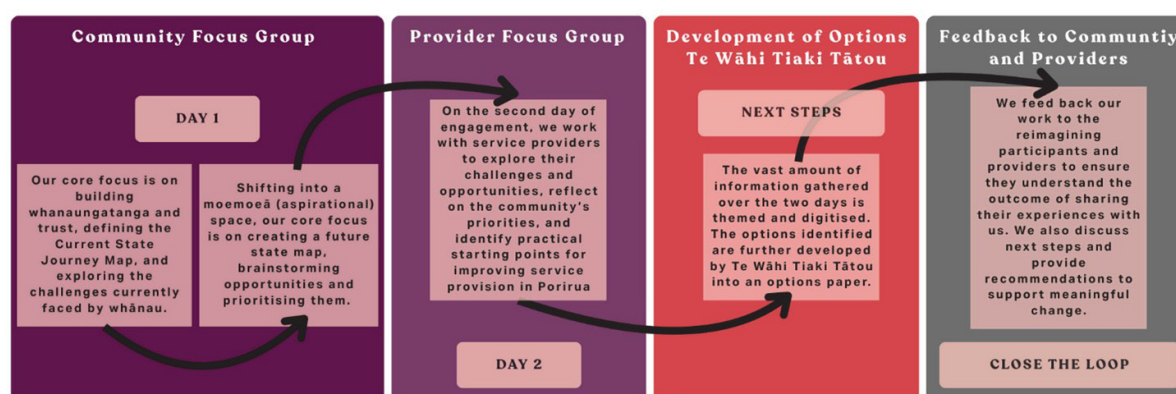
By weaving together service design principles with those of participatory action research, our reimagining sessions provide a space for both critical reflection and forward momentum. Lived experience is not an afterthought; it is central to the analysis and is the primary driver of future action. Whānau are not simply consulted; they are empowered to guide, shape and lead. Through this approach leadership is fostered from within communities, strengthening their capacity to influence decisions and enact lasting change.

Our process | ā tātou tukanga

1. Whanaungatanga

Each reimagining session (Figure 2) is fundamentally grounded in whanaungatanga. The initial hour is typically dedicated to building relationships, guided by a structured set of prompts designed to encourage participants to reflect on

Figure 2: Overview of Te Wāhi Tiaki Tātou reimagining sessions.



their identities and connections to the kaupapa. This approach cultivates a safe, culturally anchored environment, allowing participants to share at their own comfort level. Importantly, it ensures that the engagement is relational rather than extractive. All contributions are treated as valid and unfiltered expressions of lived experience. There is no critique or correction of what is shared or how it is communicated. Facilitators are available to transcribe verbal contributions for participants who may prefer to speak rather than write. This practice ensures that communication preferences or literacy levels do not become barriers to participation and true engagement.

An open invitation is also extended to providers to participate on a separate day to community members, thereby creating space for open and honest kōrero free from power imbalances. Providers generally self-select on the basis of their involvement in delivering services related to the kaupapa of the reimagining session. Establishing a provider arm alongside the community arm is considered essential; just as it is important to envision current and future states with community members, it is equally necessary to engage providers in this process. Provider sessions serve multiple purposes as they enable the identification of potential system-level improvements, create opportunities for providers to share insights across service areas and foster whakawhanaungatanga and relationship building in contexts where services are often delivered in silos. Most importantly, they lay the foundations for subsequently bringing providers together to act collectively on the recommendations that emerge from a combined understanding of lived realities and service delivery contexts.

Invitations to reimagining sessions are disseminated via newsletters, local networks and word-of-mouth. Venues are intentionally selected for their familiarity and trustworthiness to participants, such as community halls, premises within the rūnanga and established spaces our priority community already use. For example, antenatal class locations were used to engage with hapū māmā, family harm support group venues were chosen for engagement with tāne on issues of family violence and The 502 (Porirua's Youth One Stop Shop) was used for engagement with rangatahi on mental health.

2. Journey mapping

Following whanaungatanga, the session proceeds to mapping the participant journey.

Sessions on the journey maps are run in small groups, each facilitated by a member of the Te Wāhi Tiaki Tātou team. A central activity within the reimagining sessions involves the development of two journey maps: one depicting the current experience of accessing or receiving care (current state), and the other illustrating a “blue sky” future, free from barriers (future state). Our team identifies key “touchpoints” along the existing and future health system journey, which are then visually represented on a large timeline. These touchpoints serve to focus discussion and establish a shared frame of reference. Participants individually respond to each touchpoint using sticky notes, a method that mitigates groupthink (a mode of thinking in which individual members of small cohesive groups tend to accept viewpoints that represent a perceived group consensus) and ensures that quieter voices are acknowledged. This individual reflection is subsequently followed by group discussion, often catalysing deeper kōrero and collective insights. Participants are encouraged to contribute thoughts beyond the predefined touchpoints, ensuring inclusivity of all perspectives. Towards the conclusion of each session, participants vote using dots¹⁰ to identify their perceived greatest challenges and opportunities. This helps us prioritise community needs and aspirations in a manner that aligns with community thinking.

3. Shifting the mauri in the room to “reimagine”

At the end of the current state journey mapping, the mauri within the space is often heavy and marked by sadness, frustration and emotional fatigue. Recalling and engaging with past experiences of trauma, harm and systemic failure can leave participants in a diminished emotional state, making it difficult to pivot towards hopeful or forward-looking perspectives. In such a frame of mind, it becomes challenging for individuals to conceptualise meaningful change or to imagine possibilities beyond their lived realities. This emotional weight can constrain the emergence of bold or innovative ideas. Participants may dismiss potential solutions as unrealistic or unachievable, influenced by the persistent presence of structural barriers in their lives. When future thinking is anchored too heavily in current realities, it narrows the scope of imagination and aspiration.^{18,19}

Our aim is to create an environment that enables the community to think ambitiously and cre-

ences, inevitably influences how we interpret journey maps, hear community voice and engage in sense-making. Reflexive practice allows facilitators to examine their assumptions, acknowledge potential biases and consider how their perspectives may shape the process.^{20,21}

In addition to supporting individual wellbeing and self-awareness, debriefing and reflexive practice provide an opportunity to reflect on team performance, share lessons learned and identify areas for improvement.^{22,23} It helps to strengthen facilitation practice and maintain the integrity of the process as it evolves.

5. Closing the loop

Following reimagining sessions with both community and providers, the collected sticky notes are digitised and analysed thematically. The insights are then synthesised into an “options paper” that outlines key findings and recommended areas for action. Critically, this paper is returned to the community for validation. This step ensures that the process remains non-extractive and grounded in the principles of PAR by recognising community members as knowledge holders and decision-makers, not merely data sources. This feedback loop involves recapping the shared input, confirming that the identified themes accurately reflect participants’ perspectives and ensuring that subsequent actions remain firmly grounded in lived experience.

Our learnings | ngā hua o te wānanga

A number of key learnings have emerged through the implementation of our reimagining sessions. These are not entirely novel insights; rather, they reflect established principles and learning on community engagement, both in Aotearoa New Zealand and internationally.^{24–26} The themes identified represent recurring patterns observed by our team across sessions, encompassing both success factors and challenges. Given the small size of our team, all members were typically involved in each session as facilitators or support staff, allowing for consistent observation, comparison and contrast across events.

Time for debriefing was deliberately embedded within the structure of each reimagining session to ensure reflection occurred consistently. These debriefs provided immediate short-term insights, which were subsequently revisited and further analysed during team planning days, allowing

for medium-term reflection. This combination of short-term and medium-term reflection supported iterative learning and ongoing refinement of engagement processes.

Learnings were also informed by informal verbal evaluations conducted at the conclusion of each session with both community participants and providers. The decision to use informal verbal evaluation is intentional, designed to reduce participant burden and accommodate varying literacy levels. Established trust with participants enabled the team to receive constructive feedback as well as positive reflections on the process. Furthermore, sharing thematic findings and recommendations with communities and providers created an additional opportunity for feedback, which further informed and strengthened the lessons learned.

The lesson regarding how community action can achieve meaningful outcomes was informed by the success of implemented contracts, events and initiatives, as well as by both external evaluations of Te Wāhi Tiaki Tātou and internal formative and process evaluations conducted on specific projects.

Trusted faces in trusted places: Relationships matter. We rely heavily on the existing connections between our team and the community, who are familiar with, respectful of, and grounded in local kaupapa, fostering trust and rapport. Additionally, hosting sessions in locations already frequented and trusted by participants helps to reduce barriers to engagement and enhances participants’ sense of psychological safety.

Manaakitanga: We adapt our sessions to the needs of participants. This may involve shortening sessions for individuals with certain health conditions, enabling hapū māmā to bring their pēpi and tamariki or offering transport to remove logistical barriers. We also provide kai and koha as a tangible gesture of appreciation for the time, energy and knowledge shared by participants. We recognise that achieving equity in engagement requires different approaches for different people.

Decolonising engagement: Our practice centres Indigenous and community norms rather than imposing Western or clinical models of engagement. This approach has resonated strongly with our diverse community in Porirua, a population characterised by a mix of cultures, ethnicities and age groups.³ We have seen how Indigenous practices can create inclusive environments where all participants feel empowered and com-

fortable to contribute. This has enabled us to gather meaningful insights and evidence from a wide range of whānau, including those often marginalised in conventional consultation processes.

The challenge of reimagining: While the future-focussed parts of the sessions are powerful, it is inherently difficult to imagine what we have not yet experienced. For many participants, envisioning a radically different or improved health system was challenging when current realities are marked by systemic barriers, marginalisation or unmet need. We found that articulating a system that does not yet exist presents a significant cognitive and emotional challenge for the community. This therefore underscores the importance of creating space for imagination while also recognising and respecting the limitations participants may face in engaging with future-focussed thinking.

Shifting the mauri through emotion: We observed that community members are better able to express aspirations when invited to do so from an emotional standpoint, focussing on how an improved system would make them feel. When participants begin to share their future visions through the language of emotion, the mauri within the space begins to shift. This emotional anchoring creates a more positive, hopeful atmosphere and enables deeper, more imaginative engagement with future possibilities. Our role in facilitating is to support and gently guide this process, without imposing expectations, and to honour whatever people can offer.

Community-led action is possible with the right approach: We have demonstrated that community-led action is highly effective when supported by the right approach. Te Wāhi Tiaki Tātou has successfully influenced the implementation of multiple recommendations from a range of reimagining sessions. Some initiatives were realised through government funding and/or voluntary time and resource donation. Importantly, we were also able to

achieve recommendations from reimagining sessions by refining existing processes and reprioritisation, meaning that change could be achieved even without requiring significant new investment. Some examples of initiatives derived from reimagining session recommendations are provided in Appendix Table 1.

Conclusion

As part of Te Wāhi Tiaki Tātou's mission, reimagining sessions help to ensure that the voices and aspirations of Porirua whānau are not only heard but embedded in the realisation of hauora within our rohe. Reimagining sessions offer a grounded, respectful and action-oriented model for capturing community knowledge. They create space to surface felt needs, those everyday pain points and realities that may be invisible in service utilisation data or clinical outcomes but deeply affect wellbeing.

Our sessions have demonstrated that even a small team, when guided by strong values and trusted relationships, can facilitate meaningful engagement that shifts how services are conceived and delivered. The insights shared in these sessions are more than personal stories—they are a form of evidence, a source of direction and, most importantly, they are expressions of tino rangatiratanga. This enables whānau-led change that leads to more culturally safe, equitable and effective models of care. Ultimately, reimagining sessions reflect a deeper shift: from consultation to collaboration, from systems-centred to whānau-centred, and from static services to evolving, community-informed services.

**Mā te whakarongo, ka mōhio, mā te mōhio,
ka mārama, mā te mārama, ka matau, mā te
matau, ka ora.**

**Through listening, comes knowledge,
through knowledge, comes understanding,
through understanding, comes wisdom,
through wisdom, comes wellbeing.**

COMPETING INTERESTS

Nil.

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Appendix

Appendix Table 1: Examples of initiatives derived from reimagining sessions.

Initiative	Reimagining sessions	Details
Porirua free dental event	Dental	We ran a dental event across 4 days in Porirua. Three hundred and twenty-eight people received 1,019 procedures, including 180 extractions and 122 fillings. On average, each patient saved NZ\$616—exceeding the median weekly income in Porirua. Nearly 70% of participants were from high-deprivation suburbs, with 42.9% identifying as Māori and 59.1% as Pacific. The event mobilised 43 dental professionals, 29 dental assistants and 33 volunteers, some travelling from as far as Invercargill and Taranaki. In addition to treatment, participants were offered oral health education, smoking cessation support, nicotine replacement therapy and blood pressure checks. Funding was available through Health New Zealand – Te Whatu Ora.
Supervised toothbrushing programme Year 4, Corinna School	Dental	We developed, implemented and evaluated a supervised toothbrushing programme at Corinna School. Corinna School is situated in Waitangirua, a decile 10 suburb in Porirua with a majority Pacific and Māori roll. Each tamariki in Year 4 received two toothbrush and toothpaste sets for home and school use, achieving 100% participation among students present at school. Tamariki demonstrated improvements in oral symptoms, function and emotional and social wellbeing. By the end of the programme, 60% of tamariki either improved or maintained twice-daily brushing, 87% used fluoride toothpaste and 40% brushed for the recommended 2 minutes. Funding was available through Health New Zealand – Te Whatu Ora and voluntary donations from Colgate.
Porirua Has Talent	Rangatahi mental health Resilience to organised crime	We were able to channel funding for Real Talk to carry out three events at high schools in Porirua, which enabled them to reach vulnerable whānau. Anecdotal evidence from participants highlighted the initiative’s life-changing influence, with both rangatahi and community members sharing positive responses and expressing gratitude for the space to discuss vital issues. Further events are planned following funding through the Resilience to Organised Crime in Communities (ROCC) programme.
Rangatahi mental health symposium for providers	Rangatahi mental health	We co-hosted a symposium for 140 kaimahi from Porirua and the wider Wellington Region. Four speakers—Reo Va’a, Dr Wendy Allan, Catherine Daniels and Dr Sascha Feary—provided insights on trauma-informed care, resilience and whānau-centred approaches. Participants highlighted the event’s effective balance of challenging kōrero with opportunities for connection and reflection, reporting increased energy and a stronger sense of professional community. A livestream extended access to those on the waitlist. The event was funded by Atareira and Child and Adolescent Mental Health Services (CAMHS).
Midwife to Well Homes referral process	Hapū māmā	We collaborated with Wellington Maternity Care Services and lead maternity carers to identify barriers to referral to Well Homes, provide education on the service and streamline referral processes. Referral pathways were simplified and partially automated, achieving these improvements without additional funding.

Appendix Table 1 (continued): Examples of initiatives derived from reimagining sessions.

Resource co-design	Hapū māmā	Work is currently underway to co-design an antenatal resource aimed at hapū rangatahi following identification of resource gaps through our reimagining session. This mahi is funded by the Maternity Quality and Safety Programme, Health New Zealand – Te Whatu Ora.
Te Rerenga o Porirua	Multiple kaupapa	Across multiple kaupapa, we heard a consistent theme on how the quality of care is closely linked to how well providers understand and respond to the cultural identities of the communities they serve. In response, we developed a cultural competency and history course for providers, modelled on the Wall Walk developed by Dr Simone Bull. Te Rerenga o Porirua offers a locally grounded exploration of the history, diversity and lived experiences that shape Porirua, with contributions from cultural experts and endorsements from Pacific and former refugee communities. The course equips participants with the knowledge and empathy needed to foster inclusive, culturally safe environments. To date, over 400 kaimahi from providers across the Wellington Region have participated, providing very positive feedback. Funding was available through localities.
Tai Ora	Multiple kaupapa	Across multiple kaupapa we heard how community wanted access to Rongoā Māori. We created Tai Ora as a community-led healing service offering Mirimiri, Romiromi and Fofō delivered by experienced practitioners in Porirua. This was available to patients registered with Ora Toa PHO at no cost. Funding was available through localities.
WELLfed cooking programme	Diabetes	The WELLfed Diabetes Cooking Programme was developed as a collaborative initiative with WELLfed, informed by insights from the diabetes reimagining session. It brings together trusted local providers to deliver education that promotes awareness and supports holistic, community-centred diabetes management. The programme is delivered in Cannons Creek, Porirua, as an 8-week series of workshops combining diabetes self-management education with practical cooking sessions. Each session includes discussions on key diabetes topics, hands-on cooking where participants prepare and take home diabetes-friendly meals, and engagement with health professionals offering information on various aspects of diabetes care. The programme has achieved positive outcomes, with some participants reporting improvements in diabetes management and, in certain cases, reversal of their condition through sustained application of the skills learned. This programme required a small amount of initial funding, followed by reprioritisation of existing funds.
Autism education in early childhood education centres and kōhunga	Neurodiverse learners Tāngata whaikaha	We are collaborating with Autism NZ to provide information sessions supporting whānau and staff working with tamariki in early childhood education centres and kōhunga. This initiative requires no additional funding.
Peer support groups	Tāngata whaikaha	At the request of the community via reimagining sessions, we have established peer support groups for tāngata whaikaha in Porirua. This group is open to all persons with disabilities, their whānau and support people. This initiative requires no additional funding.

Appendix Table 1 (continued): Examples of initiatives derived from reimagining sessions.

Drug checking clinics	Resilience to organised crime	Recommendations on undertaking a harm reduction approach has led to the establishment of drug checking clinics in Porirua in collaboration with Know Your Stuff. This initiative requires no additional funding.
Toa Noho Tahi	Resilience to organised crime	Access to Mauri Ora was identified as a recommendation during reimagining sessions. We have channelled funding to Toa Noho Tahi to deliver a culturally grounded, holistic approach that bridges the gap between rangatahi and mainstream services through practical skill development, cultural reconnection and a focus on collective wellbeing. This initiative is funded through the Community Resilience and Whānau Support Fund.
WELLfed youth: collaboration and expansion	Resilience to organised crime	Reimagining sessions identified a need for rangatahi-specific programmes on developing life skills. We have enabled a partnership with Challenge 2000 (social workers in Porirua colleges) and WELLfed. WELLfed is co-designing and delivering a rangatahi-focussed programme centred on connection, cooking, nutrition and healthy eating habits. This expanded initiative will increase our reach and impact, empowering more young people across the community to build lifelong skills and wellbeing. This initiative is funded through the Community Resilience and Whānau Support Fund.
Vehicle for Change	Resilience to organised crime	Reimagining sessions identified a need for further support programmes for tāne. Vehicle for Change provides advocacy and support for men, and additional staffing support for the Tu Tiaki men's group sessions. This initiative is funded through the Community Resilience and Whānau Support Fund.
Hurihanga	Resilience to organised crime	Reimagining sessions identified a need for support for tāne and opportunities for enriching activities. Hurihanga Kaimahi from Wesley Community Action work with whānau living in Waitangirua who identify as members of gang communities, as well as members of the wider community. Hurihanga promotes a pro-social and pro-family approach with a strong emphasis on harm reduction. They work to increase connectivity to the community through a range of activities such as sport, pathways to employment, driver licensing and first aid and diving courses. This initiative is funded through the Community Resilience and Whānau Support Fund.
Rangatahi camp	Resilience to organised crime	Our reimagining insights have enabled Who Did You Help Today? to scope and plan a camp pilot for tamariki and rangatahi from Porirua with imprisoned parents and/or primary caregivers. The camp will offer opportunities for tamariki and rangatahi to build positive relationships with peers in a safe and supportive environment. This initiative is funded through the Community Resilience and Whānau Support Fund.
Boxing	Resilience to organised crime	Our reimagining sessions identifying the need for enriching activities and opportunities for physical activity has enabled Cannons Creek Boxing Academy in Porirua to help youth find belonging, mentorship and the strength to transform their futures through boxing. This initiative is funded through the Community Resilience and Whānau Support Fund.
Youth role models	Resilience to organised crime	Our reimagining sessions identifying the need for young people to have access to role models has enabled Big Brothers Big Sisters to provide taiohi/young people with positive role models, guidance and friendship. This initiative is funded through the Community Resilience and Whānau Support Fund.

Appendix Table 2: Te reo Māori glossary | Kuputaka te reo Māori.

Kupu (word)	Definition
ā tātou tukanga	our process
hapū māmā	pregnant women
hauora	health/wellbeing
iwi	extended kinship group, tribe, nation, people, nationality, race
kai	food
kaimahi	staff
kaupapa	topic, subject, matter for discussion, issue
koha	gift, offering, donation, contribution
kōrero	discussion
mahi	work
mana whenua	territorial rights, power from the land, authority over land or territory, jurisdiction over land or territory—power associated with possession and occupation of tribal land
manaakitanga	hospitality, kindness, generosity, support—the process of showing respect, generosity and care for others
mauri	life principle, life force, vital essence, special nature, a material symbol of a life principle, source of emotions—the essential quality and vitality of a being or entity; also used for a physical object, individual, ecosystem or social group in which this essence is located
ngā hua o te wānanga	our learnings
pēpi	baby
pūrākau	myth, ancient legend, story
rangatahi	youth, young people
rito	centre shoot, young centre leaf of the harakeke, new harakeke shoot
rohe	area
Rongoā Māori	traditional Māori medicine—a system of healing that is comprised of diverse practices and an emphasis on the spiritual dimension of health; Rongoā includes herbal remedies, physical therapies such as massage and manipulation, and spiritual healing
rūnanga	refers to Te Rūnanga o Toa Rangatira, which is the mandated iwi authority for Ngāti Toa Rangatira, and the administrative body of iwi estates and assets

Appendix Table 2 (continued): Te reo Māori glossary | Kuputaka te reo Māori.

taiohi	youth, adolescent, young person
tamariki	child
tāne	male, man
tāngata whaikaha	disabled people
tino rangatiratanga	self-determination, sovereignty, autonomy
whakapapa	genealogy, genealogical table, lineage, descent
whakawhanaungatanga	process of establishing relationships, relating well to others
whānau	extended family, family group
whanaungatanga	relationship, kinship, sense of family connection—a relationship through shared experiences and working together, which provides people with a sense of belonging

Epidemiology of bone and joint infection in Pacific children from the Auckland Region, 2018–2023

Sarah Hunter, Elsie Brown, Corina Grey

ABSTRACT

BACKGROUND: Children of Pacific ethnicity living in New Zealand have the second highest incidence of bone and joint infections (BJI) globally. This paper reports illness characteristics and outcomes for Pacific children diagnosed with acute haematogenous osteomyelitis (AHO) or septic arthritis (SA) from the Auckland Region over a 5-year period. It also reports features associated with severe and complex disease.

METHODS: Cases included all children aged ≤ 15 years hospitalised for AHO or SA in the Auckland Region, 1 January 2018–31 September 2023. Prioritised ethnicity was identified from hospital records. Direct medical hospitalisation costs, treatment type and outcomes were described up to 1 year following discharge. Complex illness was defined as recurrence/chronic infection, readmission, intensive care admission, complication following treatment or >1 surgical procedure.

RESULTS: Of 563 cases of acute BJI, 152 were children identifying as Pacific ethnicity. Compared with NZ European children with BJI, Pacific children had more eczema (34% vs 19%, $p=0.002$), multifocal sepsis (30% vs 10%, $p<0.05$) and surgical intervention (61% vs 47%, $p=0.01$) with lengthier hospitalisations (14 days vs 9 days, $p=0.001$). Most Pacific children experienced complex illness (66%). Complex illness was associated with cultures positive for *Staphylococcus aureus* and eczema diagnosis. In regression analysis, complex illness was less likely for children with a previous throat swab positive for group A *Streptococcus* (GAS).

CONCLUSION: Pacific children with BJI experience more severe illness compared with NZ European children with BJI. Eczema is common among Pacific children with BJI. Proactive eczema management may represent suitable focus for disease prevention. Prior GAS throat swab appears associated with reduced rates of complex illness.

Childhood bone and joint infection (BJI) is common in New Zealand with inequitable distribution by ethnicity.¹ Illness experience is variable. While many cases can be effectively managed with short courses of antibiotics, some children develop severe and life-threatening sepsis requiring multiple surgeries and intensive care admission.² Severe illness is also inequitably distributed by ethnicity, and reasons for this are incompletely understood.³

Within New Zealand, Pacific children experience the highest rates of childhood BJI with severe forms of disease.^{4,5} Despite this, illness features and experiences for Pacific children have not been well characterised. Recent epidemiological reports have focussed on case differences between NZ European and Indigenous Māori children, or have combined Māori and Pacific ethnicities in analysis.^{4,6,7} The Auckland Region is home to 64% of the Pacific population in New Zealand, and also has the largest population of Pacific peoples living outside of Polynesia.^{8,9} This is a relatively young population, with a third of Pacific people

in Auckland under the age of 14.¹⁰ Improved understanding of disease epidemiology in Pacific children is a necessary step in designing public health interventions to lower incidence.

Identifying risk factors for severe and complex illness is also crucial, given the serious physical, social and economic consequences of disease.¹¹ Mortality following paediatric intensive care unit (PICU) admission for musculoskeletal sepsis ranges from 5 to 10%.^{3,5} Direct hospitalisation costs to manage these cases can reach NZ\$3 million.³ In addition, disease sequelae can negatively affect quality of life in children more than a decade after treatment.¹² Admission to PICU and severe illness are frequent in Pacific children with BJI but risk factors for these complications have not previously been identified for this ethnic group. Comprehensive knowledge of risks for severe illness is useful for both clinicians and the wider community, with the overall goal of reducing disease impact.

This research aimed to examine illness characteristics and outcomes for Pacific children

diagnosed with acute haematogenous osteomyelitis (AHO) or septic arthritis (SA) from the Auckland Region. Features associated with severe and complex disease were also explored.

Methods

Health and Disability Ethics Committee approval was obtained for this study, together with institutional review board approval (reference: 19/NTA/46). This was a retrospective analysis of all cases of suspected osteomyelitis and SA managed in the Auckland Region from 1 January 2018 to 31 September 2023, with focus on Pacific patients. Children from birth to age 15 years were included. Cases of chronic infection, penetrating injuries, post-viral or reactive arthritis, post-operative infection, cases associated with significant malignancy or patients with insufficient clinical data for analysis have been excluded.

A comprehensive review of electronic clinical records was conducted. Data were collected on patient demographics, illness presentation and disease type. Ethnicity was identified from the hospital record, which is self-identified with prioritised grouping. Prioritised ethnic grouping allocates individuals to a single ethnic group based on this order: Māori, Pacific peoples, Asian, and European/Other.¹³ Census data are also prioritised. Socio-economic deprivation was measured using the 2018 New Zealand Index of Deprivation (NZDep), a surrogate marker for hardship based on residential address.¹⁴

AHO and SA incidence (by ethnicity, number of cases/100,000 children/year) was estimated using as the denominator the number of usually resident children ≤ 15 years in the Auckland Region by prioritised ethnicity according to the 2018 Census.

AHO was defined based on radiographic investigation via magnetic resonance imaging (MRI) or computed tomography (CT) and/or positive intraoperative culture or bone biopsy. SA was identified based on intraoperative culture results, culture results from aspirate or positive radiographic investigation in the setting of positive blood culture. All cases were followed for a minimum of 12 months.

Economic information was included to derive hospitalisation cost. The cost of hospitalisations was determined using a weighted discharge value (i.e., Weighted Inlier Equivalent Separations [WIES]) for all National Minimum Dataset (NMDS) events as calculated by the Ministry of Health.¹⁵

The NMDS is a national collection of public and private hospital discharge information. This paediatric WIES cost-weight encompasses medical costs, ward stays, medications, laboratory investigations, operations and nursing and other ward staff. It is based on length of stay and diagnostic-related groups (DRGs), with additional costs for interventions such as mechanical ventilation and intensive care. DRGs are billing codes for similar diagnoses grouped by resource need. To give a cost of hospitalisation, each encounter is assigned a DRG and purchase unit with weighting, which can be multiplied by the cost-weight unit price for the year of admission. In 2018/2019, the cost-weight unit price was NZ\$5,068.12, with most common purchase units either S45.01 or M55.01. A total cost of admission was produced using the WIES in New Zealand dollars (NZ\$). The total cost included the cost of related re-admissions within 12 months.

Children of Pacific ethnicity were compared to NZ European cases with regard to comorbidities, demographics, illness characteristics, treatments and outcomes.

Additional sub-group analysis was undertaken to look for patient and illness characteristics associated with complex illness among Pacific children. Complex illness was defined as recurrence/chronic infection, readmission, intensive care admission, complication following treatment or >1 surgical procedure. All statistical analysis was undertaken using RStudio. Statistical significance was evaluated using Chi-squared or *t*-Tests for continuous variables. Logistic regression analysis was performed (multivariate), examining factors associated with severe illness.

Results

An initial 994 cases were identified by clinical coding. Of these, 563 met criteria for acute BJI. Case selection is demonstrated in Figure 1. Between 2018 and 2023, 27% of BJI hospitalisations were Pacific children ($n=152$) and 31% ($n=175$) were European (Table 1).

Using the 2018 New Zealand Census, incidence of AHO was 38.5/100,000/year (95% confidence interval [CI] 27.7–52.1) for Pacific children and 17.1/100,000/year (95% CI 13.5–31.5) for European children.

Compared to European cases of BJI, Pacific children were older on average (median age 8.5 years vs 5.0 years, $p<0.05$) (Table 1). Median NZDep index was higher, indicating Pacific children

with BJI reside in neighbourhoods of greater socio-economic deprivation compared with European children with BJI (10 vs 4, $p<0.05$).

Duration of symptoms prior to hospitalisation was not statistically dissimilar between Pacific and European ethnic groups (3 days vs 4 days, $p=0.8$) (Table 1). A greater proportion of European children had a pre-hospital assessment at a community medical centre (67% vs 45%, $p<0.05$).

Disease subtypes (AHO and SA) were equivalent in both groups (Table 1). However, Pacific children appear to have more severe illness. A higher proportion presented with multifocal sepsis (30% vs 10%, $p<0.05$) or bacteraemia (60% vs 34%, $p<0.05$). Contiguous infection, defined as subperiosteal abscess, pyomyositis or AHO with adjacent SA, was more common among Pacific children (53% vs 39%, $p=0.03$). Pacific children were more likely to have disease secondary to *Staphylococcus* or *Streptococcus* (67% vs 39%, $p<0.05$), as well as methicillin-resistant *Staphylococcus aureus* (MRSA) (19% vs 3%, $p<0.05$).

Surgical intervention was more frequent in Pacific children (61% vs 47%, $p=0.01$), with a greater proportion having >1 operation (30% vs 18%, $p=0.01$) (Table 2). Duration of hospitalisation was also longer on average (13.7 days vs 8.9 days, $p=0.001$). Average hospitalisation cost and length of antibiotic treatment were not statistically dissimilar.

Once discharged, European children had higher readmission rates at 30 days (26% vs 14%, $p=0.008$) (Table 3). However, almost half of readmissions for European children were due to antibiotic and/or peripherally inserted central catheter (PICC) complications. Rates of chronic osteomyelitis were statistically equivalent for both ethnic groups, between 2 and 3% at 12 months following treatment.

Two-thirds of Pacific children had complex or severe forms of BJI ($n=102$, 67%) (Table 4). Among Pacific children, complex illness was associated with an eczema diagnosis (70% vs 40%, $p=0.01$) and was more likely with disease secondary to MRSA, *Staphylococcus* or *Streptococcus*. Conversely, a previous throat swab positive for group A *Streptococcus* (GAS) was more common in those without complex illness.

In binary logistic regression modelling, a prior GAS throat swab was associated with reduced odds of complex illness (odds ratio [OR] 0.37, $p=0.02$) (Table 5). Gram-positive organisms were associated with higher odds of complex illness (OR 4.6, $p<0.05$). Notably, residing in a more deprived

neighbourhood was not associated with complex illness in univariate analysis or multivariate regression.

Discussion

This study examined illness characteristics, treatments and outcomes for Pacific children with BJI in the Auckland Region, demonstrating a high incidence of disease as well as high rates of severe and complex illness. Compared with European children, Pacific children were more likely to present with multifocal sepsis, undergo more surgical intervention and have lengthier hospitalisations. An eczema diagnosis was more frequent for Pacific children than European children in our cohort and appears to be associated with complex illness. Conversely, a previous throat swab positive for GAS was associated with less complicated forms of infection. Gram-positive pathogens, including MRSA, increased odds of severe or complex illness for Pacific children in regression analysis.

Global incidence reporting for acute childhood BJI suggests Pacific children may have the second highest rate of AHO worldwide, following Aboriginal Australians.^{1,16–19} With incidence reaching 38/100,000/year in our study, rates among Pacific children exceed recent reporting for both Māori and European children in New Zealand. Our study setting is uniquely equipped to detect incidence for Pacific children, as it has been conducted in the region with the largest Pacific population in New Zealand.⁸ It is important to note that not only are disease rates elevated, complex and severe illness was more prevalent for Pacific children. We have identified a greater duration of hospital stay and increased number of surgeries, which escalates the impact of BJI for patients and families. It is clear that inequitable distribution of childhood BJI represents a significant public health problem, disproportionately impacting Pacific communities.

Eczema was common among Pacific children in our study and may represent a risk factor for acute BJI in this group. Importantly, prevalence of childhood eczema for Pacific children hospitalised with BJI appears to be higher than community rates. Recent observational studies report eczema prevalence at 23% for Pacific children in the community and 14% for NZ European.²⁰ In contrast, 34% of Pacific children with BJI in our study had an eczema diagnosis.²⁰ Prevalence was even higher among those with severe illness, with

70% of children having an eczema diagnosis. Eczema may contribute to invasive infection risk in several ways. Recent literature suggests higher rates of dermal *Staphylococcus aureus* colonisation in those with concurrent eczema diagnosis.²¹ In addition, dysbiosis of the skin flora and loss of other skin commensals in the setting of eczema can enhance *Staphylococcus aureus* virulence. Finally, immune response may be diminished for children with chronic eczema.²² If eczema status represents a risk factor for severe forms of childhood BJI, proactive and effective eczema management at a primary care level may be a suitable focus for disease prevention. Future research should explore the impact of eczema treatment on risk mitigation.

Pre-hospital duration of symptoms was equivalent for European and Pacific children, although community medical care consultation was more common for European patients. This likely relates to both healthcare access and the severity of illness among Pacific children.²³ In a contemporary longitudinal study of child development in New Zealand, Pacific and Māori children were found to experience more barriers to primary care consultation than children of European ethnicity.²³ Furthermore, Pacific children with BJI in our cohort more commonly presented with multifocal sepsis and bacteraemia. In this context, immediate hospital attendance is appropriate to minimise treatment delay.

A previous positive throat swab for GAS was associated with less severe forms of BJI in our study. This finding has clinical implications for identifying those at high risk of severe disease. Relative risk for GAS pharyngitis is higher among Māori and Pacific children in New Zealand and exhibits similar population distribution to childhood BJI.²⁴ It is possible that the relationship

between illness severity and previous GAS exposure could relate to adaptive immunity. This theory postulates that antibodies from previous GAS exposure confer enhanced response to invasive BJI with *Streptococcus pyogenes*.^{25,26} Further research is required to define whether children presenting with BJI and no prior GAS exposure could be considered at higher risk of complex illness.

One limitation of incidence reporting in this cohort is the use of prioritised ethnic grouping. More than 20% of Pacific peoples in New Zealand also identify as Māori, but would be classed as “Māori” using priority grouping. Not including those with dual ethnicity could mask a potentially higher incidence rate for Pacific children.^{13,27} A second limitation is use of the hospital electronic record system. Without full access to community care records, it is difficult to correctly record eczema prevalence in this cohort, which may be underestimated. Additionally, children who have relocated may have absent or incomplete community laboratory records and GAS swab results. Finally, a difference in hospitalisation cost may exist between European and Pacific cases but be masked by the inclusion of PICU cases. PICU cases are managed at significantly greater hospitalisation cost, contributing to wide CIs.³

Overall, this study has established that Pacific children with BJI experience more severe illness compared with NZ European children with BJI. Eczema is common among Pacific children with BJI. These findings highlight proactive and effective eczema management in the community as a potentially important measure to prevent more serious disease. Prior GAS throat swab appears associated with reduced rates of complex illness in this cohort.

Figure 1: Patient selection flow chart.

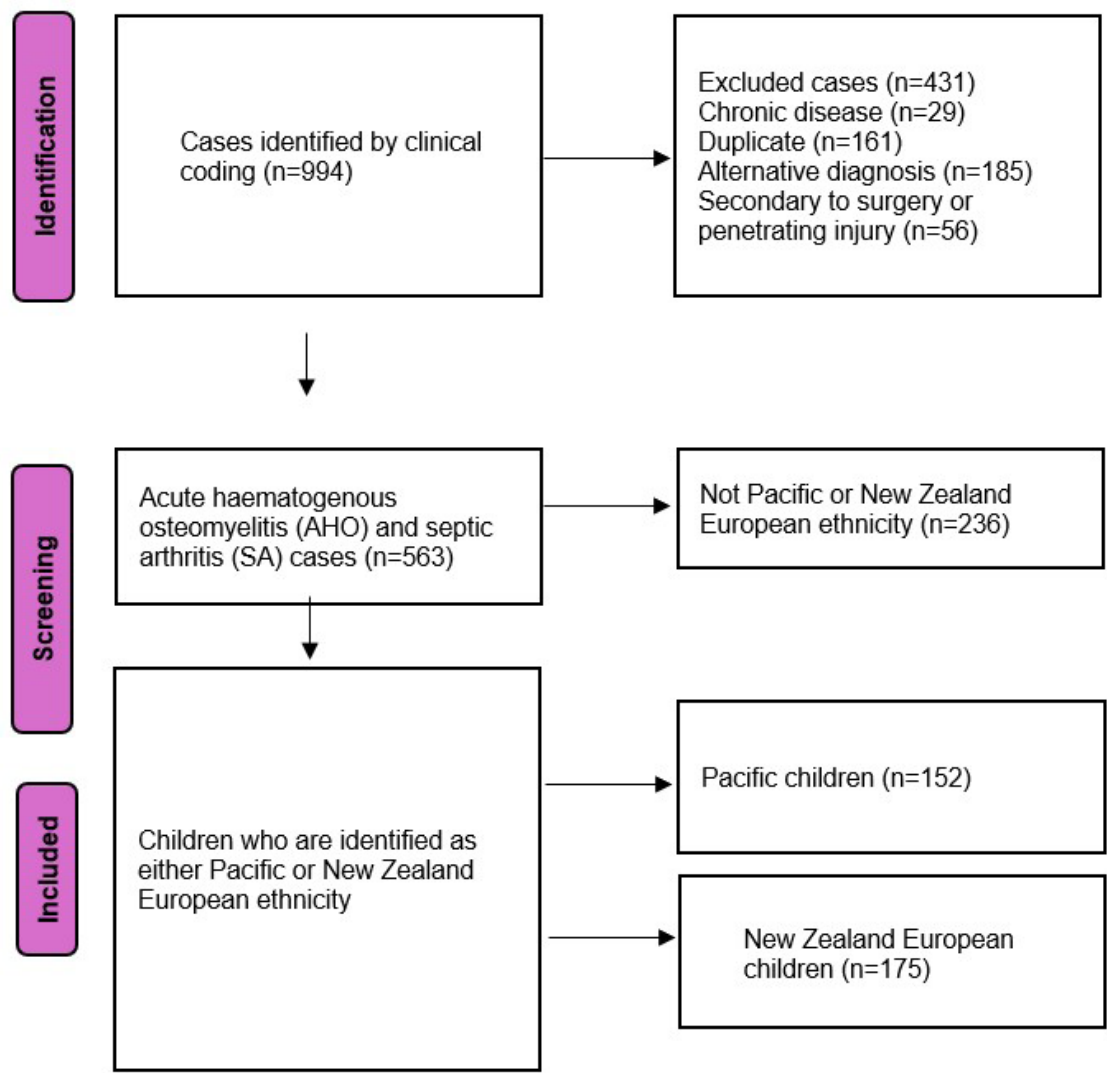


Table 1: Comparison of demographic data, Pacific children with BJI vs NZ European children with BJI.

	Pacific		NZ European		P-value
	N	%/SD	N	%/SD	
Number of cases	152		175		
Male	108	71%	103	59%	0.02
Female	44	29%	72	41%	0.02
Average age (median, IQR)	8.5(8)	4.5	5(9)	5%	0.0004
Duration of symptoms (IQR)	3.0(4)	5.1	4.0(5)	6	0.8
Median NZDep	10	1.7	4	2.6	<0.00001
Primary or urgent care consultation prior to hospitalisation	69	45%	117	67%	0.0009
Previous GAS positive throat swab	67	44%	28	16%	<0.00001
Eczema	52	34%	34	19%	0.002
Asthma	23	15%	23	13%	0.6
Congenital condition	1	1%	9	5%	0.01
Viral illness prior to admission	39	26%	79	45%	0.0002
Non-weight bearing on arrival	113	74%	158	90%	0.001
Febrile on arrival	121	80%	142	81%	0.3
Present with septic shock	11	7%	6	3%	0.12
Acute haematogenous osteomyelitis	121	80%	138	79%	0.02
Septic arthritis	31	20%	37	21%	0.02
Osteomyelitis location:					
Lower limb	71	59%	90	65%	0.4
Upper limb	26	21%	17	12%	0.02
Pelvis	17	14%	21	15%	0.07
Spine	5	4%	8	6%	0.5
Other	2	2%	2	1%	0.9
Contiguous disease*	64	53%	54	39%	0.03
Multifocal sepsis	36	30%	14	10%	<0.00001
Positive blood culture	73	60%	47	34%	<0.00001
MRSA	23	19%	4	3%	<0.00001

Table 1 (continued): Comparison of demographic data, Pacific children with BJI vs NZ European children with BJI.

Culture positive for <i>Staphylococcus</i> or <i>Streptococcus</i>	102	67%	69	39%	<0.00001
Culture negative or <i>Kingella kingae</i>	43	28%	104	59%	<0.00001

*Contiguous disease defined as subperiosteal abscess, pyomyositis or osteomyelitis with adjacent septic arthritis.

BJI = bone and joint infection; SD = standard deviation; IQR = interquartile range; NZDep = New Zealand Index of Deprivation; GAS = group A *Streptococcus*; MRSA = methicillin-resistant *Staphylococcus aureus*.

Table 2: Characteristics of treatment, Pacific children with BJI vs NZ European children with BJI.

	Pacific (N=152)		NZE (N=175)		Pacific vs NZE
	N	%/SD	N	%/SD	P-value
MRI scan	101	66%	116	67%	0.9
Surgical intervention	92	61%	82	47%	0.01
>1 surgery	45	30%	32	18%	0.01
Average days between admission and surgery	1.1	2.3	1.2	3.1	0.9
Converted to surgical management	7	5%	8	5%	0.9
PICU admission	14	9%	11	6%	0.3
Average total abx duration	41.2	18.3	38.8	16.1	0.2
Average IV abx duration	20.8	19.9	18.5	18.4	0.3
Average oral abx duration	20.5	15.3	21.1	14.6	0.7
OPIVA	46	30%	65	38%	0.2
LOS in days	13.7	14.30	8.9	12.3	0.001

BJI = bone and joint infection; NZE = New Zealand European; SD = standard deviation; MRI = magnetic resonance imaging; PICU = paediatric intensive care unit; abx = antibiotics; IV = intravenous; OPIVA = outpatient intravenous antibiotics; LOS = length of stay.

Table 3: Outcomes following treatment, Pacific children with BJI vs NZ European children with BJI.

	Pacific (N=152)		NZE (N=175)		Pacific vs NZE
	N	%/SD	N	%/SD	P-value
Readmission <30 days	22	14%	46	26%	0.008
Readmission <1 year	22	14%	28	16%	0.6
Antibiotic/PICC-related readmission	3	2%	21	12%	0.0005
Readmission for surgery	28	18%	30	17%	0.02
Recurrent disease	4	3%	13	7%	0.03
Chronic osteomyelitis	3	2%	5	3%	0.6
Growth disturbance	1	1%	4	2%	0.2
Amputation	1	1%	1	1%	0.9
DVT	4	3%	4	2%	0.8
Pathological fracture	1	1%	4	2%	0.2
Leg length discrepancy	1	1%	2	1%	0.6
Average number clinic visits	3.1	3.5	3.5	4.2	0.2
Average hospitalisation cost NZD	49,179.51	233,088.15	47,604.28	282,636.83	0.48

BJI = bone and joint infection; NZE = New Zealand European; SD = standard deviation; PICC = peripherally inserted central catheter; DVT = deep vein thrombosis; NZD = New Zealand dollars.

Table 4: Features of BJI in those with and without complex illness.

Features associated with complex illness* in Pacific children, univariate analysis					
	Pacific children with complex illness (n=102)		Pacific children without complex illness (n=50)		P-value
	N	%/SD	N	%/SD	
Median age	8.6	4.2	7	4.6	0.04
Average NZDep	9	1.5	8.6	2.1	0.3
Least deprived quintile	9	9%	3	6%	0.5
Most deprived quintile	72	71%	39	78%	0.08
Previous diagnosis of infection	33	32%	19	38%	0.5
Previous positive GAS swab	38	37%	29	58%	0.02
Eczema status	71	70%	21	42%	0.001
Median symptom duration in days	5	5.5	4.7	4.3	0.8
Culture positive for <i>Staphylococcus</i> or <i>Streptococcus</i>	83	81%	22	44%	<0.001
Culture positive for MRSA	20	20%	3	6%	0.03

*Complex illness definition: recurrence/chronic infection, readmission, PICU, complication, >1 surgery

BJI = bone and joint infection; SD = standard deviation; NZDep = New Zealand Index of Deprivation; GAS = group A *Streptococcus*;

MRSA = methicillin-resistant *Staphylococcus aureus*.

Table 5: Binary logistic regression analysis for severe and complex illness.

Model Chi-square	31.18	Degrees of freedom	7
		p-value	5.77E-5
Regression statistics			
Variables	Odds ratio	Confidence intervals	p-value
Any prior infection history	1.08	0.43–2.73	0.87
Prior GAS positive throat swab	0.37	0.16–0.85	0.02
Recurrent tonsillitis	0.33	0.06–1.71	0.19
Eczema diagnosis	0.6	0.24–1.47	0.26
MRSA	3.33	0.66–16.72	0.14
Culture positive for <i>Staphylococcus</i> or <i>Streptococcus</i>	4.58	1.94–10.79	4.98E-4
NZDep 10	1.22	0.51–2.91	0.66

GAS = group A *Streptococcus*; MRSA = methicillin-resistant *Staphylococcus aureus*; NZDep = New Zealand Index of Deprivation; LCL = lower confidence interval; UCL = upper confidence interval.

COMPETING INTERESTS

SH is employed as a clinical research training fellow of the Health Research Council of New Zealand. CG reports support from the NZ College of Public Health Medicine to attend a recent Annual Scientific Meeting (September 2025). CG holds a leadership or fiduciary role in Public Health Observatory of NZ (PHONZ) and is a Vaka Tautua board member.

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CTPA and pulmonary embolism rates between Māori and European populations in Hauora a Toi Bay of Plenty, New Zealand

Thomas H E Clark, Catherine Song, Matthew B Wheeler, Chris Frampton

ABSTRACT

AIM: Previous research suggested that Māori patients have a lower incidence of pulmonary embolism (PE) compared to Europeans.⁵⁻⁷ The aim of this study was to re-examine this in the Bay of Plenty (BOP) region of Aotearoa New Zealand.

METHOD: This retrospective study analysed all computed tomography pulmonary angiography (CTPA) scans completed from 1 February 2024 to 31 July 2024. Age-standardised rates for CTPA and PE in Māori were calculated using indirect standardisation to the European population.

RESULTS: Of the scans completed, 719 CTPA scans met inclusion criteria. When age standardised, Māori received more CTPAs than Europeans, with an incidence ratio of 1.50 (95% CI [confidence interval] 1.34 to 1.68, $p < 0.0001$). The age-standardised incidence of PE for Māori was 82.0 (95% CI 69.6 to 108) per 100,000 person years, and for Europeans was 87.0 (95% CI 65.1 to 102) per 100,000 person years, with an incidence ratio of 1.06 (95% CI 0.77 to 1.46, $p = 0.70$).

CONCLUSION: This study demonstrates no ethnic difference in the age-adjusted incidence of PE. These findings suggest that ethnicity should not be used in isolation for clinical decision making. Higher rates of CTPA in Māori suggest an equitable approach to CTPA scan requesting.

Venous thromboembolism (VTE) is a term that includes pulmonary embolism (PE) and deep vein thrombosis (DVT). VTE is the most common preventable cause of death in hospitalised patients, and since the COVID-19 pandemic, global age-standardised mortality rates for VTE have risen.¹ PE is a potentially life-threatening condition where the pulmonary arterial vasculature is obstructed by a thrombosis, typically formed elsewhere, such as a DVT in the lower limb.¹⁻³ The diagnosis is most often made using computed tomography pulmonary angiography (CTPA) in conjunction with clinical scoring tools such as the Wells Score.²⁻⁴ Risk factors for PE include older age, malignancy, tobacco smoking and obesity.³

Previous studies have suggested that patients who are Māori or Pacific peoples, when compared to European patients, have a lower incidence of PE.^{6,7} This was based on diagnosis as recorded in a hospital database. A lower rate of detection of PE on scans was also noted for Māori or Pacific peoples.^{6,7} These studies concluded that further pre-test screening tools should be employed for Māori patients, and that Māori potentially

receive less net benefit from VTE prophylaxis.⁶ Although generally this has not been translated into common practice, this study aims to further investigate the previously described differences in the rate of PE in Māori and Europeans.

We hypothesise that the rate of PE in Māori and European patients is equivalent and that by examining the said rate in a different way we may see a different result to previously reported literature. In this study we undertook a retrospective analysis of the diagnosis of PE by analysing all CTPA scans in the Hauora a Toi Bay of Plenty (BOP) region and analysed rates of PE by self-identified ethnicity.

Method

Study design

This retrospective study collected scan data for all CTPA scans on all patients in the BOP region over a 6-month period from 1 February 2024 to 31 July 2024. In the BOP, patients who are suspected of PE generally get an inclusion or exclusion assessment by a clinician (e.g., Wells

Score, PERC score +/- D-dimer) and referral for CTPA based on the results and overall clinical suspicion. The inclusion criteria for this study were CTPA scans for patients who were diagnostically evaluated by CTPA for a new PE. The result of each scan was collected as well as clinical information including gender, age and self-identified ethnicity. The primary outcome measures were to compare the rate of CTPA scans requested and the rate of PE identified between Māori and European populations, with age standardisation. Secondary outcomes included comparison of CTPA and PE rates between gender and age groups.

Multiple scans for the same patients over the 6-month study period were included, provided the clinical question was for assessment of a new PE. CTPA scans requested for indications other than the diagnosis of PE were excluded. Scans for patients with existing known PEs who were scanned to reassess for extension or resolution were excluded. Scans that were non-diagnostic of PE due to motion artifacts or poor contrast where the radiologist suggested repeating the scan were excluded; if repeated successfully, the repeat scan was included. As per institutional policy, all scans are interpreted by a senior radiologist with post-graduate qualifications allowing them to practice independently.

Data collection

The study sample was identified retrospectively from the central radiology database with the search terms “Angiogram - Pulmonary CT”, which encompasses the majority of scans performed on those in the BOP region. The BOP region has a population of 334,140 according to the 2023 Census.⁸ All CTPA scans are reviewed by a consultant radiologist, with some having been reviewed by a training registrar before this. CTPAs were counted as positive if concluded so by the final radiology report. Central/second reviews were not conducted as part of the study. Demographic and clinical data were collected from electronic patient health records on the regional clinical portal (rCP). Ethnicity was collected in the form of self-reported total response.

Statistical methods

For the analysis of ethnicity, multiple self-reported ethnicities were prioritised, as per ethnicity data protocols,⁹ so that for example, a patient self-identifying as Māori and NZ European would be analysed as Māori. The number of person-years was obtained for each demographic

using the 2023 Census data and the incidence of PE and CTPA was calculated for each ethnicity, gender and age group. Indirect age standardisation was used to compare the Māori and European incidences only, due to small samples in other ethnicity groups. For this, the incidence of PE and CTPA was calculated for Māori patients in age brackets of 20 years (0–19, 20–39, etc.), and then the rate for each age bracket was applied to the European population for that age. The Poisson approximation was used to calculate the confidence intervals and p-values for the incidence and incidence ratios. MedCalc was used for these analyses.¹⁰ Results were considered statistically significant with a p-value of <0.05.

Ethical considerations

This study was exempt from a formal ethics review by the Health and Disability Ethics Committee, as this study constitutes a minimal risk quality improvement activity as per the National Ethical Standards for Health and Disability Research and Quality improvement. All local approvals were obtained before data collection and analysis.

Results

Between 1 February 2024 and 31 July 2024, a total of 734 CTPA scans were performed in the Hauora a Toi Bay of Plenty region. Of these, 719 CTPAs met inclusion criteria. Females accounted for 443 (61.6%) of eligible CTPA scans and males 276 (38.4%). When calculated as CTPAs per person-years this gave an incidence ratio (IR) of 0.66 (95% confidence interval [CI] 0.57 to 0.77; $p < 0.001$) for males. There was an increase in the number of scans with increasing age, from 244.2 CTPAs per 100,000 person-years (95% CI 198.5 to 297.3) in 20 to 39-year-olds, to 1791 CTPAs per 100,000 person-years (95% CI 1514 to 2104) in over 80-year-olds. Māori patients had 166 (23.1%) scans performed and European patients had 506 (70.4%) scans performed. There were also 23 (3.2%) for Asian patients, 9 (1.3%) for Middle Eastern, Latin American and African (MELAA) patients and 15 (2.1%) for Pacific peoples (Table 1). When adjusted for population, Europeans had 512.2 (95% CI 468.5 to 558.8) CTPAs per 100,000 person-years, and there were 466.3 (95% CI 398.1 to 542.9) CTPAs per 100,000 person-years for Māori (Table 1). The IR of Māori (compared to Europeans) having a CTPA is 0.91 (95% CI 0.76 to 1.09; $p = 0.29$). When looking at the percentage of CTPAs with PE by ethnicity, Europeans were

positive 16% (95% CI 12.7 to 19.9) of the time and Māori 10.2% (95% CI 6.0 to 16.4) which was not statistically significant.

During the study period 102 PEs were detected, meaning that 14.2% of CTPAs identified a PE. Of those, 81 (79.4%) were in European patients, 17 (16.7%) were in Māori patients, three (2.9%) were in MELAA patients and one (1.0%) was in a Pacific person (Table 1). There was an increase in the incidence of PE with increasing age compared to the 20–39 age range, with an IR of 4.45 in those aged 40–59 (95% CI 1.64 to 15.02), 11.48 in those aged 60–79 (95% CI 4.60 to 36.92) and 25.52 in those aged ≥80 (95% CI 9.64 to 85.10). Without age standardisation, the incidence of PE in the BOP region was 82.0 per 100,000 in Europeans and 47.8 per 100,000 in Māori. The IR for PE was 0.58 (0.32 to 0.99; $p=0.035$) for Māori patients (Table 2) vs European patients without age standardisation.

Indirect age standardisation was used to compare both the incidence of CTPAs per 100,000 person-years and the incidence of PE per 100,000 person-years, between European and Māori populations. Standardised to the European population there were 770 (95% CI 716 to 826) CTPAs per 100,000 person-years in Māori patients. Compared to the 512 (95% CI 469 to 559) CTPAs in Europeans, this gave an IR of 1.50 (95% CI 1.34 to 1.68; $p<0.0001$) for Māori (Figure 1). The incidence of PE in Māori standardised to the European population was 87.0 (95% CI 65.1 to 102) per 100,000 person-years. Compared to the 82.0 (95% CI 69.6 to 108) per 100,000 person-years in Europeans, this gave an IR of 1.06 (95% CI 0.77 to 1.46; $p=0.70$) (Figure 2), showing no difference in the age adjusted incidence of PE in Māori compared to Europeans.

Discussion

The question of whether differences exist in the incidence of PE in Māori compared to Europeans in New Zealand has potential implications for clinical decision-making. This retrospective study of CTPA scan data over a 6-month period from the BOP explains findings from the previous research, but with differing recommendations. While Māori did have an overall lower rate of PE, our study found no statistically significant difference when age adjusting incidence of PE between Māori and European populations. The observed difference is therefore attributable to differences in the age structure of Māori and Europeans populations, with Māori having an overall younger

mean population age.⁸ This is also consistent with well-established evidence linking advancing age to increased PE risk, reinforced by this study.^{1–4} Although CTPA rates may initially appear similar between Māori and European populations, age standardisation reveals that Māori have a 1.5 times higher chance of undergoing CTPA than Europeans. A higher rate of CTPA and the same rate of PE will account for the lower rate of positive scans in Māori patients (10.2%) compared to European patients (16.0%). This increased rate of investigation demonstrates equitable diagnostic imaging practices between ethnic cohorts.

The strengths of this study were its robust study design and that the data were acquired by searching all results of CTPA scans, rather than by patients' diagnostic codes or referrals to a thrombosis clinic. Therefore, this study captured all individuals who underwent CTPA, minimising bias and allowing for comparison of patterns in CTPA ordering in the population. Another strength was a large sample size with a substantial Māori population, reducing the random error in the study. This is in part due to this study being in the BOP region with its high Māori population.⁸

Limitations of the study were its retrospective study design and capturing only a 6-month period. Data were sourced only from the BOP's two public hospitals, which limits the generalisability of the findings to other regions. Patient demographics were sourced from a regional clinical e-record, potentially introducing a source of error if data were incorrectly logged on the record. Using level one prioritised output, patients who recorded multiple ethnicities were aggregated to single ethnicity categories, with an unknown effect on sub-group analysis.

A central review and a blinded sub-group analysis were not performed. As there was no assessment of thrombotic load, there was potential for inter-observer reporting variation, especially with smaller peripheral vessel emboli.

Our study found that the overall rate of PE detected on CTPA was 14.2%. This rate is slightly lower than the Royal College of Radiologists' recommendation for CTPA positive yields of 15.4% to 37%,¹¹ but is consistent with other studies domestically, including a 2015 study from Hutt Hospital which reported a rate of 15%¹² and a 2013 study from Timaru Hospital which reported a rate of 14%.¹³ A large multicentre Australasian study from 2016 reported an overall CTPA yield of 14.6%, although individual sites ranged widely

Table 1: Characteristics of the 719 CT pulmonary angiograms in the Bay of Plenty (between 1 February 2024 and 31 July 2024).

Patient characteristics	CTPA n (%)	CTPA per 100k person years (95% confidence interval [CI])	Incidence ratio [IR] (95% CI)	Percentage of CTPAs with PE [%, n] (95% CI)	IR (95% CI)
All	719 (100)	430.4 (399.5 to 463.0)	–	14.2 (11.6 to 17.2), n=102	–
Gender					
Female*	443 (61.6)	567.0 (515.4 to 622.4)	1.00*	12.9 (9.75 to 16.7), n=57	1.00*
Male	276 (38.4)	375.7 (332.7 to 422.8)	0.66† (0.5681 to 0.7719)	16.3 (11.9 to 21.8), n=45	1.27 (0.8377 to 1.9066)
Age (years)					
0–19	11 (1.5)	25.3 (12.6 to 45.2)	0.10† (0.05000 to 0.1932)	0.0 (0.0 to 33.5), n=0	0.00 (0.0000 to 9.8215)
20–39*	99 (13.8)	244.2 (198.5 to 297.3)	1.00*	5.1 (1.6 to 11.8), n=5	1.00*
40–59	173 (24.1)	431.6 (369.6 to 500.9)	1.77† (1.3726 to 2.2860)	12.7 (8.0 to 19.3), n=22	2.52† (0.9304 to 8.5111)
60–79	288 (40.1)	832.0 (738.7 to 933.9)	3.41† (2.7027 to 4.3260)	17.0 (12.6 to 22.5), n=49	3.37† (1.3496 to 10.834)
80+	148 (20.6)	1791 (1514 to 2104)	7.34† (5.6494 to 9.5599)	17.6 (11.5 to 25.7), n=26	3.48† (1.3144 to 11.599)
Ethnicity (level one prioritised output)					
Asian	23 (3.2)	209.1 (132.6 to 313.8)	0.41† (0.2564 to 0.6195)	0.0 (0.0 to 16.0), n=0	0.00 (0.0000 to 1.0251)
European*	506 (70.4)	512.2 (468.5 to 558.8)	1.00*	16.0 (12.7 to 19.9), n=81	1.00*
Māori	166 (23.1)	466.3 (398.1 to 542.9)	0.91 (0.7594 to 1.0870)	10.2 (6.0 to 16.4), n=17	0.64 (0.3554 to 1.0886)
MELAA	9 (1.3)	521.3 (238.4 to 989.6)	1.02 (0.4627 to 1.9474)	33.3 (6.9 to 97.4), n=3	2.08 (0.4207 to 6.3054)
Pacific peoples	15 (2.1)	313.1 (175.2 to 516.4)	0.61† (0.3396 to 1.0179)	6.7 (0.17 to 37.1), n=1	0.42 (0.01042 to 2.3869)

* = group used as baseline for incidence ratio (IR)
† = statistically significant p value (<0.05)

Table 2: Characteristics of the 102 pulmonary emboli (PE) in the Bay of Plenty (between 1 February 2024 and 31 July 2024).

Patient characteristics	PE n (%)	PE per 100,000 person years (95% CI)	IR (95% CI)
All	102 (100)	61.1 (49.8 to 74.1)	–
Gender			
Female*	57 (55.9)	73.0 (55.3 to 94.5)	1.00*
Male	45 (44.1)	61.3 (44.7 to 82.0)	0.84 (0.56 to 1.26)
Age (years)			
0–19	0 (0.0)	0.00 (0.00 to 10.0)	0.00 (0.00 to 1.02)
20–39*	5 (4.9)	12.3 (4.00 to 28.8)	1.00*
40–59	22 (21.6)	54.9 (34.4 to 83.1)	4.45† (1.64 to 15.02)
60–79	49 (48.0)	142 (105 to 187)	11.48† (4.60 to 36.92)
80+	26 (25.5)	315 (206 to 461)	25.52† (9.64 to 85.10)
Ethnicity (level one prioritised output)			
Asian	0 (0.0)	0.00 (0.00 to 30.0)	0.00 (0.00 to 0.42)
European*	81 (79.4)	82.0 (65.1 to 102)	1.00*
Māori	17 (16.7)	47.8 (27.8 to 76.5)	0.58† (0.32 to 0.99)
MELAA	3 (2.9)	174 (36.8 to 508)	2.12 (0.43 to 6.42)
Pacific peoples	1 (1.0)	20.9 (0.530 to 116)	0.25 (0.01 to 1.46)

* = group used as baseline for incidence ratio (IR)

† = statistically significant p value (<0.05)

Figure 1: CT pulmonary angiogram per 100,000 person-years in the Bay of Plenty, with indirect age standardisation, $p<0.0001$.

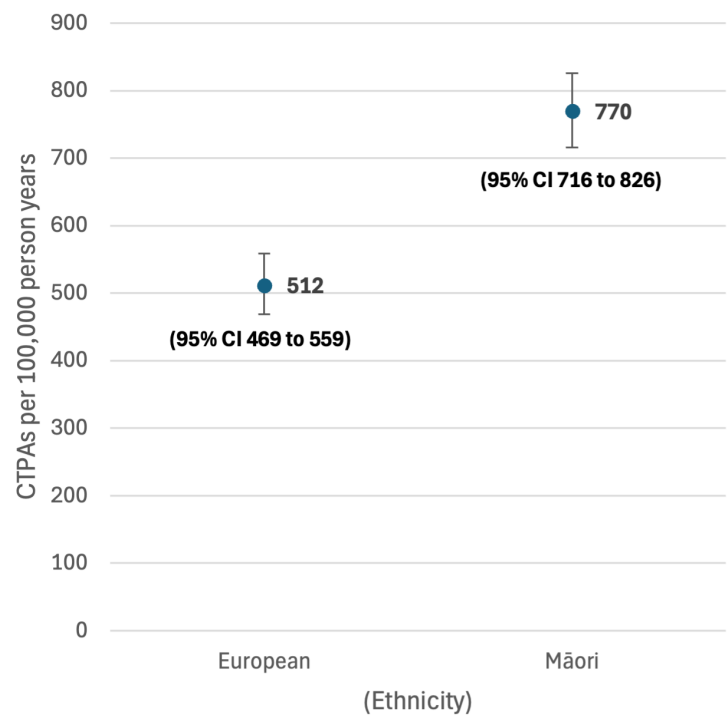
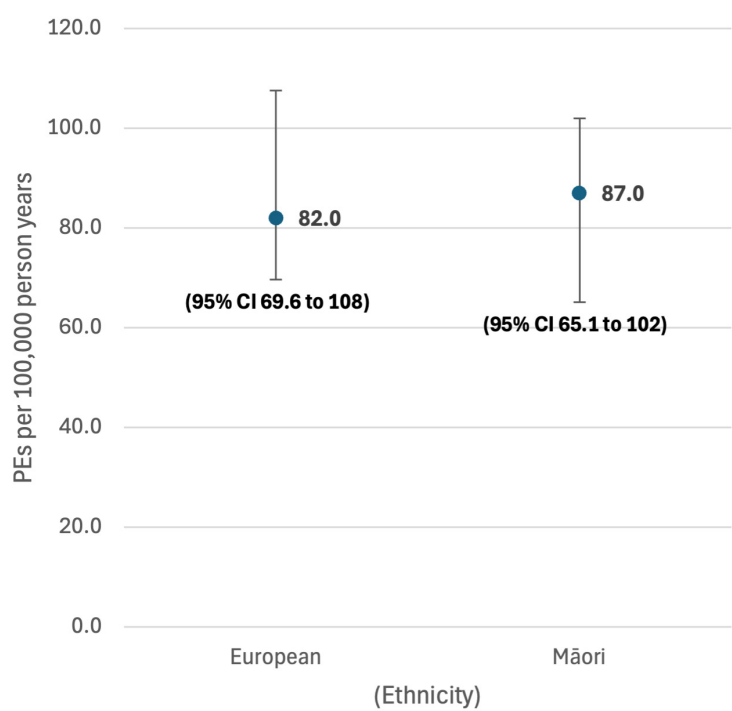


Figure 2: Pulmonary emboli per 100,000 person-years in the Bay of Plenty, with indirect age standardisation, $p=0.70$.



from 9.3% to 25.3%.¹⁴ The diagnostic yield of 14.2% is consistent with rates internationally, with a recent 2025 Canadian study reporting rates of 12.2%.¹⁵ Studies from the United States report yields below 10%, with multicentre pooled data showing rates as low as 3.1%.^{16,17} In contrast European centres report an average yield of 29%.¹⁸ Our study also showed that the rate of PE detected on CTPA for Māori patients was 10.2% and 16.0% for European patients. In comparison, a 2016 study from Waitematā reported a positivity rate for Māori, Asian and Pacific (non-European) patients of 9.3%, and 23.3% for European patients.⁶

Previous New Zealand studies concluded that there is a higher incidence of VTE in Europeans compared to Māori.⁷ At first look our study was consistent with that, but with age-standardisation the difference was no longer seen. This suggests that the previously observed lower rate of PE

in Māori from other studies might be explained by differences in the age breakdown of the population, with Māori having a younger mean age.⁸ It is also important to note that at the time, approximately only 7.7% of the Waitematā population identified as Māori according to census data.⁸ In contrast, the most recent 2023 Census data indicated that 32.9% of the BOP population identify as Māori,⁸ providing a substantially larger and more representative Māori sample.

In conclusion this study found that Māori and European patients have comparable rates of PE, which contrasts with earlier findings that suggested a lower incidence among Māori.^{7,8} These results indicate the need for equal clinical suspicion for PE across all ethnic groups and suggest that previously observed disparities may have been influenced by demographic differences and potential under-representation in earlier studies.

COMPETING INTERESTS

Nil.

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Trends in thoracic spine injury rates in New Zealand: an eleven-year (2013–2023) analysis of ACC claims

Kesava Kovanur Sampath, Tyler Nitschke

ABSTRACT

BACKGROUND: This study examines national trends in thoracic spine injury (TSI)–related claims in New Zealand over an 11-year period (2013–2023), with a focus on incidence patterns by sex, age group, injury type and ethnicity.

METHODS: A descriptive longitudinal study design was used to analyse 11 years' (2013–2023) data from the Accident Compensation Corporation (ACC). TSIs were grouped into fractures/dislocations, soft tissue injuries and pain syndromes. Incidence rates per 100,000 population were calculated using Stats NZ Tatauranga Aotearoa denominators. Trends were explored using descriptive analyses, population pyramids and heatmaps and modelled using Poisson and negative binomial regression to estimate annual percent change (APC). Forecasts to 2033 were generated using time-series models.

RESULTS: Between 2013 and 2023 there were 1,003,713 new TSI claims. From 2013 to 2023, the incidence of TSI increased from 1,749 to 1,901 per 100,000 ($z = -10.49$, $p < 0.001$). Our findings demonstrate that females had more claims than males. Modelled APCs were +0.32% (95% CI: -0.29% to +0.94%) for males and +0.25% (95% CI: -1.22% to +1.74%) for females, both non-significant. Fractures (APC: +1.24% [95% CI: +0.13 to +2.35, $p = 0.028$]) accounted for only 1.8% of claims ($n = 18,334$) compared to soft tissue injuries ($n = 981,796$). However, the APC was non-significant for soft tissue injuries. The highest burden occurred in the 30–54 age groups. In terms of ethnicity, European and Asian groups had higher TSI rates than Māori and Pacific peoples.

CONCLUSION: TSIs have increased modestly over the past decade. The burden varies by sex, age and ethnicity. These findings support targeted prevention with implications for workforce health and equity-focused policy planning.

Epidemiological data on thoracic spine injuries (TSI) are lacking in the literature when compared to cervical and lumbar spine injuries. The thoracic spine is thought to be relatively stable and therefore may have a low injury risk.^{1,2} In New Zealand, almost half of patients with major trauma have thoracic injuries. Thoracic trauma is second only to head and spinal cord injuries as the cause of death in trauma patients.³ However, it is important to note that the majority of these fatalities are attributable to thoracic organ injuries (e.g., heart, lungs and major vessels) rather than TSI per se. Nonetheless, TSIs often occur alongside high-impact trauma involving the chest and can result in significant morbidity and long-term disability. The Accident Compensation Corporation (ACC) data combine cervical and thoracic injuries (neck and upper back); however, no published ACC data exist examining the thoracic spine as its own entity.⁴ Another example of TSI commonly reported together with another spinal segment is thoracolumbar injuries.⁵ Therefore, profiling TSI on its own may be considered timely.

TSI may include several tissues/structures including vertebral fractures, muscles strains, ligament sprains, disc injuries and so on. According to the ACC Read Code reference list, SNOMED International Fully Specified Name for thoracic sprain includes “back strain of thoracic region (disorder)”, with the preferred term being “strain of thoracic region” and the Read term being “thoracic sprain”.⁶ Although these terms are often used interchangeably (wrongly), sprains and strains are an umbrella term used in clinical practice to refer to damage to the soft tissues in the body, including ligaments, tendons and muscles.⁷ Evidence shows that work-related sprains and strains in New Zealand incur a substantial cost (NZ\$132 million in 2017) and a major public and occupational health burden resulting in at least 1.3 million lost workdays.⁷ Although these figures are not specific to TSI, higher costs are predicted to be associated with injuries to the back and upper body.⁸

Thoracic spine fractures (TSF) are increasing in incidence, especially in older populations.⁹ TSF can include compression, flexion distraction,

fracture-dislocations and burst fractures and may lead to chronic pain and limited mobility, resulting in significant physical, emotional, social and increasing financial burdens.^{10,11} While the direct and indirect costs associated with a thoracolumbar fracture have been established, there is a dearth of literature on TSI of other segments. Traumatic mechanisms including motor vehicle accidents and falls are common causes of TSI.¹² Additionally, osteoporosis can commonly contribute to TSI.¹⁰ A recent narrative review found that only few studies could correlate a mechanism of injury to the spinal region injured, particularly that of the thoracic spine.¹³ The review found falls, motor vehicle accidents, pedestrian accidents and sports to be common causes of spinal injury. However, it was not outlined which spinal regions were affected by these mechanisms. The review also found spinal injury aetiologies, and injury diagnoses, to be heavily influenced by the location of the study.¹³ This therefore supports the need for New Zealand-based data to be analysed as the type of injuries may be different here.

ACC is an accident compensation scheme, providing insurance cover for accidental injuries. Coverage applies to New Zealand citizens and residents as well as temporary visitors.¹⁴ New Zealand's no-fault injury compensation scheme provides registered medical practitioners with information about the patient's injury diagnosis and medical care provided. To be covered under the ACC scheme, the injury must be a result of a personal injury caused by an accident. The definition of an accident is outlined in the *Accident Compensation Act 2001*.¹⁴ ACC provides non-identifiable information gathered from ACC45 forms, completed when claiming a personal injury. ACC data has been well utilised by New Zealand practitioners to understand injury trends and associated economic impacts.¹⁵ Despite the increasing prevalence in TSI and the associated burden of care, there is a lack of TSI-specific data in New Zealand. This study intends to fill this gap by utilising the available ACC TSI dataset. To our knowledge, no other studies have specifically profiled TSI trends.

This study aims to: 1) describe national trends in TSI incidence in New Zealand between 2013 and 2023, 2) examine demographic differences in TSI incidence by sex, age group and ethnicity and to assess whether temporal trends varied across these sub-groups, 3) characterise patterns across diagnostic categories (fractures/dislocations, soft tissue injuries and pain syndromes) and quantify

their relative contributions over time, and 4) evaluate disparities using regression-based estimates of annual percent change (APC) and rate ratios (RRs) and to forecast future incidence (2024–2033) using time-series models.

Methodology

Operational definitions

Operational definitions for different terms used in this study are summarised in Table 1. The *Accident Compensation Act 2001* outlines what qualifies an accepted claim.¹⁴ For the purpose of this study, the injury had to have been classified and recorded as a TSI. The injury had to have been accepted as an ACC claim during the study period to be included in the dataset.

Eligibility

Inclusion criteria

The injury had to have been accepted as an ACC claim during the study period (01 January 2013 to 31 December 2023) to be included in the dataset. Upon further request, ACC provided data for claims by ethnicity, injury description by age group, accident cause by age group, injury description by accident cause and injury claims of each spinal region by age group.

Exclusion criteria

Injuries other than TSI in the initial dataset received from ACC (e.g., lumbar fractures) were excluded from the dataset.

Data source

Longitudinal national TSI claims data were obtained from ACC for the period 2013–2023. Counts of accepted claims were stratified by year, sex, age group (18 categories: 0–4 years through ≥85 years) and ethnicity (Asian, European, Māori, Pacific peoples). Population denominators were derived from Stats NZ Tatauranga Aotearoa intercensal estimates (2013, 2018, 2023), with linear interpolation applied where necessary. Annual incidence rates were calculated per 100,000 population.

Data preparation

Initial data abstraction was conducted by author NT, who extracted the aggregate data from the dataset provided by ACC. The extracted data were subsequently cross-checked and verified by author KSK. The initial data set received from ACC included lumbar injuries. Therefore, efforts

Table 1: Key definitions related to thoracic spine injury research.

Term	Definition
Thoracic spine injury	A thoracic spine injury is described as an injury to the thoracic vertebrae. This includes the following ACC Read Codes (N121, N1292, N12B1, N12C1, N141, N3319, S102 (S1021 – S1026), S103 (S1030 – S1036), S112 (S1121-S1129), S112A, S113 (S1131-S1139), S113A, S492, S4921, S4931, S4934-S4936, S4923- S4926, S49A (S49A1, S49A3 – S49A6), S49B (S49B1, S49B3 – S49B5), S571, S5N1, SE2, SK1A, SK19, SK190).
Claim	The name given to an application made by the client (or made by someone on behalf of the client) under ACC legislation for cover and/or a specified entitlement (support) for a personal injury. Definitions are as provided by ACC and other relevant documentation. All terms are described within the context of this study. A claim may cover multiple years. A single claim can span multiple years. If a claim extends beyond one year, it is considered “active” in each year it remains open.
Injury diagnosis	Injury diagnosis is defined as the injury classification of the injury suffered by the claimant, including soft tissue injury, fracture/dislocation or pain syndrome.
Injury description	Injury description can be described as the specific injury suffered by the claimant, linked to a specific ACC Read Code/Codes.
Accident cause	The mechanism of injury interpreted via ACC from ACC45 claim form, that resulted in a thoracic spine injury.
Costs	All costs refer to 2024 Q1 inflation-adjusted New Zealand dollars. Costs are GST exclusive and based on payment date.

Note: Definitions provided below are based on Accident Compensation Corporation (ACC) (2024) and other relevant documentation. All terms are described within the context of this study.

were made to ensure that only thoracic spine data were part of this study. From the available ACC dataset, there were three injury diagnosis categories (fracture, soft tissue injuries and pain syndrome) that encompassed several different injury descriptions (see Appendix 1). The difference between injury diagnosis and descriptions have been provided in Table 1. The thoracic fracture subset had a number of injury diagnoses (Appendix 1) which were classified under two main categories: 1) “level specified” (e.g., T7/8) where the fracture level was known, and 2) “level unspecified” where the fracture level was unknown. Both authors then reviewed the

final structure, definitions and categorisation of diagnostic groups (e.g., fracture, soft tissue, pain syndromes) and reached consensus regarding data inclusion, cleaning and interpretation for analysis. This collaborative approach ensured accuracy and consistency in the final dataset used for statistical modelling and visualisation.

Statistical analysis

All statistical analysis and data visualisation was conducted using selected packages: “MASS”,¹⁶ “dplyr”,¹⁷ “tidyr”¹⁸ and “ggplot2”¹⁹ packages in R R Core.²⁰ Microsoft Excel was also used in generating a few graphs. The overall

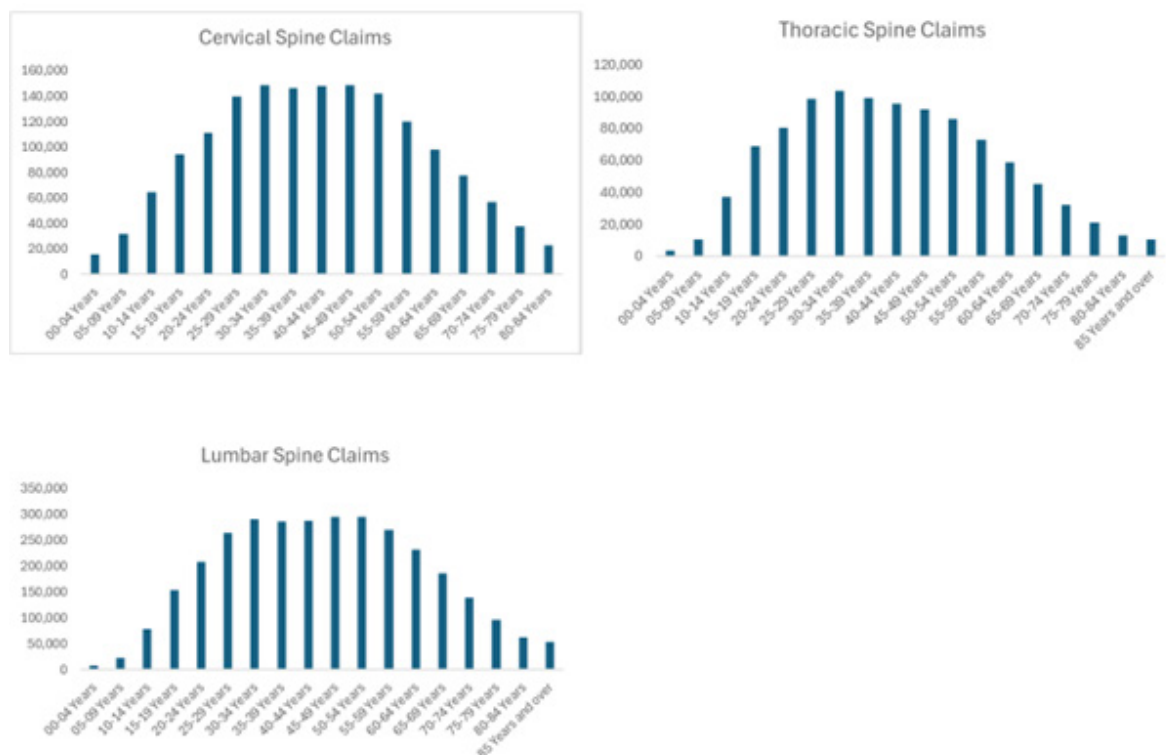
distribution of TSI frequency (summed over the 10-year analysis period) and its relationship with population demographics (age and sex) were evaluated visually, using population pyramids. Incidence rates were calculated as the number of accepted claims per 100,000 population per year. Differences in rates between two groups (e.g., 2013 vs 2023, males vs females) were assessed using z-tests for differences in two proportions, with corresponding p-values reported. To assess temporal trends, generalised linear models were fitted with a log link and population offsets. Poisson regression was used as the primary approach, and negative binomial regression was applied when evidence of overdispersion was present ($\text{Pearson}\chi^2/\text{degrees of freedom} > 1.5$). From these models, the annual percent change (APC) was derived as $([e^{\beta}-1] \times 100)$, where β is the estimated slope for year. Ninety-five percent confidence intervals (CIs) for APC were obtained from the standard errors of the regression coefficients. Interaction terms (Year x Sex, Year x Ethnicity) were included to test whether temporal

trends differed across demographic sub-groups. Rate ratios (RRs) and 95% CIs were reported by exponentiating model coefficients, with Asians as the reference group for ethnicity and males for sex. Finally, time-series models (ARIMA) were fitted to overall incidence rates to forecast 5–10 years beyond the study period (2024–2033). Model selection was based on Akaike information criterion (AIC) and residual autocorrelation diagnostics. Forecast uncertainty was expressed as 95% prediction intervals. The formulas used for all statistical procedures are provided in Appendix 2.

Results

From January 2013 to December 2023 there were 1,003,713 new thoracic spine injury-related ACC claims accounting for 17.5% of all spinal injury claims. A total of NZ\$2,804,150,246.47 has been spent between 2013 and 2023 on TSI-related diagnoses. ACC claims by spinal region and age group can be seen in Figure 1.

Figure 1: New injury claims by spinal region and age group.



Overall incidence trends (2013–2023)

A total of 1,003,713 TSI claims were recorded in New Zealand between 2013 and 2023. Annual incidence rates increased from 1,749 per 100,000 in 2013 to 1,901 per 100,000 in 2023. Regression estimated an APC of +0.27% (95% CI: +0.14 to +0.41, $p < 0.01$), which indicates a statistically significant but modest upward trend in the overall incidence of TSI in New Zealand from 2013 to 2023 (Figure 2a). A drop in TSI claims was also noted during 2020 and 2021, probably due to COVID-related interruptions.

Diagnostic categories

Thoracic fractures

Fracture rates were stable until 2020 (Figure 2b), after which they increased steadily, reaching 40 per 100,000 in 2023. Regression estimated an APC of +1.24% (95% CI: +0.13 to +2.35, $p = 0.028$). Out of a total of 17,763 fractures, only 1,452 (8.1%)

fractures were “level specified”, whereas 16,311 (91.9%) fractures were “level unspecified”. From the available level-specific data, the incidence of thoracic fractures (from high to low) was as follows: T11/12 ($n = 516$), T7/8 ($n = 214$), T5/6 ($n = 192$), T3/4 ($n = 186$), T1/2 ($n = 179$), T9/10 ($n = 165$).

Pain syndromes

Pain syndrome claims (Figure 2c) peaked in 2014 (15.6 per 100,000) then declined and stabilised at ~10 per 100,000. Regression estimated an APC of -1.0% (95% CI: -2.0 to +0.1).

Soft tissue injury

Thoracic sprains were the most common soft tissue injury description across all age groups. Soft tissue injuries dominated overall TSI burden (Figure 2d), with rates around 1,700–1,950 per 100,000, peaking in 2019 and stabilising thereafter. The APC was +0.9% (95% CI: -0.1 to +1.8).

Figure 2: Trend rates (2013–2023) for thoracic spine injury (TSI), thoracic fractures, pain syndrome and thoracic soft tissue injuries

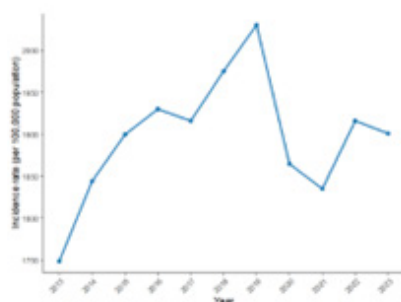


Fig 2a. TSI Trends (2013-2023)

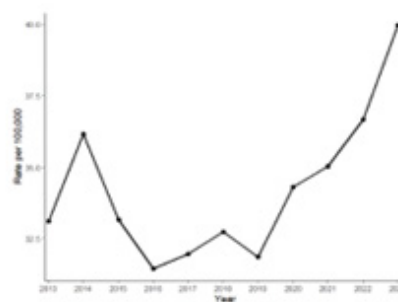


Fig 2b. Thoracic Fracture Trends (2013-2023)

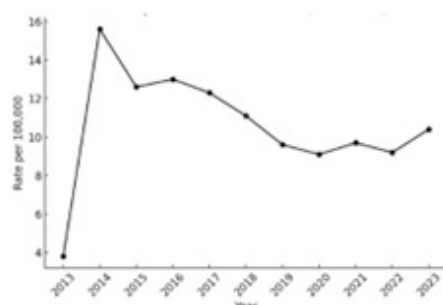


Fig 2c. Pain Syndrome Trends (2013-2023)

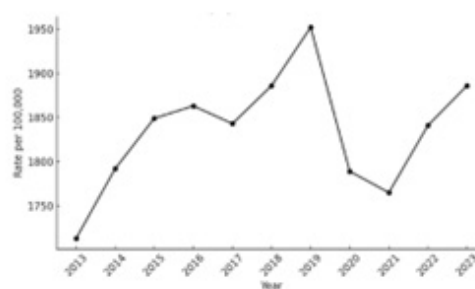


Fig 2d. Soft-tissue Injury Trends (2013-2023)

Forecasting

Time-series forecasting (ARIMA) projected (Figure 3a, 3b, 3c) continued modest increases in fracture incidence over the next decade (2024–2033), rising from 40 per 100,000 in 2023 to ~45 per 100,000 in 2033. Soft tissue injury incidence was projected to remain stable at ~1,900 per 100,000, while pain syndromes were predicted to remain low (<12 per 100,000). Forecast prediction intervals widened over time but supported the overall stability of soft tissue injuries and the gradual increase in fractures.

Sex-specific trends

Between 2013 and 2023, the incidence of TSI remained relatively stable for both males and females. Females consistently exhibited higher incidence rates than males across all study years, although both sexes demonstrated broadly parallel temporal patterns. Model-based regression analysis (Figure 4) estimated the APC in incidence as +0.32% per year for males (95% CI: -0.29% to +0.94%) and +0.25% per year for females (95% CI: -1.22% to +1.74%). Neither of these trends reached

statistical significance. The interaction term for sex by year was also non-significant ($p=0.86$), indicating no evidence of sex-specific divergence in temporal trends. Collectively, these findings suggest that while females continue to experience higher incidence than males, overall TSI incidence has remained stable over the past decade without significant upward or downward change in either sex.

Age- and sex-specific patterns

Population pyramids (Figure 5) revealed marked contrasts between injury categories. Fracture incidence was relatively low in younger age groups but increased sharply in older females, reflecting age-related vulnerability (e.g., osteoporosis).

From the “level specific” fracture data, the difference in fracture counts between sexes is shown in Figure 6a. A descriptive heatmap of thoracic fracture counts by thoracic level, age group and sex has been provided in Figure 6b. Pain syndromes displayed a flatter distribution across adulthood, with moderate female predominance.

Annual claims by injury type confirmed that

Figure 3: Observed and forecasted incidence rates of thoracic spine injuries (TSIs) per 100,000 population in New Zealand from 2013 to 2033. Observed data (2013–2023) are shown as solid lines, while forecasts (2024–2033) are represented by dashed lines with 95% confidence intervals (CIs) shaded.

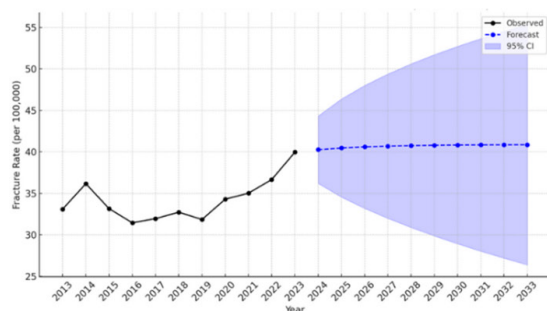


Fig 3a. Thoracic fracture incidence rates observed and forecast (2013-2033)

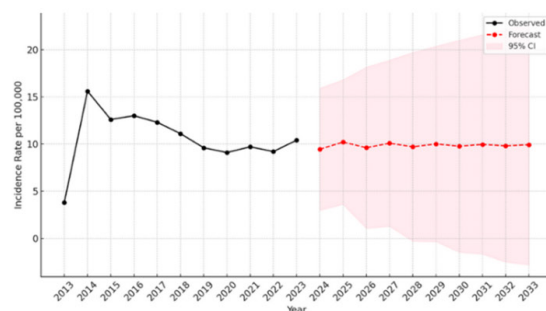


Fig 3b. Thoracic pain Syndrome incidence rates observed and forecast (2013-2033)

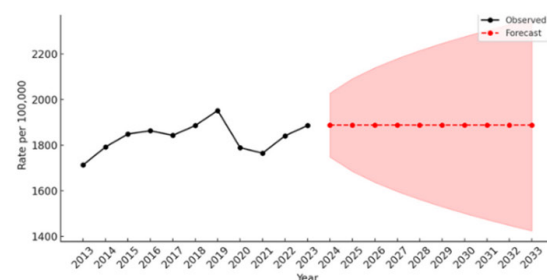
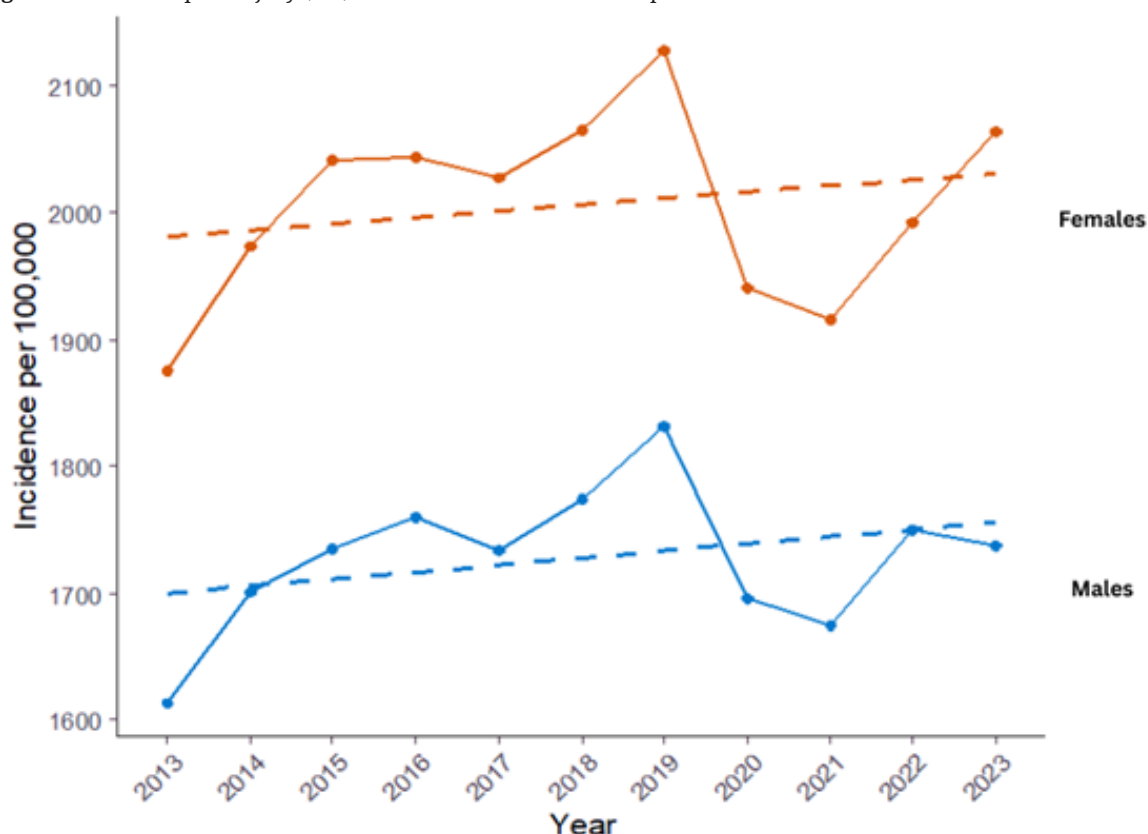


Fig 3c. Thoracic soft tissue injury incidence rates observed and forecast (2013-2033)

Figure 4: Thoracic spine injury (TSI) incidence rates in males compared with females.

soft tissue injuries contributed the greatest burden each year concentrated in working-age adults of both sexes. A visual presentation (heatmap) of various soft tissue injuries has been provided in Figure 7.

Ethnicity-specific trends

Incidence rates varied substantially by ethnicity (Figure 8). In 2013, Europeans recorded the highest incidence (2,121 per 100,000), followed by Māori (1,142), Asians (975) and Pacific peoples (917). By 2023, European incidence remained highest (2,010), while Asian incidence rose sharply (+44% to 1,403). In contrast, Māori and Pacific rates declined (-23% and -6%, respectively). Negative binomial regression showed that temporal trends differed significantly by ethnicity (Year × Ethnicity interaction, $p < 0.001$).

Estimated APCs were as follows: Asian, +4.0% per year (95% CI: 3.0 to 5.0, $p < 0.001$); European, +0.4% per year (95% CI: -0.2 to 1.0); Māori, -0.6% per year (95% CI: -1.1 to -0.1, $p < 0.05$) and Pacific

peoples, +0.2% per year (95% CI: -0.5 to 0.8). Rate ratios (RRs) at baseline (2013) showed Europeans had more than double the incidence of Asians (RR=2.22, 95% CI: 2.08–2.36), Māori had 21% higher incidence (RR=1.21, 95% CI: 1.14–1.30) and Pacific peoples were not significantly different (RR=0.97, 95% CI: 0.90–1.04).

Discussion

To the best of the authors' knowledge, this study presents the first comprehensive analysis of TSI claims in New Zealand over an 11-year period, using national ACC data from 2013 to 2023. During the period of interest, the overall incidence of TSI increased from 1,749 to 1,901 per 100,000 population; a statistically significant increase. Although soft tissue injuries accounted for most claims, fracture-related injuries showed a gradual upward trend. Pain syndromes remained comparatively rare and stable over time.

Figure 5: Population pyramids showing the distribution of thoracic spine injury claims by age group and gender. Separate pyramids are presented for three diagnostic categories: a) fractures, b) pain syndromes, and c) soft tissue injuries.

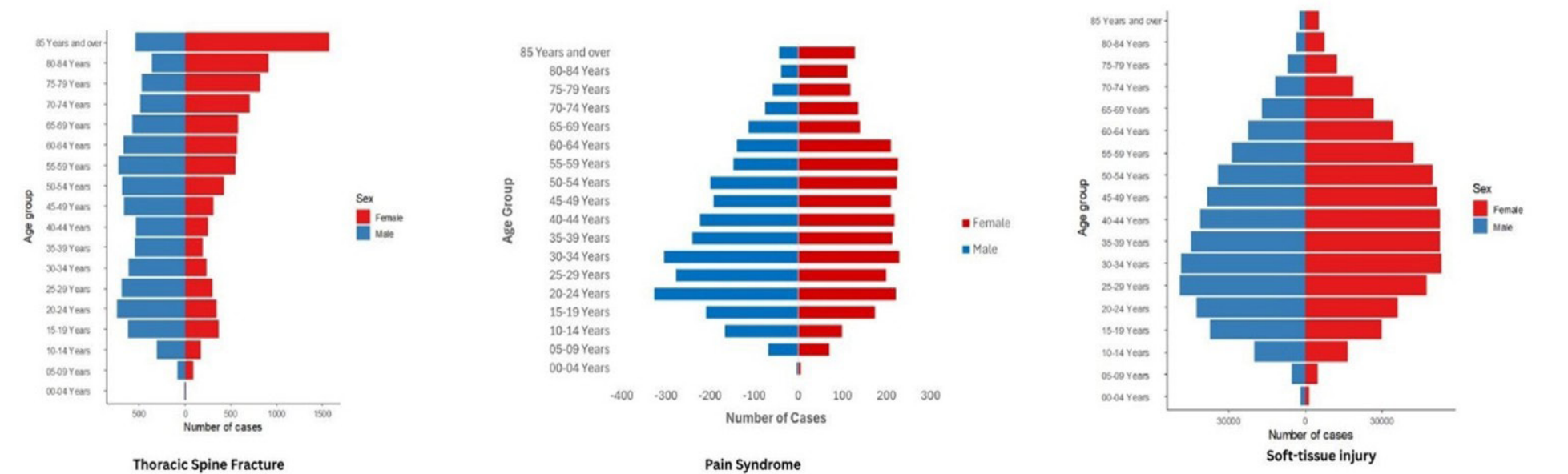


Figure 6: “Level specific” thoracic fracture incidence with heatmap by age group and gender in New Zealand (2013–2023).

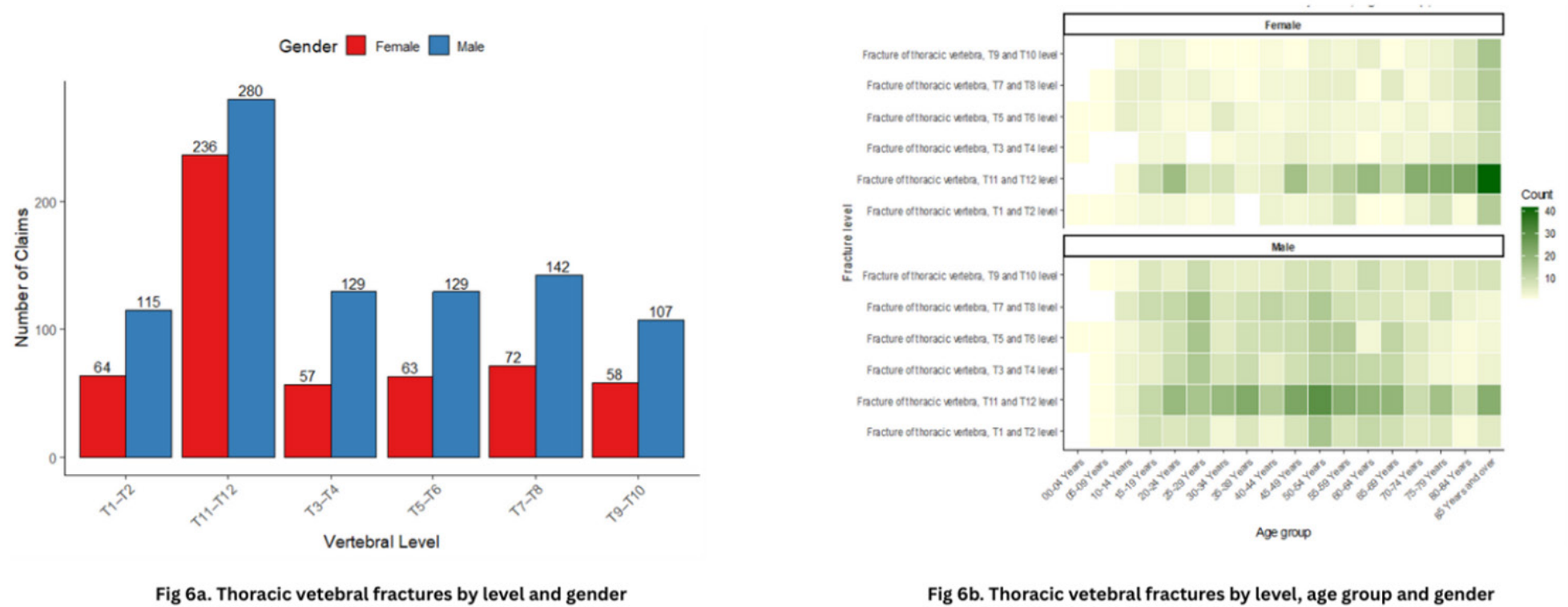


Figure 7: Heatmap depicting the burden of thoracic soft tissue injuries (sprain and strain of thoracic spine, injury of muscle and tendon at thorax level, thoracic disc prolapse and radiculopathy and thoracic sprain).

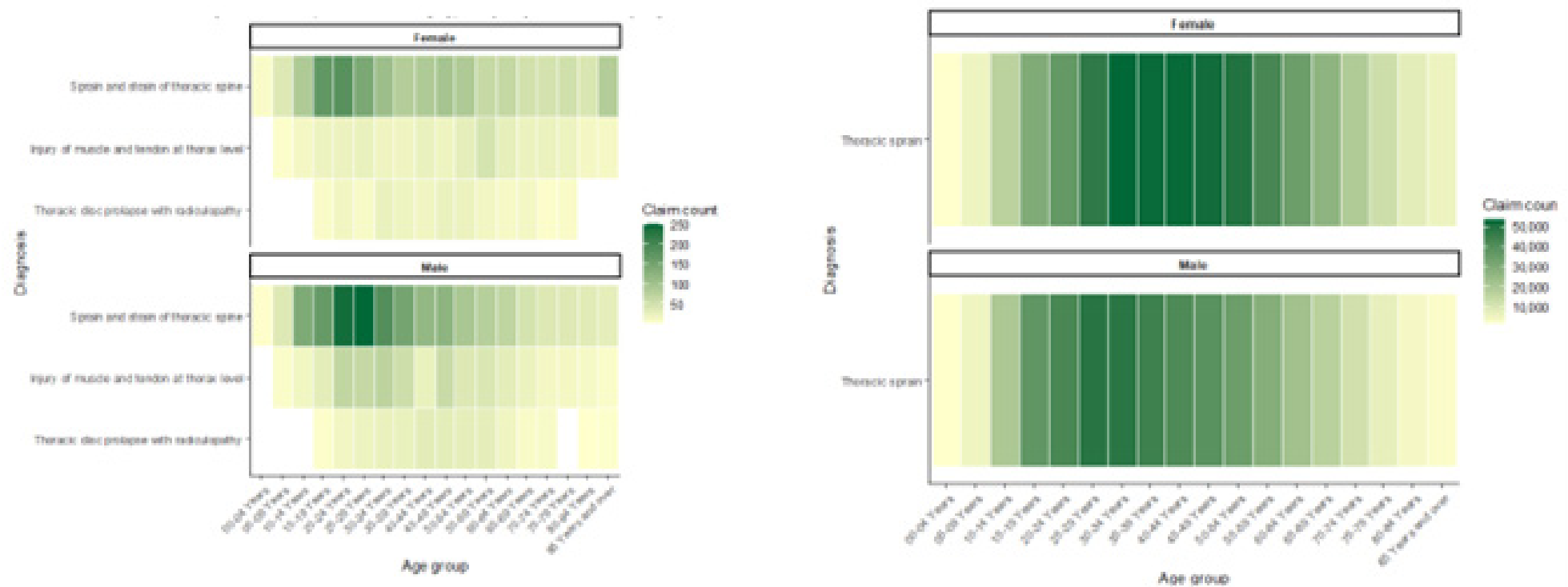
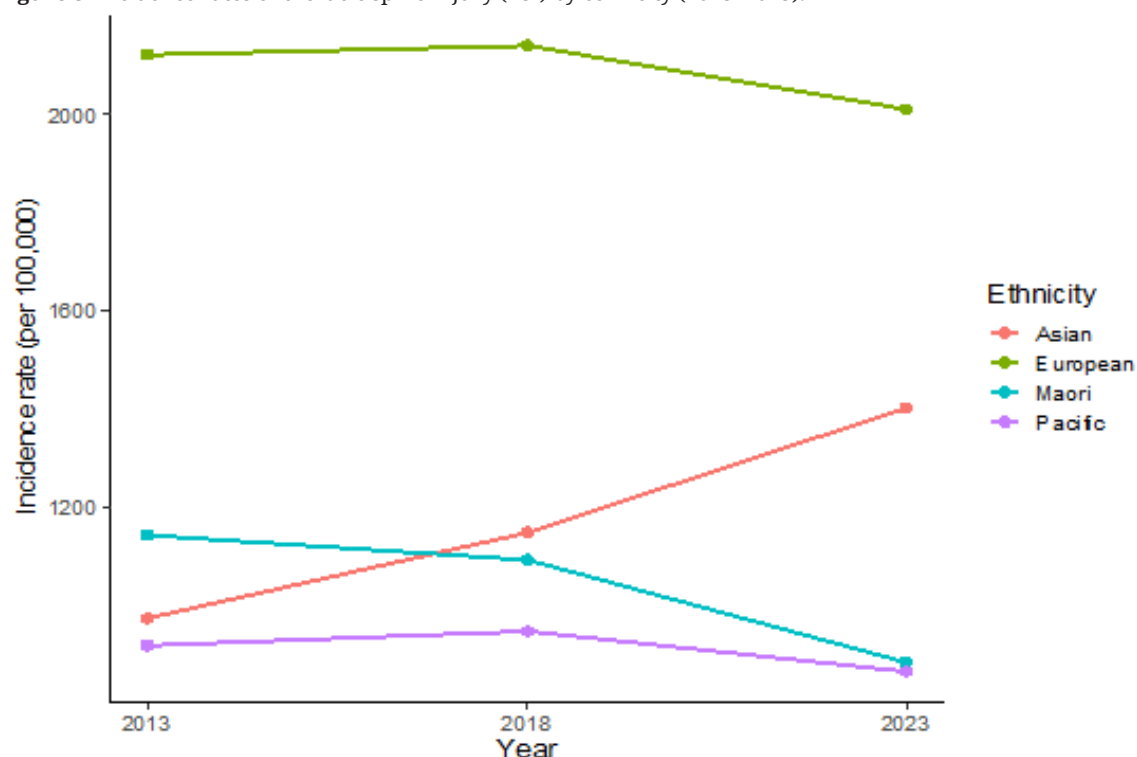


Figure 8: Incidence rates of thoracic spine injury (TSI) by ethnicity (2013–2023).

Thoracic fracture

Our findings suggest that thoracic fracture incidence rates steadily increased over the study period (2013–2023), consistent with vertebral fracture trends observed globally.²¹ Specifically, our analysis showed fracture incidence to be higher in older females (>65 years of age). This is not surprising given that women aged over 50 years are at higher risk of osteoporotic fractures compared to men of similar age (one in two women compared one in five men).²² The gold standard for diagnosing osteoporosis is through measuring bone mineral density (BMD) using a dual energy x-ray absorptiometry (DEXA) scan.²³ Currently, DEXA scans are not considered a standard public provision in New Zealand and are possibly considered as an option for at-risk populations, especially the elderly. However, primary healthcare practitioners have access to several free resources, for instance, Osteoporosis New Zealand offers evidence-informed tools such as Know Your Bones™ to support osteoporosis screening and patient education. Sustained efforts are required to ensure that health practitioners are aware of such tools to ensure screening and identification of osteoporosis early to prevent fractures at a later stage.²⁴ Falls prevention

programmes have also been shown to be successful in preventing falls which is a key mechanism of fractures in older adults.^{25,26}

Of the fractures that were coded by segmental level, T11/T12 vertebra saw the most claims. This is in agreement with the literature where the thoracolumbar junction is the most injured region.¹ Within T11/T12 fractures, incidence was high in middle-aged men (45 to 55 years), whereas the trend changed in people above 65 years of age, where women had a higher T11/T12 fracture rate. This level (of those classified by segmental level) had the most claims in all age groups except 10 to 14 years, where T7/T8 fractures predominated. However, most fractures were classified as “closed fractures of thoracic vertebra” or “closed fractures of thoracic vertebra level unspecified” with no thoracic level given. Hence, efforts must be made to ensure clinicians filling the ACC form clearly code the injury classifications by thoracic level affected to accurately understand thoracic segmental level trends.

Soft tissue injuries

Thoracic soft tissue injuries had the highest number of new TSI claims of all injury descriptions. Compared to thoracic fractures that accounted

for only 18,334 cases, soft tissue injuries accounted for 981,796 claims, which equates to a ratio of approximately 1:53. This substantial difference highlights the predominance of soft tissue injuries in TSI claims. A few reasons for this imbalance may include the high frequency of work-related strain injuries,²⁷ lower thresholds for reporting musculoskeletal pain and the broader clinical coding of non-specific thoracic complaints. In contrast, fractures may require considerable trauma (unless relating to osteoporosis or other disease processes) and may therefore occur less frequently. Also, thoracic fractures can be asymptomatic or cause mild pain; hence, can easily be under-diagnosed.²⁸ Furthermore, vertebral fractures may often be undiagnosed by radiologists, with a misdiagnosis rate of up to 50%, and therefore under-reported.²⁹

Our findings demonstrated that the burden of thoracic soft tissue injuries was higher in working-age adults of both sexes. This is in agreement with previous findings.^{27,30} Certain occupations and lifestyle choices contribute to the risk of TSI. This suggests that repetitive strain, poor ergonomics and physical demands in certain jobs may increase TSI risk, especially strains and sprains. New Zealand, like many other countries, has undergone an unprecedented shift towards an ageing population, resulting in an increase in the average age of its workforce. The median age of the workforce, which was 36 in the year 1991, has already risen to 44 by 2021. Hence, for an increasingly ageing workforce to remain healthy and productive, implementation of effective workplace risk management practice is required.²⁷ Such a strategy is timely given that sprains and strains made-up the highest proportion of work-related claims (38%) in 2017 resulting in the highest level of ACC expenditure on work-related injuries (41%).⁸ While current prevention strategies for sprains and strains focus on individual behavior, broader contextual factors associated with the etiology of these are often ignored.⁷ Research utilising system-based frameworks such as prevention through design have shown promising results in the prevention of sprains and strains in the working class.^{31,32} However, the universal applicability of such programmes requires further investigation.

Ethnicity

Our study found that in 2023, European incidence remained highest, while Asian incidence rose sharply (+44%). In contrast, Māori and Pacific rates declined (-23% and -6%, respectively). The

Asian population experienced the highest increase in TSI incidence in New Zealand. This is similar to the trend observed in a study on tendon and ligament injuries in New Zealand which noted a 52% increase in tendon and ligament injuries claims by the Asian population.¹⁵ New Zealand's Asian population has seen rapid growth in the last 5 years, now comprising approximately 18% of total population.³³ Hence, a larger population base can lead to higher absolute numbers of reported injuries. The rise in Asian incidence rates may suggest changing health service utilisation, risk exposure or reporting behavior in this growing population group. This finding is interesting given that the Asian population has the lowest primary health organisation (PHO) enrolment compared to other ethnic groups in New Zealand.³⁴ Further, access to the health system was found to be poorer among Asians, mainly due to lack of knowledge, cost of service and transport.³⁵ However, the subsidy/funding provided towards investigation, treatment, work cover and transport by ACC could be speculated as a facilitator for this sub-group to report injuries. In terms of the Māori and Pacific population, it is well known that persistent challenges still exist in accessing timely and culturally appropriate healthcare services that may lead to underreporting or delayed diagnosis of TSI in these communities.³⁶ Further research is essential to identify and develop targeted interventions that address the specific needs of each community.

Strengths and limitations

The main strength of this study is the nationwide analysis over the course of 11 years. The stratification by age, sex and ethnicity enabled a robust analysis of TSI data. This provides robust, population-wide insights into injury trends, demographics, diagnoses and causes, filling a significant gap in publicly available data on TSI in New Zealand. However, this study also presents several limitations. The accident causes given were relatively ambiguous and often could not be related to a particular activity. This makes it difficult to profile these injuries and promote future injury mitigation. Future studies should look to understand this relationship. Ambiguity within ACC reporting of thoracic spine fractures means that most fractures were not reported by thoracic level. This limits the precision of segmental-level analysis and may lead to under-representation of certain injuries. As a descriptive study, it does not assess causality between demographic factors

and injury incidence. Correlations found between age, gender and injury type cannot be interpreted as causal relationships. This is an area of future research. The dataset in turn relied on administrative efficiency and reflects only injuries that were reported and accepted as claims. It may exclude under-reported or misclassified cases, especially minor injuries or those not recognised as thoracic in origin. Ethnicity data were only available for 2013, 2018 and 2023, limiting trend analyses in that dimension. Further, cultural and socioeconomic differences, combined with access, may influence who submits claims, resulting in under-representation of certain demographics including ethnicity. Future studies are required to investigate such differences. It is important to note that the data set represents only the claims accepted by ACC. Therefore, TSI claims declined by ACC are missing and may throw further insights into gaps in access, communication and classification thereby improving equity and prevention. Finally, the findings are specific to New Zealand's ACC system and may not be generalisable to other countries without similar injury compensation frameworks.

Implications for practice and research

The increasing incidence of TSI, particularly thoracic spine fractures in older adults (especially females) and soft tissue injuries in working-age populations, warrant urgent need for targeted prevention strategies. Some successful strategies may include ergonomic workplace interventions, fall prevention programmes and public education

campaigns. The attitude of healthcare practitioners towards a fracture prevention programme (e.g., osteoporosis screening questionnaire) is an area of immediate research in New Zealand. The divergent trends observed across ethnic groups, especially the continuing trend of lower reporting rates in the Indigenous population, require sustained exploration that is culturally sensitive. Such an investigation will enable us to understand underlying drivers and ensure equity in access, reporting and outcomes. In terms of policy, forecasts projecting continued increases in fractures underscore the need for anticipatory healthcare planning and injury prevention investment by concerned authorities (e.g., Ministry of Health, ACC, etc.).

Conclusion

TSI claims in New Zealand have risen modestly over the past decade, with variation by sex, age and ethnicity. While soft tissue injuries remain the dominant diagnostic category, fracture claims are increasing and may place a growing burden on the health system. Therefore, targeted prevention strategies are required urgently. Ethnic trends are diverging, with lower incidence rates (speculatively because of lower reporting) in Indigenous communities. Hence, sustained culturally sensitive strategies are necessary to mitigate injury risk and promote equity. The study's findings offer timely evidence for TSI incidence rates and the need for public health planning in managing TSI.

COMPETING INTERESTS

Nil.

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Appendices

Appendix 1: Diagnosis and injury descriptions.

Diagnosis	Injury description
Fracture/dislocation	Closed fracture thoracic vertebra
	Fracture of thoracic vertebra
	Fracture of thoracic vertebra, level unspecified
	Closed fracture thoracic vertebra, wedge
	Multiple fractures of thoracic spine
	Fracture of thoracic vertebra, T11 and T12 level
	Closed fracture thoracic vertebra, transverse process
	Fracture of thoracic vertebra, T7 and T8 level
	Fracture of thoracic vertebra, T5 and T6 level
	Fracture of thoracic vertebra, T3 and T4 level
	Fracture of thoracic vertebra, T1 and T2 level
	Closed fracture thoracic vertebra, spinous process
	Fracture of thoracic vertebra, T9 and T10 level
	Closed fracture thoracic vertebra, burst
	Closed fracture thoracic vertebra not otherwise specified
Pain syndromes	Pain in thoracic spine
Soft tissue injury	Thoracic sprain
	Sprain and strain of thoracic spine
	Injury of muscle and tendon at thorax level

Appendix 2: Summary of statistical formulas used in analysis.

1. Incidence rate

Incidence rate=
 $(\text{number of cases/population}) \times 100,000$
 Expressed per 100,000 population. Applied
 across years, sexes, age groups and
 ethnicities.

2. Standard error (SE) of a rate

$SE = (\sqrt{\text{number of cases/population}}) \times 100,000$
 Used to estimate uncertainty in incidence
 rates. Applied when calculating z-scores and
 confidence intervals.

3. Z-test for comparing two rates

$$Z = (R_1 - R_2) / \sqrt{(SE_1^2 + SE_2^2)}$$

Where R_1 , R_2 =incidence rates of two groups
 (e.g., 2013 vs 2023, male vs female).

SE_1 , SE_2 =standard errors of the rates.

4. Percentage change

Percentage change=
 $([\text{final rate} - \text{initial rate}] / \text{initial rate}) \times 100$
 Used to calculate relative change in
 incidence over time (e.g., 2013 to 2023).

5. Annual percent change (APC) from regression

$$APC = (e^{\beta \text{Year}} - 1) \times 100$$

Where β Year is the regression coefficient
 from a Poisson or negative binomial model

Appendix 2 (continued): Summary of statistical formulas used in analysis.

using the log link function.

6. Confidence interval for APC

$$CI_APC = (e^{[\beta \pm 1.96 \times Se\beta]} - 1) \times 100$$

Derived from the standard error of the Year coefficient. Provides the 95% confidence interval for the APC estimate.

7. Rate ratio (RR)

$$RR = e^{\beta}$$

Estimated from the coefficient β in a Poisson or negative binomial regression comparing one group to a reference.

8. Confidence interval for rate ratio

$$RR_CI = (e^{[\beta \pm 1.96 \times Se\beta]})$$

Provides a 95% CI for the rate ratio estimate.

9. Time-series forecasting (ARIMA model)

$$\hat{Y}_{t+1} = c + \Phi Y_t + \theta \epsilon_t + \epsilon_{t+1}$$

Where Φ , θ , and c are estimated from the data. Used to predict future incidence rates based on past trends.

10. Model fit statistics

Dispersion = residual deviance / degrees of freedom

$$AIC = -2 \times \log(\text{Likelihood}) + 2 \times k$$

Where k = number of estimated parameters.

Used for model diagnostics.

COVID-19 is a living example of Darwinian natural selection, and SARS-CoV-2 evolution is occurring under (and in) our noses

Rohan Ameratunga, Euphemia Y Leung, See-Tarn Woon, Edward Lea, Lydia Chan, James AH Mehrrens, Hilary J Longhurst, Richard Steele, Klaus Lehnert

ABSTRACT

This review explores COVID-19 (coronavirus disease of 2019) from the perspective of Darwinian natural selection and consequent evolution of SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2). COVID-19 has caused unprecedented societal and economic turmoil. The human host population has responded with widespread vaccination, therapeutic monoclonal antibodies, convalescent plasma and antiviral drugs. SARS-CoV-2 has demonstrated remarkable resilience and has been able to quickly adapt to its rapidly changing habitat. SARS-CoV-2 has generated new antibody and vaccine evasive mutations in its genome, while simultaneously optimising its infectivity by improving its affinity to the ACE2 receptor and host proteases. Molecular analysis of SARS-CoV-2 has demonstrated natural selection of advantageous mutations in both individual patients with chronic COVID-19 infection and at a host population level, leading to extinction of less fit strains. COVID-19 is living proof of Darwinian evolution, which is occurring in observable time rather than over millions of years. Viewing COVID-19 from an evolutionary perspective will help mitigate the current and future pandemics. The aim of this article is to illustrate these concepts, using examples from the human host peer-reviewed literature.

Charles Darwin's theory of natural selection and evolution is the basis of modern biology. Darwin's seminal observations during the voyage of HMS *Beagle* led him to hypothesise that closely related species had evolved specific physical (phenotypic) traits to optimally adapt to their environment. Species and subspecies with advantageous traits were more likely to survive competition, resulting in greater reproductive success, leading to increased fitness. From an ecological perspective, fitness is closely linked to the reproduction number (R_0) which is related to the basic reproductive success of a species.

If there is a subsequent change in environment, other individuals with more favourable traits would thrive and successfully reproduce, resulting in greater fitness. These individuals would numerically dominate by outcompeting the previous incumbents, which could become extinct. This is the basis of natural selection leading to evolution. Although Darwin did not understand the molecular basis of heredity, he was aware adaptive traits could be passed to progeny.

COVID-19 (coronavirus disease of 2019) has occurred at a time of major scientific advances, including the routine deployment of sophisticated molecular biology techniques such as second

and third generation genome sequencing. This coupled with powerful computing tools has allowed detailed characterisation of the molecular evolution of SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2). Linking *in silico* predictions of advantageous mutations with subsequent population-based SARS-CoV-2 genome sequencing has validated the utility of these computing tools.¹

Natural selection of SARS-CoV-2 before the availability of vaccines

The origin of SARS-CoV-2 is unknown.² Since its appearance, SARS-CoV-2 has shown remarkable resilience to its rapidly changing environment. In late 2019 and early 2020 SARS-CoV-2 spread unhindered among unprotected human hosts. R_e is defined as the proportion of susceptible human hosts, which was very large before the advent of vaccines. Because of the high R_e , there was little selection pressure to generate new SARS-CoV-2 variants. There was thus a period of relative evolutionary stasis for SARS-CoV-2 early in the pandemic.

In the context of COVID-19, R_0 is defined as the average number of new individuals infected by each SARS-CoV-2 infected human host. Prior to

the availability of vaccines R_0 values were consistently above two, indicating rapid transmission of COVID-19. Lockdowns and travel restrictions by human host populations had a salutary impact on viral transmission. Some countries, such as New Zealand, sought an elimination strategy by closing borders and imposing strict entry controls with managed isolation quarantine facilities for returning citizens. During lockdowns, SARS-CoV-2 had reduced access to susceptible human hosts (R_e) resulting in a temporary reduction of R_0 and evolutionary selection pressure.

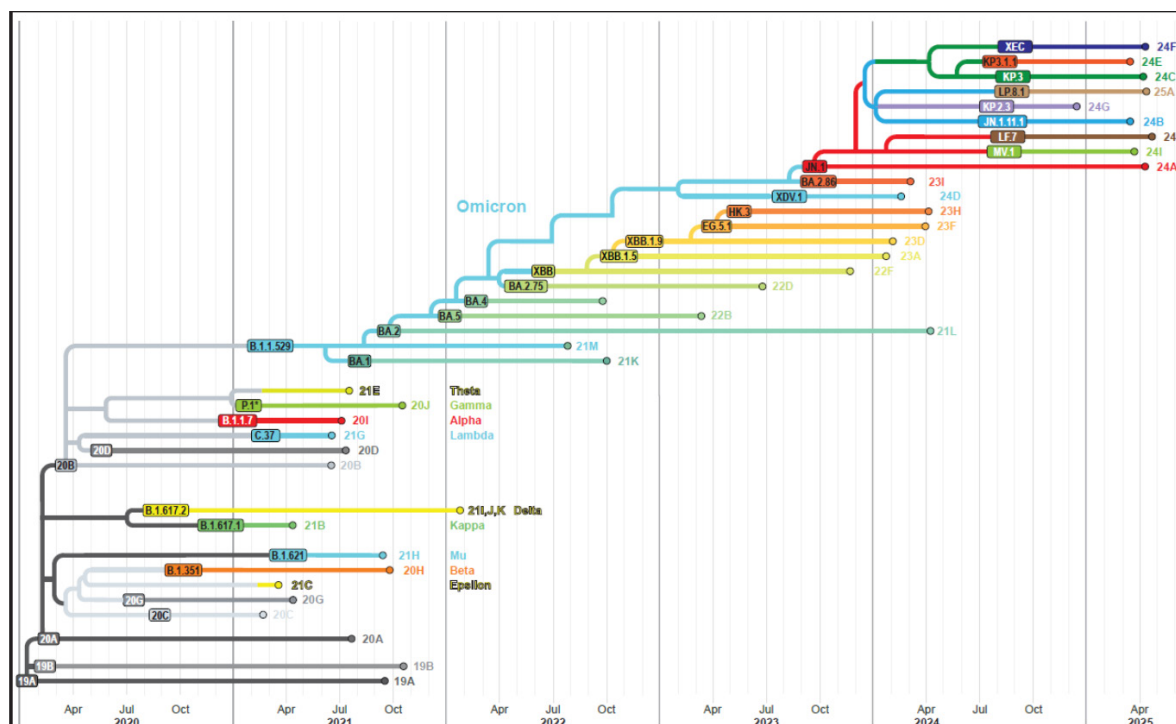
Early in the pandemic multiple pre-existing drugs were deployed by human hosts in the hope of efficacy against SARS-CoV-2; they were largely unsuccessful. These ineffective drugs did not exert selection pressure and had little impact on the R_e and R_0 of COVID-19.

In mid-2020 a new viral mutation was identified (D614G) which improved the affinity of the SARS-CoV-2 spike (S) glycoprotein for cellular ACE2 receptors resulting in increased infectivity and R_0 . These clades outcompeted the ancestral Wuhan virus (causing the first known outbreak

of COVID-19), which eventually became extinct. The extinction of early SARS-CoV-2 variants was evident initially from real-time genome sequencing of individual patients and later from wastewater sampling. Wastewater samples are the modern equivalent of ancient tar pits, excavated to establish the fossil record. Wastewater surveillance correlates closely with that of SARS-CoV-2 genome sequencing data from patients, attesting to its utility.³

After the period of relative evolutionary stability, three new dominant variants of concern (VOCs) emerged in late 2020: Alpha (B.1.1.7), Beta (B.1.351) and Gamma (P.1) (Figure 1). These VOCs were characterised by increased disease severity and transmissibility. These VOCs had several non-synonymous mutations in their S glycoprotein, allowing greater infectivity. Examples of adaptive S glycoprotein mutations in the Alpha VOC included the 69/70 deletion, increasing affinity for the ACE2 receptor and P681H enhancing furin cleavage.⁴ These VOCs presented as successive waves of infection in many countries.

Figure 1: Simplified phylogeny of SARS-CoV-2 strains based on 3,969 genome sequences collected between December 2019 and April 2025. Branch points indicate inferred dates of divergence; circles at branch termini indicate the last collection date of the virus variant or lineage. Virus clade identifiers are given on the right-hand side of each branch; representative strains are indicated in boxes placed on each virus branch at the approximate date of first observation. Asterisks indicate proxies for multiple sub-strains. Where available, common names of important virus strains are indicated. Based on data and visualisation from: <https://nextstrain.org/ncov>. Accessed 29 April 2025.



Natural selection and evolution of SARS-CoV-2 variants during the period of increased vaccine coverage

Human hosts began mass production of vaccines from early 2021, but there was inequitable distribution of vaccines because of vaccine hoarding by developed human host countries. Consequently, there was rapid circulation of SARS-CoV-2 in unvaccinated human host communities, which had a large R_0 . Consequent to low vaccine coverage, a new variant, Delta (B.1.617) emerged in late 2020 from India, which rapidly outcompeted previous VOCs and became dominant in many parts of the world (Figure 1).

During 2022 an increasing proportion of the global human host population received COVID-19 vaccines.⁵ Vaccination initially caused intense selection pressure on the fitness of SARS-CoV-2.⁶ No longer could the virus freely infect unprotected humans and efficiently transmit to new human hosts.

The emergence of SARS-CoV-2 Omicron (B.1.1.529) and breakthrough infections in vaccinated persons

From this new and increasingly hostile environment for SARS-CoV-2, Omicron (B.1.1.529), a new highly infectious variant emerged from Southern Africa in late 2021. COVID-19 vaccination may have been the main driver for the subsequent evolution of SARS-CoV-2 Omicron's subvariants. Compared to earlier VOCs SARS-CoV-2 Omicron had many more non-synonymous mutations in its S glycoprotein, resulting in higher binding affinity for the receptor-binding domain (RBD) of the ACE2 receptor while simultaneously evading neutralising antibodies.

Mutations in the Omicron S glycoprotein at positions 417, 452, 484, 486 and 501 have contributed to antibody evasion.⁷ SARS-CoV-2 Omicron was able to deftly navigate these twin obstacles, as evasion of neutralising antibodies by reducing its affinity for the ACE2 receptor and human host proteases would have resulted in reduced fitness and eventual extinction. Because of Omicron's high R_0 , it rapidly displaced SARS-CoV-2 Delta.

SARS-CoV-2 Omicron has thus successfully exploited a new habitat niche by infecting previously vaccinated individuals, albeit at lower efficiency than unvaccinated human hosts. While

vaccination did not completely prevent COVID-19 infection it resulted in a shortened period of shedding, which likely reduced the R_0 .⁸ Because protective T cell responses are intact in vaccinated human hosts, the disease severity of breakthrough infections is lower. COVID-19 vaccines protect the human host against a chaotic dysfunctional cellular immune response to SARS-CoV-2.⁹

SARS-CoV-2 Omicron's infection of COVID-19 survivors and human hosts with waning immunity

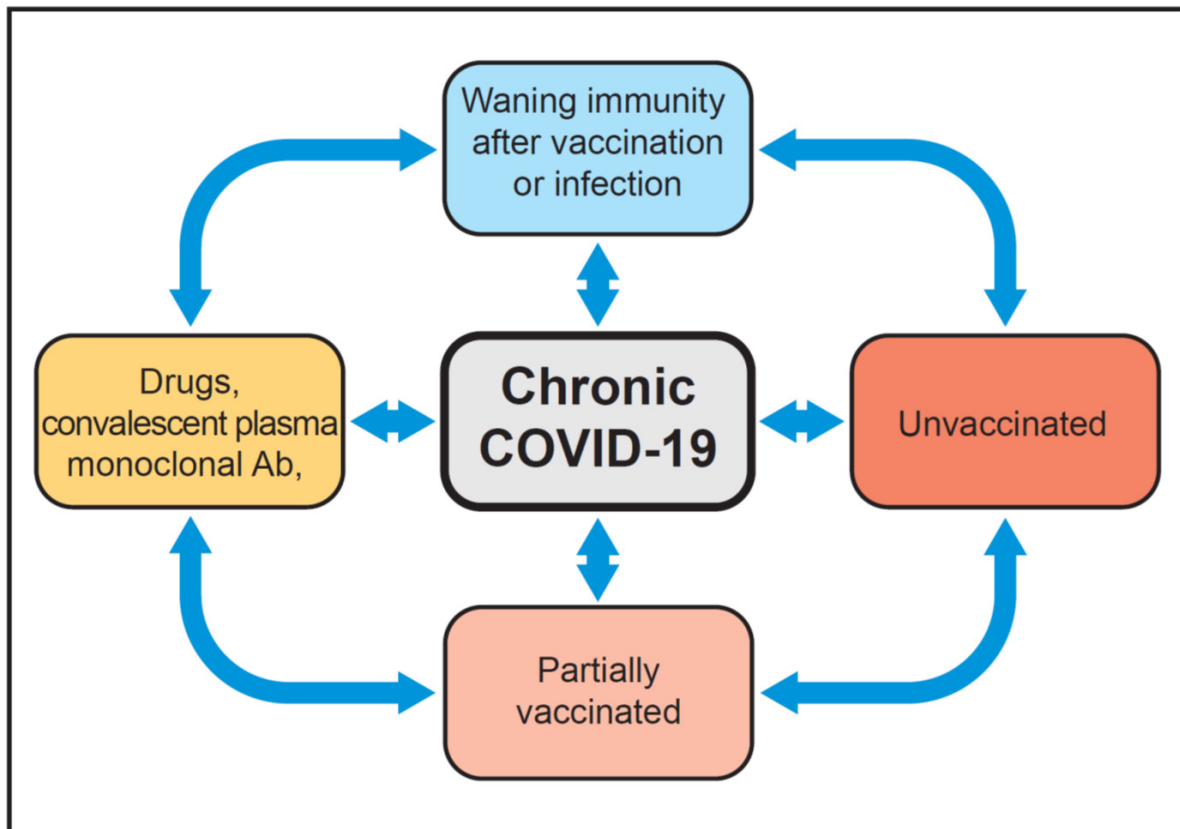
SARS-CoV-2 Omicron and its subvariants have rapidly exploited another new environmental niche: human hosts who have been previously infected with COVID-19 (Figure 2).¹⁰ This is another remarkable achievement, as human hosts with previous COVID-19 infection develop mucosal immunity. COVID-19 survivors also generate protective responses to a broader range of SARS-CoV-2 antigens, including the nucleocapsid (N) protein, in contrast to vaccinated individuals.¹¹ Because T cell immunity is intact, these previously infected individuals typically have mild symptoms, but can transmit disease to other human hosts.

Human hosts with waning immunity offer a new frontier for evolving SARS-CoV-2 variants.¹² Like human hosts who are unvaccinated or under-vaccinated because of vaccine hesitancy or apathy, those with waning immunity may also serve as a reservoir for the evolution and transmission of SARS-CoV-2 (Figure 2).

Some of SARS-CoV-2 Omicron's mechanisms of increased fitness

Some of the molecular mechanisms by which SARS-CoV-2 Omicron has evolved are discussed here. SARS-CoV-2 infects human hosts via mucosal surfaces, and virus replication is limited to the upper respiratory tract for several days after infection. Mucosal immunity may play a critical role in preventing infection. Human hosts with selective IgA deficiency (sIgAd) lack mucosal protection and may be at higher risk of severe COVID-19.¹³ A recent study from Türkiye showed sIgAd was much more common in severely affected COVID-19 human hosts admitted to hospital compared with the general population prevalence of sIgAd.¹⁴ Parenterally administered vaccines induce suboptimal mucosal immunity which has favoured SARS-CoV-2 Omicron's fitness (R_0).

Figure 2: Evolution of SARS-CoV-2 variants in response to environmental selection pressure. Patients with chronic COVID-19 infection are vulnerable to prolonged infection, which may allow the development of novel drug and vaccine evasive variants. These in turn will circulate and undergo further evolution with selective pressures, such as new vaccines, and drugs, such as monoclonal antibodies.



SARS-CoV-2 Omicron and its more recent subvariants (XBB.1.5 etc.) have evolved other mechanisms to increase fitness. The latency between infection and the appearance of viral budding is known as the eclipse time. Infectiousness with SARS-CoV-2 Omicron typically begins earlier: on day 3 compared with days 4–5 with other VOCs.¹⁵ The duration of viral shedding is also longer in SARS-CoV-2 Omicron which may extend the period of transmission.¹⁶ Mutations leading to a shorter eclipse time and longer shedding period favour a higher R_0 . SARS-CoV-2 Omicron also achieves higher human host nasal viral loads than its predecessors as its newer subvariants appear to be more efficient in suppressing innate immunity.¹⁷

SARS-CoV-2 Omicron triggers sneezing, which is an effective mechanism for transmitting the infection to new human hosts.¹⁸ Omicron also has a lower affinity for pulmonary alveolar cells and is thus less prone to cause acute respiratory distress syndrome.¹⁹ Teleologically, this may improve its transmission (and fitness, R_0) by

triggering sneezing rather than coughing. Sick human hosts with lower respiratory tract symptoms are more likely to self-isolate and SARS-CoV-2 may have less opportunity to infect new human hosts, leading to reduced fitness.

Molecular basis of SARS-CoV-2's rapid adaptation to new hostile environments

Global genome surveillance has shown that SARS-CoV-2 has rapidly generated multiple mutations to optimally adapt to its human host. There are several molecular mechanisms by which this genomic diversity could be generated.

SARS-CoV-2 requires an RNA-dependent RNA polymerase to replicate. Although this polymerase has 3' proof-reading activity, replication errors occur at about $1\text{--}2 \times 10^6$ bases per reproduction cycle.²⁰ Human host cellular machinery also contributes to this mutation rate. The APOBEC family of enzymes and cellular adenosine deaminase may contribute to viral mutagenesis.

Viral recombination is another recently recognised mechanism for generating genomic diversity.²¹ This can occur when the human host is simultaneously co-infected with two strains of SARS-CoV-2. The resulting hybrid viral progeny can have characteristics of both parental strains, with potential to increase its fitness. There are many examples of SARS-CoV-2 recombination including XB (B.1.631 and B.1.634), XC (Alpha and Delta), XD (BA.1 and Delta), etc.²¹ The most recent recombinant lineage is the SARS-CoV-2 XBB clades (BA.2.75 and BJ.1 [BA.2.10.1]) which were recently in widespread circulation, attesting to the importance of viral recombination as a mechanism of viral evolution.

Some antiviral drugs deployed by human hosts could also inadvertently accelerate the development of new SARS-CoV-2 variants. Molnupiravir acts by greatly increasing the mutation rate of SARS-CoV-2 beyond tolerable limits for successful viral replication. However, if there is poor human host adherence to treatment the result may be new VOCs with increased fitness.

Evolution of SARS-CoV-2 virulence

There is no evolutionary advantage for an obligate parasite, such as SARS-CoV-2, to kill its human host. A highly virulent virus which causes rapid death of the host cannot transmit efficiently, leading to a reduction in R_0 . There may be a balance between virulence and transmission efficiency which leads to an equilibrium of intermediate virulence with efficient transmission.²² However, it is dangerous to assume all viruses will lose their virulence over time and that the disease becomes milder.

Because SARS-CoV-2 can transmit infection to new individuals before the human host succumbs, the death of the human host may not adversely influence viral fitness. Purely by chance, a variant of high consequence (VHC) could evolve which has both increased fitness and high case-fatality rates. SARS-CoV-2 Omicron appears have a lower affinity for TMPRSS2, an endothelial receptor, expressed in respiratory, gut and other tissues, which may underlie its lower case-fatality rate. A single amino acid change can greatly enhance the virulence of SARS-CoV-2 Omicron by increasing its affinity for TMPRSS2.²³

Viral mutations leading to early cell death (and thus increased virulence) can occur during intra-host evolution, and there is a small possibility these could be transmitted through the bottleneck described below.²⁴ Given the large number of

infected human hosts, even a very low probability event leading to a VHC may become amplified. A VHC could emerge from stochastic events, recombination of SARS-CoV-2 strains or from immunodeficient patients with chronic COVID-19 infection, as discussed below (Figure 3).

Origin of variants of concern (VOCs)

As noted, a characteristic feature of VOCs is the large number of non-synonymous mutations in the S glycoprotein allowing antibody evasion, while simultaneously improving affinity for the ACE2 receptor and human host proteases. Intra-human host viral evolution occurs as part of COVID-19 infection. Because the infectious period is typically limited in previously healthy human hosts, only a few minor variants are generated during each infection.²⁵ Furthermore, there is a natural bottleneck for SARS-CoV-2 transmission as only one to two viral genomes are required to infect a new human host (Figure 3). Most of these minor variants are not transmitted through this bottleneck. Such a bottleneck could account for antigenic drift but not the large antigenic shifts associated with VOCs. The origin of these VOCs was therefore puzzling as intra-human host viral evolution in previously healthy individuals would not allow so many mutations to accumulate in such a short period.

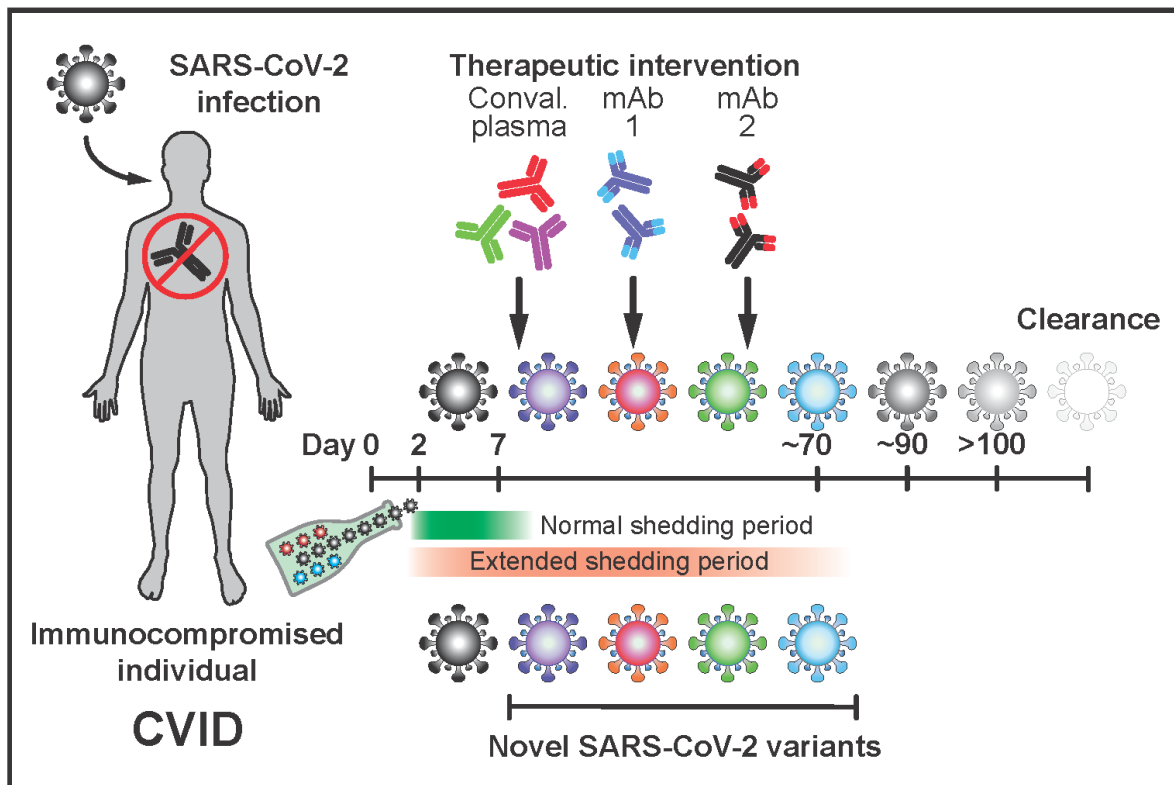
One possible source of VOCs is unrecognised viral evolution occurring in under-surveyed human host populations in developing countries. This would require undetected accumulation of multiple mutations over many months before the emergence of VOCs. This seems unlikely given global travel. Intermediate variants would have been identified in countries undertaking frequent SARS-CoV-2 genome surveillance during the period when such VOCs were evolving.

A second possibility is animal reservoirs of SARS-CoV-2, such as mink and white-tailed deer, where viral evolution could be occurring before spill-back into human hosts.²⁶ There is currently no robust evidence to support this hypothesis.

Chronic COVID-19 infection, a micro-incubator for accelerating SARS-CoV-2 natural selection and evolution

The third and most likely explanation for the origin of new VOCs is viral evolution in human hosts chronically infected with SARS-CoV-2 (Figure 3). Chronic COVID-19 infection occurs in immuno-

Figure 3: Intra-human host viral evolution in chronic COVID-19 infection. There is limited intra-human host viral evolution in immunocompetent persons with a narrow bottleneck. Because of the extended infectious period, the transmission bottleneck does not apply to chronic COVID-19 infection in immunocompromised persons, such as those with common variable immunodeficiency disorders (CVID).²⁷ The environment rapidly changes with use of convalescent plasma or monoclonal antibodies. This leads to the selection and emergence of escape mutants, leading to rapid viral evolution within an individual. The human host either eventually clears the virus or succumbs to the infection.



deficient human hosts where there is a stalemate between SARS-CoV-2 and a suboptimal immune response.²⁷ The inability to rapidly achieve sterilising immunity allows continuous replication of SARS-CoV-2 over weeks or months, leading to the accumulation of multiple mutations, some of which may confer a selective advantage to the virus progeny.

Human hosts with chronic COVID-19 infection may act as an incubator for the accelerated evolution of new SARS-CoV-2 VOCs (Figure 3). Because of prolonged viral shedding, the transmission bottleneck is removed from these immunodeficient human hosts, who may transmit many different SARS-CoV-2 variants to previously healthy human hosts (Figure 2, Figure 3).

Furthermore, treatment of these chronically COVID-19 infected human hosts with monoclonal antibodies or convalescent plasma results in the rapid emergence of resistant SARS-CoV-2 variants (Figure 3). Many of the advantageous mutations identified in VOCs are recapitulated in individual

human hosts with chronic COVID-19 infection. Mutations at position E484, for example, are common in both chronic COVID-19 infection and in VOCs, which are associated with monoclonal antibody evasion.²⁸ Alarming, patients with chronic COVID-19 infection could also generate nirmatrelvir (the active ingredient of Paxlovid) resistance.²⁹

Identification of similar SARS-CoV-2 mutations in patients with chronic COVID-19 infection to those of VOCs is evidence of selection pressures, leading to convergent evolution, which improve the fitness of new SARS-CoV-2 variants.³⁰ This is robust evidence VOCs have originated from human hosts with chronic COVID-19 infection.

Viewpoint: Can Darwin's theories predict the future of the COVID-19 pandemic?

There are several possible future scenarios for COVID-19, some of which could result from

stochastic events, recombination of SARS-CoV-2 strains, chronic COVID-19 infection or accelerated evolution caused by drugs and vaccines. There are at least three possible scenarios from an evolutionary standpoint. From the perspective of human hosts, the worst to best-case scenarios are as follows:

1. The worst-case scenario is the evolution and emergence of a VHC. Mutations which confer virulence are often linked to transmissibility.²² As noted, there is an equilibrium between virulence and transmission efficiency. In the case of SARS-CoV-2 this equilibrium may not be stable with the large number of human hosts infected and relatively high mutation rate. The other pertinent consideration in COVID-19 is removal of the transmission bottleneck in immunocompromised individuals leading to the generation of multiple variants, including the potential for a VHC. Thus, the emergence of a VHC remains a possibility if immunocompromised human hosts are not protected and isolated when chronically infected with SARS-CoV-2. Current vaccines will likely provide some protection against a future VHC and reduce the case fatality rate. It is hoped more effective drugs such as Paxlovid (nirmatrelvir/ritonavir) will be made widely available in the event a VHC emerges. From the human host perspective, there are fortunately other potential treatment strategies, including modified ACE2 receptors administered intranasally.³¹ These drugs could be administered concurrently with antivirals to interrupt transmission of SARS-CoV-2 and mitigate disease severity. Given the critical requirement for cell entry, therapeutic soluble ACE2 receptors will maintain their antiviral efficacy even if SARS-CoV-2 VHCs emerge. Intranasal ACE2 treatment has been shown to abrogate severe COVID-19 in murine models of COVID-19, and human trials of these drugs have commenced.
2. The mostly likely scenario is endemicity of SARS-CoV-2 with ongoing waves of infection caused by new VOCs. These new variants will circulate quickly with global travel and removal of other restrictions such as face mask use. Between these waves of infection there is likely to be ongoing antigenic

drift, most likely caused by the small changes to the viral genome due to intra-host viral evolution. With international travel, competition and selection between SARS-CoV-2 strains will occur rapidly and new clades with higher fitness will soon outcompete incumbents. It is thus unlikely there will be large phylogeographic variations in SARS-CoV-2.

Vaccine manufacturers have continued to innovate, for example including both the Wuhan and Omicron (BA.1) S glycoproteins in bivalent vaccines. Viral evolution is outpacing these efforts, and newer Omicron variants such as XBB.1.5 were not neutralised by bivalent vaccine-induced antibodies, although cellular immune responses are less likely to be adversely impacted. Subsequently, the Omicron XBB.1.5 S glycoprotein was included in COVID-19 vaccines and was effective in reducing disease severity.

Most recently the US Food and Drug Administration (FDA) has authorised vaccines based on the JN.1 and KP.2 Omicron subvariants. Human host vaccine hesitancy and apathy will thwart the efforts of vaccine manufacturers, leading to waning immunity allowing circulation of SARS-CoV-2 (Figure 2). Recurrent COVID-19 caused by a never-ending parade of new SARS-CoV-2 VOCs, with potential for cumulative organ damage, will lead to an increasing global burden of disability.

3. The best, but least likely, scenario from the perspective of the human host, is extinction (global eradication) of SARS-CoV-2. Because of the rapid evolution of SARS-CoV-2, it is unlikely current vaccines will prevent breakthrough infections and transmission of future SARS-CoV-2 variants. Future live-attenuated nasal COVID-19 vaccines may enhance mucosal immunity and complement those administered systemically to reduce the risk of breakthrough infections. Inclusion of other viral antigens such as the N protein may also reduce the risk of vaccine evasion leading to breakthrough infections and viral transmission. These enhanced vaccination strategies may result in long-lasting sterilising immunity, which will greatly reduce the number of susceptible human hosts (R_0). New

therapeutics such as ibuzatrelevir will also play an important role in treating SARS-CoV-2 and reducing the risk of chronic COVID-19 infection in immunodeficient hosts, preventing accelerated viral evolution. Experience from HIV suggests that combinations of antiviral therapies may improve efficacy and reduce the risk of SARS-CoV-2 drug resistance; clinical trials will inform future treatment strategies. Improved vaccines in combination with affordable and widely available antiviral drugs may result in gradual habitat denial

to SARS-CoV-2, leading to its eventual extinction.

Conclusion

Viewing COVID-19 from the perspective of Darwinian natural selection and evolution may lead to new and more effective strategies to mitigate current and future pandemics. Extinction of SARS-CoV-2 must remain the primary goal of human host scientists designing second generation COVID-19 vaccines and novel therapeutics.

CONFLICTS OF INTEREST

The authors have no relevant affiliations or financial involvement with any organisation 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.

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RA conceived and wrote the first draft. KL drew the diagrams and contributed to editing the text. All other authors edited the manuscript. All authors have contributed to this manuscript in terms of drafting and editing the final version of the manuscript.

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Nurse endoscopists: a rational response to rising rates of young-onset colorectal cancer in Aotearoa New Zealand

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ABSTRACT

Young-onset (<50 years) colorectal cancer (YOCRC) has been increasing in Aotearoa New Zealand since the birth cohort born around the mid-1950s. Possible responses include education and public health measures, none of which are likely to make a major impact in the foreseeable future. Many YOCRCs are presenting at late stages with predominantly distal cancers. Our current National Bowel Screening Programme (NBSP), screening people 60–75 years, was introduced with inadequate resources; as a result, some colonoscopy services have been moved from symptomatic cases to screening, resulting in diagnostic delays and poorer outcomes. Extending screening to 40 or 45 years will markedly increase the need for follow-up colonoscopies and stretch services beyond breaking point. Sigmoidoscopy is associated with a substantial and sustained reduction in risk of distal colorectal cancer incidence and mortality. As there are too few endoscopists for the existing workload, increasing the nurse endoscopist workforce is a rational step. Initial training would focus on flexible sigmoidoscopy (FS) and concentrate on symptomatic patients <50 years. Steadily increasing nurse endoscopist numbers will contribute to management of the rising incidence of YOCRC. Without disrupting the NBSP or putting much extra strain on need for follow-up colonoscopies, nurse-led FS clinical services can expand to anyone with relevant symptoms and, as a longer-term goal, eventually become part of an expanded screening programme that could include one-off FS at age 50. If we are agreed that this is essential, training and service must be adequately funded and accompanied by a public advocacy campaign to ensure sufficient resources.

Rates of young-onset colorectal cancer (YOCRC) are continuing to rise

Unlike colorectal cancer (CRC) among older adults, CRC is increasing in those <50 years in Aotearoa New Zealand¹ and in many other countries.^{2–7} It is presenting largely as left-sided (distal) colon cancer and rectal cancer^{8,9} and a substantial proportion have advanced disease,^{8,10,11} although survival is better, perhaps because treatment is more aggressive among these younger patients.^{10,11}

Some YOCRC is associated with a specific genetic predisposition (e.g., Lynch syndrome, familial adenomatous polyposis) and others have a positive family history. However, the majority are of unknown aetiology,² although there is evidence of an association with known dietary and lifestyle risk factors¹² and, most recently, a finding that early-life mutagenic exposure to colibactin-producing bacteria may be relevant.¹³

Our modelling shows that the birth cohort

born around the mid-1950s had the lowest CRC incidence and mortality; these have risen among those born in subsequent generations.¹⁴

Many YOCRC are presenting at late stages, almost certainly because of a marked lack of awareness of the potential meaning of symptoms (e.g., pain, change in bowel habit) and even signs (e.g., blood in stool, anaemia) among both young people themselves and healthcare professionals. A recent study confirms that missed diagnostic opportunities in CRC are far too common.¹⁵

Possible responses—education and public health

The proper response to this growing problem is multipronged:

- increased public and medical awareness, which necessitates a substantial investment in the relevant education;
- encouragement to present early with symptoms;

- timely accurate diagnosis when symptoms develop;
- development of effective biomarkers;¹⁶
- encouragement of improved diet and exercise.¹⁷

Possible responses—expanding screening

None of these are likely to make a big impact in the foreseeable future and, thus, there is a need to markedly improve early detection. However, the current National Bowel Screening Programme (NBSP) does not cover this at-risk group. One possibility is lowering the NBSP earliest age of screening (currently 60 years, soon to be 58 years) by at least 15–20 years. Given that incidence is increasing even among teens and that substantial numbers of YOCRC are occurring in the 30–34 age group,^{5,18,19} the starting age for screening would need to be lowered substantially.

The NBSP was introduced without adequate resources, despite repeated warnings from Aotearoa New Zealand gastroenterologists.^{20,21} As a result, some colonoscopy resources have been moved from symptomatic cases to screening, with patients experiencing delays and suffering poorer outcomes, exacerbating the “postcode lottery”.^{22,23} Accordingly, extending the existing faecal screening programme down even to age 40 or 45 years will markedly increase the need for follow-up colonoscopies as well as subsequent surveillance colonoscopies and stretch existing endoscopy services well beyond breaking point. As noted above, the need for screening-associated follow-up colonoscopies is already delaying diagnostic colonoscopies, potentially further worsening the pattern of late presentation among YOCRC patients.

Colonoscopy has the advantage, rare in screening modalities, of being able to detect lesions with high specificity and sensitivity as well as treat most pre-cancerous lesions, thus lowering both incidence and mortality. For instance, one of the only randomised clinical trials of colonoscopy undertaken established a 10-year risk of CRC of 0.98% in the group invited for screening and 1.20% in the “usual care” (no intervention) group; relative risk (RR)=0.82 (0.70–0.93).^{24,25} The RRs for CRC mortality and overall mortality were statistically non-significant: 0.90 and 0.99 respectively. Even if Aotearoa New Zealand had the resources to undertake routine colonoscopy screening, these outcome data and the low uptake seen elsewhere

both among those ≥ 50 years (around 30%)²⁶ and those 45–49 years (less than 2%)²⁷ would preclude this as a solution to both overall screening and screening among younger people.

Other possible approaches to screening include testing for plasma Septin 9 DNA methylation²⁸ or using the cell-free DNA blood-based test²⁹ (both approved by the United States [US] Food and Drug Administration [FDA]),^{30,31} but the latter producing poorer results than faecal immunochemical test for blood [FIT] when community uptake is comparable³² or using the updated Cologuard³³ faecal DNA test (also FDA approved³⁴). However, these are all primary screens that still require a follow-up colonoscopy following a positive result. Even if these prove to be more acceptable to those < 50 years, they are thus not strong alternatives and, at present in Aotearoa New Zealand, there is little thinking past FIT plus colonoscopy.

The rational response to this wicked problem,³⁵ in addition to the public health and educational responses outlined above, is to add a different modality to the screening process, namely flexible sigmoidoscopy (FS), a modality that has greater sensitivity and specificity than the current stool screening, albeit with slightly lower overall acceptability.

Sigmoidoscopy has been shown to be associated with a substantial^{36,37} and sustained (up to two decades)^{38–42} reduction in risk of incidence of and mortality from, particularly, distal CRC. For instance, the multicentre UK Flexible Sigmoidoscopy Screening Trial randomised men and women (aged 55–64 years) 2:1 to the control group (no further contact) or intervention (invited to once-only FS). After 406 exclusions, the control group included 112,927 participants and the intervention included 57,099 participants. Of those invited to screening, 40,624 (71%) attended. Median follow-up was 21.3 years. In the invited-to-screening group, CRC incidence was lower than in the control group: cumulative incidence at 21 years was 3.18% vs 4.16%; hazard ratio (HR)=0.76 (0.72–0.81). CRC mortality was lower in the intervention group than among controls: HR=0.75 (0.67–0.83). Effects were most marked in the distal colorectum for both incidence (HR=0.59 [0.54–0.64]) and mortality (HR=0.55 [0.47–0.64]).⁴⁰

In the long-term follow-up (median: 15.4 years for incidence and 18.8 years for mortality) of the Italian FS study, CRC incidence was reduced by 19% in the intention-to-treat analysis and by 33% in the per-protocol analysis.⁴³ The comparable

reductions in CRC mortality were 22% and 39% respectively. CRC incidence was reduced in both men and women, and CRC mortality reduced primarily in men.⁴³

A recent meta-analysis reported a 26% reduction in RR of CRC incidence and a 30% reduction in CRC mortality.⁴⁴ FS significantly reduced the incidence of CRC compared with non-screening, usual care and FIT. Findings for both incidence and CRC mortality were consistent across men, women, distal cancer, late-stage cancers, ages 55–59 and age ≥60.⁴⁴ Two other meta-analyses produced comparable results.^{45,46}

Both FIT⁴⁷ and FS^{38,48} screening do less well identifying proximal cancers. However, a combination of screening and testing for anaemia markedly improves detection, even in symptomatic patients. A cohort study of 7,375 patients (≥55 years) referred from 2004 to 2007 with suspected CRC to 21 English hospitals yielded 127 proximal and 429 distal CRCs. A broad definition of anaemia (<130g/L men; <120g/L women) identified 80% of proximal cancers. In patients without anaemia and/or an abdominal mass and with rectal bleeding or increased stool frequency, the proximal cancer yield was 0.4% (13/3,031), leading the investigators to conclude that proximal cancers are accompanied by anaemia as defined and that, in patients without anaemia or an abdominal mass or both and who have rectal bleeding or increased stool frequency, “proximal cancer is rare.”⁴⁹ A separate study that employed a combination of FIT screening and testing for iron-deficiency anaemia (IDA) in 1,000 symptomatic patients reported that the combination of positive tests for both FIT and IDA missed only two patients with advanced malignancy.⁴⁷ Evidence that precursor serrated sessile lesions are more common in women <50 years^{50,51} raises some concerns about missed diagnoses, ameliorated in part by the likelihood that the frequent presence of synchronous adenomas⁵¹ improves detection.

The US Surveillance, Epidemiology, and End Results (SEER) programme data on 309,466 individuals (2000–2020) were used to establish that 73% of CRCs in people ≥50 years were visible by sigmoidoscopy, leading the researchers to note that FS should be considered “a viable option for CRC screening, particularly in younger patients unwilling or unable to undergo colonoscopy.”⁵² A comparable argument holds for using FS in young people when FIT-associated follow-up colonoscopies will overwhelm the service needed for diagnosis. Diagnostic services and

screening in this younger population are urgently needed.

Other studies are consistent with the finding that around 70% or more of YOCRC present with distal colon cancer and rectal cancer,^{1,4,7,53} and that increases in these distal CRCs are accounting for almost all the rise of YOCRC.^{1,7} The combination of FS and testing for anaemia should prove to be an effective approach to screening in this population.

FS needs to be added, in the first instance, as a diagnostic procedure and, subsequently, specifically to screen people from, say, age 40 years. This will provide a necessary focus on the rising rates of YOCRC without adding to the need to greatly expand the FIT screening programme and the consequent major increase in demand for follow-up and surveillance colonoscopies.

Towards a solution

As there are too few endoscopists to cope with the existing workload, there is a need to add to the workforce. We should begin to expand the nurse endoscopist workforce, with initial training focusing on undertaking sigmoidoscopies, especially among those <50 years.

We propose a nurse-led FS service as part of an integrated interdisciplinary team approach to those with red-flag lower gastrointestinal (GI) symptoms: substantial change in bowel function, faecal blood and unexplained weight loss. Longer term, this expanded service can contribute to CRC screening for those <50 years.

Pros of an expanded FS service:

- FS is quick, relatively safe (no need for intravenous sedation or analgesia) and cheaper than colonoscopy.
- As noted above, most YOCRCs are left-sided and therefore suitable for investigation by FS,^{1,4,7,53} particularly among those with fresh rectal bleeding.⁵⁴
- It is possible to protect against missing proximal lesions by combining FS with abdominal examination and blood tests for anaemia and iron deficiency.⁴⁹
- The characteristics of FS-detected high-risk adenomas define with high precision the need for a complete colonoscopy.⁵⁵
- The ability to identify the need for colonoscopy via the nature of distal lesions, testing for anaemia, and the low false-positive rate of FS together markedly reduce

the need for follow-up colonoscopies.⁵⁶

- FS has been used successfully in many clinical services for investigation of lower GI symptoms⁵⁷ and for CRC screening, where it has been shown to reduce distal CRC incidence and mortality.^{58,59}

Cons of an expanded FS service:

- FS is relatively unpleasant and can be stressful but is made less so by prior access to informational videos and availability of Entonox inhalation.⁵⁶
- There is an overall higher than expected risk of proximal CRC presenting with an isolated change in bowel habit or a combination of change in bowel habit and rectal bleeding.⁶⁰ However, the fact that YOCRC is more commonly left-sided,^{1,4,7,53,54} coupled with the data derived from the nature of distal lesions⁵⁵ and the empirical evidence that testing for anaemia is highly effective,⁴⁹ all reduce the risk of missing right-sided lesions.
- Although rates of YOCRC are rising, the absolute numbers are low. That suggests that risk stratification may be one approach—for example, initially focussing screening on those with high-risk lifestyle factors¹² or strong family histories. However, these are not very efficient filters for YOCRC and are often absent.
- Some future technological disruption might marginalise FS as a primary diagnostic or screening modality, but that will be a problem for all endoscopists and the current need is exigent.

Pros of nurse-led FS service:

- Publications from the 1980s onwards have called for increasing the employment of nurse (and other non-physician) endoscopists.⁶¹
- A large randomised trial in 29 centres in the United Kingdom (UK) showed that nurses completed FS with the same degree of competence as doctors.⁶²
- With proper training and supervision, nurse-led colonoscopy and FS are safe and of a standard comparable to medical-specialist endoscopists^{63–65} and, when institutionalised, results in a substantial increase in access to CRC screening.⁶⁵

- It has been shown that break-even costs per procedure can be achieved with a team of one senior gastroenterologist supervising three active nurse endoscopists.⁶⁶
- Further, some economic models have shown that an FS programme (with or without stool testing) to screen average-risk populations can be cost effective⁶⁷ and will be economically advantageous in the long term.¹⁴
- If introduced as a suitable interdisciplinary model,⁶⁸ such a service would have a lower impact on existing (inadequate) services than reducing the screening age of NBSP.¹⁴

Cons of nurse-led FS service:

- Such a service will require specialist back-up and will increase workload on downstream investigations, treatment and follow-up.⁶¹ However, much of that applies, irrespective of who is doing the original FS. As noted above, break-even costs per procedure can be achieved with a team of one senior gastroenterologist supervising three active nurse endoscopists.
- An excellent UK clinical trial compared the cost effectiveness of nurses and doctors for both upper GI endoscopy and FS.⁶⁹ The key finding was that although “*differences did not reach traditional levels of significance, patients in the doctor group gained 0.015 QALYs more than those in the nurse group.*” This does not seem to present a strong argument against a nurse-led service.

Nurse endoscopy training

A 2017 study predicted that, as screening increased in what subsequently became the NBSP, there would be an “*increased demand for endoscopy procedures and endoscopists.*”⁷⁰ This conclusion did not reference the growing burden of cancer in those <50 years, even though that was already becoming clear.^{71–73}

Nurses and other non-medical personnel are currently doing routine FS (and colonoscopy) in the US,⁷⁴ the UK,⁷⁵ Canada⁶⁵ and the Netherlands.⁶⁶ The UK has moved to institutionalise non-medical endoscopists and to diversify the endoscopy workforce. In 2023, Health Education England transferred responsibility for endoscopy training to regional endoscopy training academies.⁷⁶ The UK FS training programme lasts 7 months,⁷⁷ with an organised

follow-up surveillance programme that has a website to monitor non-medical FS practice.⁷⁸

Within the Gastroenterology Nurses' College of the New Zealand Nurses Organisation, the nurse endoscopist sub-group is focussed on professional support for current nurse endoscopists, education and upskilling, mentoring, recruitment and expert consultation, as well as articulating and promoting the *"nurse endoscopist role to the broader health and patient community."*⁷⁹ They have established the prerequisites, training requirements and credentialling process for nurse endoscopists.⁸⁰ The sub-group was officially named the New Zealand Nurse Endoscopists Association (NZNEA) in November 2023.⁸¹

For Aotearoa New Zealand, standard workforce planning applies to nurse endoscopists/practitioners (NE/Ps) as to any role in Health New Zealand – Te Whata Ora: a need is identified and an appropriate training plan with funding is issued with the inclusion of long-term financial and education sustainability. We have an ageing population; due to a variety of forces, we do not have enough gastroenterologists.⁸²

An initial nurse endoscopist training programme began at The University of Auckland and, by 2019, four nurses had completed a 1-year academic programme (and >200 scopes) and all were accredited in at least one of the following: gastroscopy, FS and colonoscopy.⁸³ One of us (NG) is now implementing training in Waikato, with an emphasis on an NE/P pathway, as described in documents on which the NZNEA working group has agreed.⁸⁰ There is support from Te Whatu Ora management in Waikato, the New Zealand Nurses Organisation, the New Zealand Society of Gastroenterology, the Nursing Council of New Zealand and GI doctors and surgeons, particularly in Waikato, as well as other parts of Aotearoa New Zealand. Offering an opportunity to become an NE/P provides career progression and a challenging incentive to stay and care for our people and our communities and contribute to a potential brake on the current major losses of nurses in Aotearoa New Zealand, particularly to Australia.⁸⁴

Nurse endoscopist training is not different from that of those who are medically trained. The New Zealand Conjoint Committee for Recognition of Training in Gastrointestinal Endoscopy (NZCCRTGE) accepts nurses who become conjointly registered, thereby meeting the national standard.⁸⁵ The training programme could be decentralised as in the UK, and there are already opportunities at

other sites, e.g., Canterbury Charity Hospital.

It is important to acknowledge that nurses performing endoscopic procedures are advanced in relevant skills; this allows them to perform duties that have been traditionally performed only by those who are medically trained. In Aotearoa New Zealand (and indeed worldwide) there is a shortage of medically trained individuals available to perform such duties/procedures/care and thus nurse endoscopists can contribute as leaders and members of teams that fill this particular need. Built into NE/P training will be managing histology results, assessing patients, interpreting bloods and referring for/requesting other investigations; these are already well within the role of a nurse practitioner.⁸⁶ Finally, the NE/P is able to prescribe conscious sedation, initiating and continuing treatment if required dependent upon setting.⁸⁶

Although, as described, the intention is that full endoscopy training be implemented, in relation to YOCRC there is an urgent need for FS training and this should be the initial focus.

Implications

As more nurse endoscopists are trained, we will be increasingly able to manage the rising incidence of CRC among those <50 years. Without disrupting the NBSP and without putting much extra strain on the need for follow-up colonoscopies (see above), Aotearoa New Zealand will be able to offer nurse-led FS clinical services to anyone <50 years with relevant symptoms:

- any fresh rectal bleeding;
- any early symptoms of CRC.

This growing capacity can eventually become part of an expanded screening programme that, at a minimum, could include one-off FS at age 50. The US Preventive Services Task Force recommends that screening for CRC start at age 45.⁸⁷ The American Cancer Society recommendation that screening begin at age 45 is a qualified recommendation, whereas the recommendation for regular screening in adults aged ≥50 years is strong.⁸⁸ We are currently doing neither in Aotearoa New Zealand.

Conclusions

Like many new developments in healthcare, nurse endoscopy seems to have gone through

three general phases of enthusiasm: 1) it is the key to all endoscopy problems; 2) it is more trouble than it's worth; and finally 3) it requires a training programme, provides a needed clinical service and can take its place in the healthcare system.

If we are agreed that it is essential, training

and the service must be adequately funded and accompanied by a public advocacy campaign to ensure that sufficient resources are maintained, including for the needed expansion of follow-up. The return on this investment will be multifold in lives saved and costs reduced.¹⁴

COMPETING INTERESTS

Nil.

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Paediatric ingestion of one hundred small high-power magnets—the dangers of the online marketplace

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Foreign body ingestion is common in paediatric patients.¹ Most foreign body ingestions pass spontaneously without causing injury, and only a minority require intervention. Ingestion of multiple magnetic objects, however, can have serious consequences such as pressure necrosis, perforation and fistulation and thus the majority (75–87.5%) of patients require surgical or endoscopic intervention.^{2–4} Accessibility to high-power magnets is a rising concern for our paediatric population, which may be due to the ability to purchase from online marketplaces at inexpensive prices.⁵

We present the case of a 13-year-old boy admitted to hospital with 4 days of generalised abdominal pain. He disclosed ingesting approximately 80–100 5x2mm high-power (neodymium) magnets about 1 week prior, which were purchased from an overseas online marketplace (Temu™). On examination his abdomen was maximally tender in the right lower quadrant with guarding.

Abdominal X-ray revealed four linear chains of magnets localised to the right lower quadrant of the abdomen (Figure 1). These appeared to be in separate parts of bowel adhered together due to magnetic forces. There were no features of bowel obstruction or pneumoperitoneum. Computed tomography (CT) imaging was distorted by metallic artefact from magnets although it did not reveal any pneumoperitoneum.

The patient went forward for exploratory laparotomy. Intraoperative findings were of several chains of magnets at different segments of small bowel and caecum. These were adhered at multiple points in the right lower quadrant causing pressure necrosis (Figure 2, Figure 3). In total there were two areas of pressure necrosis of the caecum and two areas of the small bowel. An ileocolic resection and two small bowel wedge

resections were performed to retrieve magnets (Figure 4). Intraoperative image-intensifier revealed no further magnets remaining in abdomen. There was no intra-abdominal contamination. A nasogastric was placed intraoperatively due to risk of ileus.

Post-operative recovery was complicated by anastomotic staple-line bleed and post-operative ileus, which were both managed conservatively without requiring reintervention. The patient was discharged on post-operative day 8 after successfully progressing diet.

Conclusion

Ingestion of multiple magnets can have serious consequences including pressure necrosis, perforation, obstruction, fistula and sepsis.^{2–4} Given the majority are managed with surgical intervention, this can lead to further complications later in life including adhesional bowel obstruction, abdominal hernia and chronic pain.^{6,7} Preventative strategies are important to reduce risk of harm to paediatric patients.⁸

Both Australia and New Zealand product safety laws have outlined a permanent ban on the sale of small high-powered magnets.^{9,10} While these laws can be enforced locally, it is more difficult to regulate products supplied by overseas merchants on large-scale online marketplaces. These platforms are easily accessible especially by children, with purchases being inexpensive and not always requiring age verification. This case highlights not only the dangers of magnet ingestion but also the dangers of the online marketplace for our paediatric population. Despite current product safety laws in New Zealand, there is alarming difficulty in enforcing regulations on products purchased from overseas online marketplaces, which remains a serious concern.

Figure 1: Abdominal X-ray with four linear chains of magnets in the right lower quadrant.

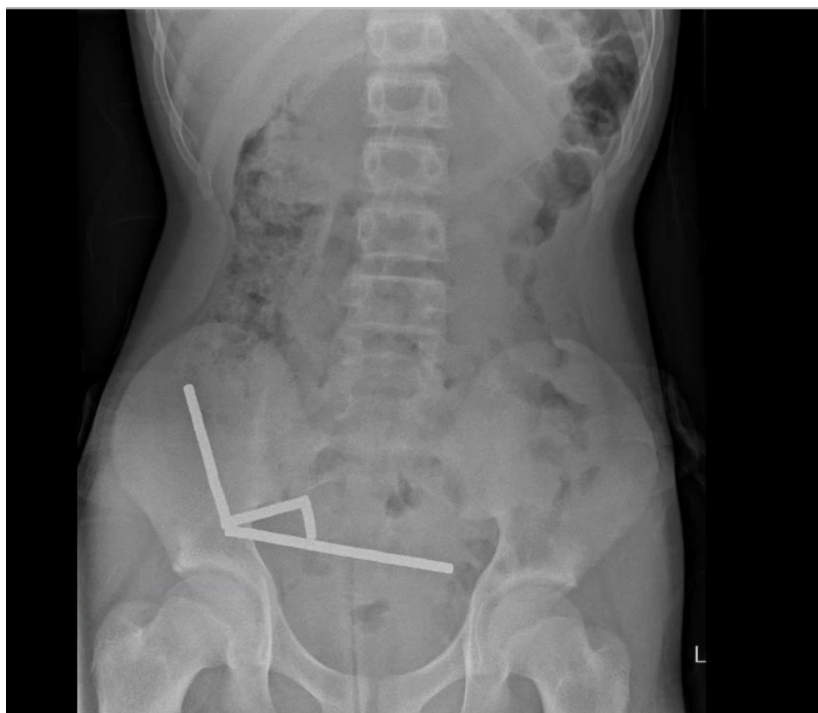


Figure 2: Intraoperative image with arrow pointing to two segments of bowel adhered by magnets.

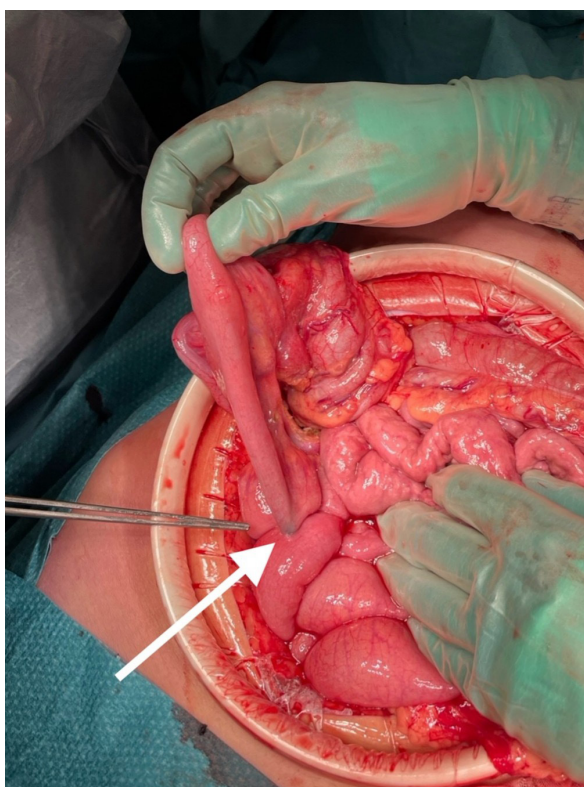


Figure 3: Intraoperative image with circle indicating area of pressure necrosis on the caecum and arrow pointing to chain of magnets in the terminal ileum.

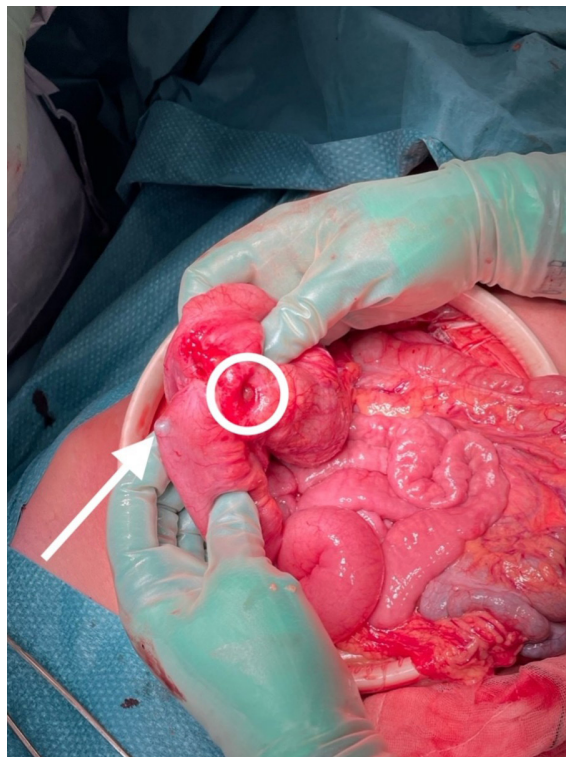


Figure 4: Approximately 80–100 high-powered magnets retrieved from operation.



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Klebsiella pneumoniae liver abscess following screening colonoscopy: a case report

Seong Shin, Maggie Chapman-Ow

ABSTRACT

Colonoscopy is a cornerstone of colorectal cancer screening with a low incidence of complications such as bleeding and perforation. Infectious complications such as liver abscesses are exceedingly rare. We report a case of a 72-year-old Sri Lankan man with a background of diabetes mellitus and diverticulosis who developed a pyogenic liver abscess (PLA) following an uncomplicated colonoscopy performed as part of the New Zealand bowel screening programme. The abscess was caused by *Klebsiella pneumoniae*, a pathogen commonly associated with such infections. He was successfully treated with broad-spectrum antibiotics and ultrasound-guided drainage. This case raises the possibility of a rare association between colonoscopies and pyogenic liver abscesses, even in non-invasive procedures, particularly in high-risk patients, though direct causality cannot be established. We reviewed potential mechanisms and relevant literature in this case report.

A 72-year-old Sri Lankan man presented to the emergency department on 24 May 2025 with a 2-day history of increasing lethargy, general weakness and right upper quadrant abdominal pain. Symptoms began 3 days after a screening colonoscopy performed on 19 May 2025, prompted by a positive faecal immunochemical test (FIT) as part of the New Zealand bowel screening programme. The procedure was uneventful, revealing only small-mouthed diverticula and haemorrhoids, and no mucosal interventions such as biopsies or polypectomies were performed.

His past medical history included ischaemic cardiomyopathy with a left ventricular ejection fraction of 24%, previous coronary artery bypass grafting, inferior ST elevation myocardial infarction, peripheral vascular disease, type 2 diabetes mellitus and stable Parkinson's disease.

On examination, he was septic with a fever (38.2°C) and mild right upper quadrant tenderness. Laboratory results showed a C-reactive protein (CRP) of 263mg/L, white cell count of $14.37 \times 10^9/L$, and normal liver function tests. A computed tomography (CT) scan revealed a large hepatic abscess in the right lobe, measuring 6.6x6.2x8.8cm with no evidence of colitis, perforation, diverticulitis or any other potential sources of infection (Figure 1). Hydatid and amoeba serology were negative, and blood cultures showed no growth. Ultrasound-guided aspiration

of the hepatic abscess on 27 May 2025 yielded purulent material positive for *Klebsiella pneumoniae* (Figure 2).

The patient was admitted to the intensive care unit for cardiovascular support. He received broad-spectrum antibiotics (cefuroxime, metronidazole and gentamicin), later rationalised to a narrower spectrum antibiotic based on sensitivities. Following ultrasound-guided drainage of the abscess and antibiotic therapy, his condition improved with resolution of inflammatory markers, sepsis and fever.

Discussion

Population-based studies from North America have reported the incidence of pyogenic liver abscess (PLA) to be approximately 2.6 to 3.6 cases per 100,000 population. PLA remains a potentially serious condition, with in-hospital mortality rates ranging from 5.6 to 10%.^{1,2} *Klebsiella pneumoniae* has been identified as the causative organism in about 27% of cases, and other commonly isolated pathogens include the *Streptococcus milleri* group (44%), *Escherichia coli* (16%) and anaerobic bacteria (20%).² While various underlying causes of PLA have been described in the literature—including diverticulitis³—approximately 56% of cases are classified as cryptogenic, with no identifiable cause.²

Risk factors for PLA include diabetes mel-

Figure 1: Computed tomography (CT) scan showing a large hepatic abscess in the right lobe.



Figure 2: Microbiological analysis of hepatic abscess aspirate.

ASPIRATED PUS

SPECIMEN / SITE: Right Lobe Liver Abscess
 GRAM STAIN : Profuse neutrophils seen
 Moderate numbers of Gram negative bacilli seen

CULTURE

No obligate anaerobes isolated.

1) Heavy growth of *Klebsiella pneumoniae*

For this organism there is no longer a 'S' category for cefuroxime.

Isolates with wild-type susceptibility (previously reported as 'S') are now reported as 'I' (susceptible, increased exposure).

	(1)
Amoxycillin	R
Cefuroxime	I
Ceftriaxone	S
Ceftazidime	S
Aztreonam	S
Gentamicin	S
Amikacin	S
Cotrimoxazole	S
Ciprofloxacin	S
Amoxycillin/clav.	S
Meropenem	S
Cefepime	S
Piperacillin-tazobactam	S
	(1)
S = Susceptible standard dosing regimen	
I = Susceptible increased exposure	
R = Resistant	

litus, immunosuppression, malignancies and Asian ethnicity—potentially related to the higher prevalence of hypervirulent *Klebsiella pneumoniae* K1 and K2 serotypes in this population.^{4,5,6,7} In our patient, the combination of Asian ethnicity and underlying comorbidities—particularly diabetes mellitus—may have contributed to the development of PLA. Additionally, conditions such as end-stage renal disease, biliary tract infections, liver cirrhosis, gastrointestinal malignancies, appendicitis, diverticulitis and recent endoscopic retrograde cholangiopancreatography (ERCP) have all been implicated with increased risk of PLA.⁴

While the literature remains limited, there is growing recognition of a possible link between colonoscopies and PLA, particularly in high-risk patients. Although a colonoscopy is generally considered a safe procedure, several case reports have described PLA developing shortly after the procedure, typically in the setting of mucosal interventions.^{5,8–11} A recent study also found that upper gastrointestinal endoscopy was significantly associated with subsequent PLA development, whereas lower gastrointestinal endoscopy was not.⁴ The true incidence of PLA following a colonoscopy remains undefined but appears to be extremely low, with most evidence arising from isolated case reports. Colonoscopy-specific risk factors include invasive mucosal interventions such as polypectomy or biopsy, which were absent here, suggesting that even non-invasive procedures may pose a risk in susceptible individuals. Notably, the clinical timeline observed in our patient—onset of symptoms within 3 to 5 days—mirrors other reported cases, where symptoms typically emerged within 4 to 7 days post-procedure.

The biological plausibility lies in the translocation of gut flora, including *Klebsiella pneumoniae*, across the colonic mucosa due to microtrauma, even without invasive interventions such as polypectomies.^{11,12} In this patient, the presence of diverticula could have provided a nidus for bacterial translocation. *Klebsiella pneumoniae*, a gram-negative bacillus colonising the gastrointestinal tract, can then hematogenously spread to the liver via the portal vein, leading to abscess formation. While the temporal proximity suggests a potential link, the absence of mucosal disruption makes coincidental occurrence a plausible alternative, and our report aims to highlight

this for clinical awareness rather than to imply causation.

Prevention strategies for post-colonoscopy infectious complications, including *Klebsiella pneumoniae* liver abscesses, remain limited and inadequately defined. Current guidelines from the American Society for Gastrointestinal Endoscopy (ASGE) do not recommend routine antibiotic prophylaxis for colonoscopy due to the low risk of infectious complications.¹³ The use of prophylactic antibiotics in high-risk individuals—such as those with diabetes, immunosuppression or undergoing complex endoscopic interventions—remains controversial, with no consensus guidelines currently in place. This case underscores the importance of vigilance for post-procedure infections in susceptible individuals, though the rarity precludes routine prophylactic measures. Alternative strategies warranting consideration include: risk stratification (based on factors such as diabetes status, ethnicity and colonic findings like diverticulosis) and optimising bowel preparation to reduce luminal bacterial load (particularly in patients with diverticular disease). Additionally, structured follow-up measures—such as post-procedure phone calls or routine blood tests in high-risk patients—could be explored as part of national screening programmes to enable earlier detection and management of rare but serious events like PLA. Further research is needed to evaluate the utility and cost-effectiveness of such interventions.

Conclusion

In conclusion, we present a patient with a *Klebsiella pneumoniae* PLA, diagnosed 5 days after undergoing an uncomplicated screening colonoscopy. Even though causality cannot be established, this case potentially highlights *Klebsiella pneumoniae* PLA as a rare but serious complication of colonoscopies, even in the absence of invasive mucosal interventions. Clinicians should maintain a high index of suspicion in patients presenting with fever or abdominal pain post-colonoscopy, particularly those with risk factors such as diabetes. Future studies are needed to establish the incidence, explore risk stratification and preventive strategies to enhance the safety of colorectal screening programmes.

COMPETING INTERESTS

Nil.

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Now you see it, now you don't—the use of dual energy chest radiography to differentiate lung nodules from pleural plaques

Thomas May, Bobby S Bhartia, Martyn P T Kennedy

We present a case in which dual exposure dual energy chest radiography (DECXR) differentiated a lung cancer from overlying pleural plaques.

Case report

An 87-year-old smoker and retired decorator with previous asbestos exposure presented with symptoms suggestive of a chest infection. A chest radiograph (CXR) (Figure 1) demonstrated bilateral asbestos-related calcified pleural plaques. Assessment with DECXR (Figure 2) identified a left upper zone non-calcified opacity separate to the plaques. Further assessment led to a radiological diagnosis of T1c N0 M0 lung cancer. The patient received curative treatment with stereotactic radiotherapy.

Discussion

Dual exposure dual energy chest radiography

performs two rapid exposures at differing energies. The greater attenuation of low-energy X-ray photons by calcium differentiates calcific structures from soft tissue. Digital subtraction of the bones and calcification provides an unimpaired assessment of the soft tissue visible on the radiograph.

DECXR can differentiate lung masses from composite rib shadowing or pleural plaques without the routine need for computed tomography (CT). Other potential clinical applications include improved identification of cardiovascular calcification¹ and pulmonary nodules,² as well as visualisation of lines and tubes.² Potential disadvantages include artefacts due to mis-registration of the two images and an increase in radiation exposure.³

However, compared to CT imaging, DECXR has much lower radiation exposure,^{3,4} shorter reporting times and lower costs.

Access to DECXR is an important and under-utilised tool to improve the safety and efficiency of chest radiology assessments.

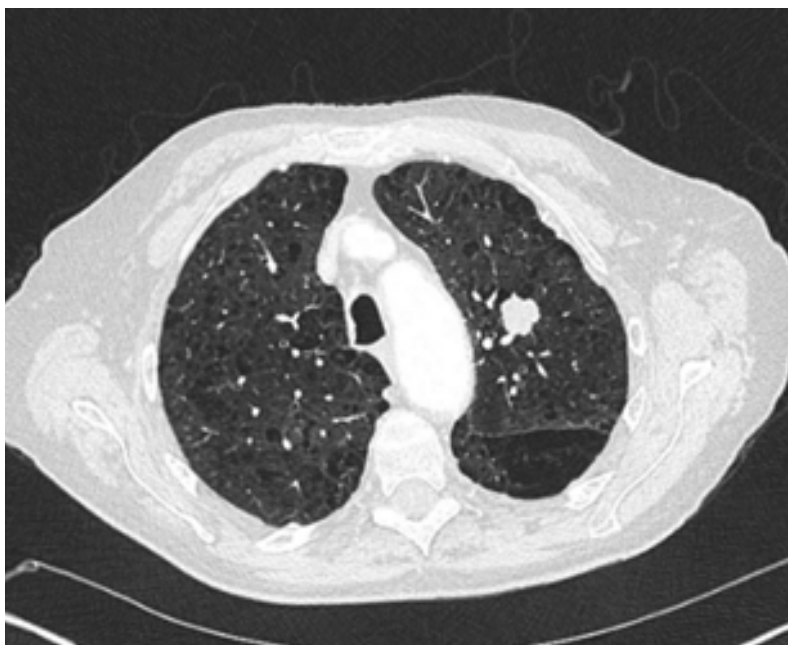
Figure 1: Anteroposterior chest radiograph (CXR) showing bilateral asbestos related pleural plaques, with some left upper zone changes that are more prominent than on previous radiographs.



Figure 2: Digital subtraction of the bones and calcified structures with dual exposure dual energy chest radiography (DECXR) confirms a left upper zone soft tissue lesion.



Figure 3: CT imaging confirming a T1c left upper lobe tumour.



COMPETING INTERESTS

The authors have no conflicts of interests to declare.

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Through the Back Door

NZMJ, 1925

We regret to find that an attempt is being made by the Minister of Health to proceed with a Dentists' Amendment Bill, in order to allow some thirty unregistered dentists the opportunity of having their names placed on the Register. Our opposition is mainly on the ground that if it is possible to do this thing where dentists are concerned, the doctors' turn may come next. After the war, and out of sympathy for returned soldiers, there were several instances where the standard of examinations and other tests was temporarily reduced, and no one had the heart to offer much objection. Unqualified dentists then enjoyed the privilege

of being conceded an examination of an absurdly low standard, and the Minister of Health at the time said plainly enough that this would be the last concession. The present Minister of Health, however, wishes to give those who failed in this examination, in spite of what was said previously, another and a more than ever ample opportunity, and if he is reported correctly in the public press he justifies his attitude on the ground that "the paramount interest should be the health of the community." We are not sorry that we can give him at least this measure of support, that we agree with the reason but not with the conclusion.