In-Center Hemodialysis and Patient Travel Time in Aotearoa New Zealand: A Nationwide Geospatial and Data Linkage Study

BIRRELL, Johanna M, WEBSTER, Angela C, CROSS, Nicholas B, KINDON, Andrew, HOBBS, Matthew, HEDLEY, James A, DRISCOLL, Tim and DE LA MATA, Nicole L

KI REPORTS
KIReports.org

CLINICAL RESEARCH

In-Center Hemodialysis and Patient Travel Time in Aotearoa New Zealand: A Nationwide Geospatial and Data Linkage Study

Johanna M. Birrell[1,2], Angela C. Webster[1,3], Nicholas B. Cross[1,2], Andrew Kindon[4,5], Matthew Hobbs[4,5,6], James A. Hedley[1], Tim Driscoll[1] and Nicole L. De La Mata[1]

[1]School of Public Health, University of Sydney, Sydney, New South Wales, Australia; [2]Department of Nephrology, Te Whatu Ora Waitaha Canterbury, Christchurch, New Zealand; [3]Department of Renal Medicine, Westmead Hospital, Sydney, New South Wales, Australia; [4]GeoHealth Laboratory, Te Taiwhenua O Te Hauora, University of Canterbury, Te Whare Wānanga O Waitaha, Christchurch, Ōtautahi, New Zealand; [5]Faculty of Health, Te Kaupeka Oranga, University of Canterbury, Te Whare Wānanga O Waitaha, Christchurch, Ōtautahi, New Zealand; and [6]College of Health, Wellbeing & Life Sciences, Sheffield Hallam University, Sheffield, UK

Introduction: Prolonged travel time to receive dialysis is associated with decreased quality of life and increased mortality. However, patient travel time is rarely systematically analyzed during health service planning. This study's aims were as follows: (i) examine spatio-temporal trends in travel time for people commencing dialysis in Aotearoa New Zealand (NZ), (ii) assess the relationship between travel time and dialysis modality, and (iii) create interactive nationwide maps to support renal service planning.

Methods: AcceSS and Equity in Treatment for kidney disease (ASSET), a health-linked data platform, was used to include all people commencing dialysis in NZ from 2006 to 2019 ($N = 6690$). Patients' one-way driving times from their residential location to the nearest hemodialysis unit were estimated using geospatial software. Multiple logistic regression modelling explored the association between travel time and dialysis modality, adjusting for demographic, clinical, and service factors.

Results: Median one-way driving time was 14 minutes (interquartile interval [IQI]: 8–31) and was significantly higher for patients living in rural (45 minutes [IQI: 28–62]) than in urban areas (11 minutes [IQI:8–18]; $P < 0.001$). Patients living farther from a unit were independently less likely to receive in-center hemodialysis (0.62 [95% confidence interval, CI: 0.52–0.72] for driving time ≥ 30 minutes; odds ratio, OR: 0.82 [95% CI:0.68–0.99] for 20–29; reference < 10), as were those in regions with greater hemodialysis unit capacity pressure. Our interactive maps demonstrate marked interregional variation in dialysis modality, patient travel time, and unit capacity.

Conclusion: Innovative service design is needed to reduce the burden of travel time, particularly for rural dialysis patients. We present novel geospatial techniques to support dialysis service planning that is targeted to the areas of greatest need.

Kidney Int Rep (2025) ■, ■–■; https://doi.org/10.1016/j.ekir.2024.12.028
KEYWORDS: dialysis; first nations peoples; geo-spatial mapping; health equity; health services research; travel time

NZ is a Pacific nation with a population of approximately 5 million people. NZ citizens and permanent residents are eligible for government-funded kidney replacement therapy (KRT), and almost all dialysis takes place in the public sector. Contrary to other countries, NZ has historically had a large proportion of home-based KRT (including peritoneal dialysis and home hemodialysis).[1-3] However, there has been a recent trend towards the use of in-center hemodialysis care (including hospital and satellite facilities, where patients receive nursing support for hemodialysis). The proportion of long-term dialysis patients receiving in-center hemodialysis in NZ has increased from 46% in 2006 to 64% in 2022.[1] In-center hemodialysis can result in a substantial travel burden, with patients typically attending a center 3 times per week for treatment.[4,5] Prolonged travel to a dialysis center raises difficulties for patients in terms of lifestyle, fatigue, and mortality.[6,7]

The value of designing health systems to provide individualized care that incorporates patients' goals

Correspondence: Johanna M. Birrell, Collaborative Centre for Organ Donation Evidence, 129A, Edward Ford Building (A27), School of Public Health, The University of Sydney, New South Wales 2006, Australia. E-mail: jbir8326@uni.sydney.edu.au

Received 5 November 2024; revised 15 December 2024; accepted 23 December 2024

and preferences is increasingly recognized.[8-13] Patients' convenience and quality of life are important performance metrics for dialysis services but are difficult to measure directly.[13-15] Therefore, indirect indicators derived from routinely collected data can serve as valuable tools for assessing the impact of current KRT service design on patients. The ASSET platform provides a potential source of such data. ASSET is a nationwide data linkage project developed to support research into the equity of health service delivery for people with kidney failure in NZ.[16]

Using the ASSET platform, this study aimed to do the following: (i) examine spatio-temporal trends in travel time for patients commencing dialysis in NZ from 2006 to 2019, (ii) assess the impact of patient travel time and resource constraints on dialysis modality, and (iii) create interactive nationwide maps to support renal service planning that is targeted to locations of highest need. This novel approach has the potential to be applied in other jurisdictions internationally.

METHODS

Hemodialysis Unit Capacity and Location

Capacity of in-center hemodialysis facilities across NZ was defined for the study period (2006–2019). Unit details, including month and year of establishment, hemodialysis chair counts, and expansions were obtained through online surveys completed by each nephrology department, Kidney Health NZ resources, Australia and New Zealand Dialysis and Transplant Registry reports and media releases.[1,2,17] Unit location x,y coordinates were obtained from Google Maps.[18] These unit data were uploaded to an online interactive map with time slider function using Esri ArcGIS Online software.[19]

Data Sources and Linkage

Incident dialysis patients in NZ from 2006 to 2019 were identified using the ASSET data linkage platform (detailed study protocol available).[16] Data sources accessed from ASSET were the Australia and New Zealand Dialysis and Transplant Registry, the National Minimum Dataset, and the National Non-Admitted Patient Data Collection, deterministically linked using encrypted National Health Index numbers. Patients' variables extracted from the Australia and New Zealand Dialysis and Transplant Registry were age, sex (either male or female, as specified during the registration process for patients undergoing KRT for end stage kidney disease),[1] ethnicity, primary renal disease, body mass index, KRT start date, KRT modalities, dates of modality change, recorded treatment centers, late referral status (defined as the first assessment by a specialist nephrologist within 3 months of commencing KRT), and death date (if applicable). Ethnicity categories were recoded to align with Stats NZ categories.[20] It was possible for multiple ethnicities to be recorded for a single patient (total response ethnicity).[20]

Domicile codes (geographic areas corresponding to 2013 Census Area Units, referenced by the NZ Ministry of Health)[21] were used to represent individuals' usual residential address. These codes were obtained from the National Minimum Dataset for the hospital admission date temporally closest to each patient's dialysis commencement date. The National Non-Admitted Patient Data Collection was used as a secondary source to identify the domicile codes for patients with a missing code in the National Minimum Dataset. The domicile codes were linked to District Health Board regions, Rural-Urban Geographic Classification for Health codes, New Zealand Index of Deprivation 2018 socioeconomic deciles, and Stats NZ Area Unit 2013 codes using concordance files.[22-25] Urban areas were defined as Geographic Classification for Health "Urban 1" and "Urban 2" categories and rural as "Rural 1" to "Rural 3." Population-weighted centroid coordinates for each domicile code were obtained from the University of Canterbury GeoHealth Laboratory[26] and linked to patients' records.

For each patient in the cohort, International Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification diagnostic codes were extracted for the 5 years preceding the dialysis start date. A Charlson Comorbidity Index and M3 Multimorbidity Index was calculated for each patient using the International Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification codes, with renal disease excluded from the scoring criteria.[27,28]

Calculation of Driving Time and Distance

Each dialysis region was categorized into distinct time periods based on the date of establishment of new hemodialysis units within the region. Patients were then allocated to categories according to their dialysis region and the date they commenced dialysis, aligning them with the relevant time period for analysis. For analysis of the effect of new units opening, dialysis regions were classified as "intervention regions" if a new hemodialysis unit was established within their boundaries during the study period, or "control regions" otherwise.

The one-way driving distance and time from the population-weighted centroid of the assigned residential domicile to the nearest hemodialysis unit in their dialysis region at the time of dialysis commencement, was calculated for each patient. This was performed using the ArcGIS Online "Find Nearest" tool[29] and provided a proxy for patients' minimum travel burden to receive in-center hemodialysis treatment.

Hemodialysis Capacity Pressure Index

A "Hemodialysis Capacity Pressure Index" score was calculated for each dialysis region and time bracket (2006–2010, 2011–2015, and 2016–2019). This novel index (adapted from previous studies)[2,30] was calculated as the mean number of new dialysis patients per year, divided by the local region's hemodialysis chair capacity, during the relevant time bracket.

Statistical Analysis

Statistical analyses were conducted using RStudio version 2023.03.0.[31] Travel distances and times were expressed as medians (IQIs) and groups were compared using the Mann-Whitney U test because of the positively skewed nature of the data. Multiple logistic regression analysis was performed for the outcome of receiving in-center hemodialysis at 1 year after dialysis commencement. This timeframe was chosen based on previous descriptive analysis of the KRT modality data, which demonstrated a median time between commencing dialysis and reaching a stable treatment modality of 12 months (Supplementary Figure S1). Variables were retained in the model if statistically significant on univariate analysis with a P value threshold < 0.05, using backward elimination.

The following variables were included in the model: driving time to the nearest hemodialysis unit (< 10, 10–19, 20–29, ≥ 30 mins), age (< 45, 45–54, 55–64, 65–74, ≥ 75 years), sex, socioeconomic index (New Zealand Index of Deprivation 2018 quintile), total response ethnicity (European, Māori, Pacific, Asian, other ethnicity), body mass index category (normal: 18.5–24.9, underweight: < 18.5, overweight: 25.0–29.9, obese: ≥ 30.0 kg/m^2), M3 Multimorbidity Index (a higher score indicating a greater level of multimorbidity; possible range ≥ 0 with 99th percentile 1.93), late referral, year bracket of starting KRT (2006–2010, 2011–2015, 2016–2019), health region category of NZ,[32] and Hemodialysis Capacity Pressure Index (for the patient's region at the time of dialysis commencement). Charlson Comorbidity Index and rurality were excluded from the model because of the high correlation with other variables (M3 Index and driving time respectively). Results were presented as ORs and 95% CIs. Model fit was assessed using the McFadden's R-squared test, c statistic and Hosmer-Lemeshow test. Statistically significant interaction terms were included in a supplementary model.

Geospatial Mapping

ArcGIS Online software was used to plot a pin for each patient's domicile population-weighted centroid coordinates, categorized by their dialysis modality at 1 year and the year bracket of dialysis commencement (2006–2010, 2011–2015, 2016–2019). A map of former District Health Board boundaries was obtained from the "ArcGIS Living Atlas of the World"[33] and boundaries were dissolved to align with dialysis service regions. Interactive polygon maps were generated for the proportion of patients receiving in-center hemodialysis and the Hemodialysis Capacity Pressure Index in each dialysis service region, by year bracket. Superimposed color bubbles were used to indicate hemodialysis unit locations and chair capacities. Interactive polygon maps were also created by domicile to illustrate the potential weekly burden of travel time to dialysis for patients residing in that area (using each patient's domicile code and travel time calculations, as detailed above).

Ethics Approval

The ASSET project, including this study, received ethics approval from the University of Sydney (HREC 2020/871). The Health and Disability Ethics Committee, New Zealand determined that the ASSET project was out of scope for ethics review because of the use of deidentified data, which did not require any approval from the committee.

RESULTS

Cohort Characteristics

A total of 6690 incident dialysis recipients were included in the analysis (Figure 1), of whom 45% were receiving in-center hemodialysis and 55% were receiving home-based dialysis at 1 year after commencing dialysis (Table 1). The median age of the study cohort was 59 (IQI: 49–68) years. Median one-way driving time to the nearest hemodialysis unit was 14 (IQI: 8–31) minutes for the overall cohort and was significantly shorter in the in-center hemodialysis group (12 [IQI: 8–24]) minutes than the home-based dialysis group (17 [IQI: 9–37] minutes; $P < 0.001$). In Supplementary Table S1, we list the dialysis regions and time brackets that were used for driving time calculations and in Supplementary Figure S2, we illustrate travel route calculations.

A total of 1245 patients (19%) were living in a rural location at dialysis commencement, of whom 429 (34%) were receiving in-center hemodialysis at 1 year. Among rurally located in-center hemodialysis recipients, the median one-way driving time to the nearest hemodialysis unit was 45 (IQI: 28–62) minutes; significantly higher than in the urban in-center

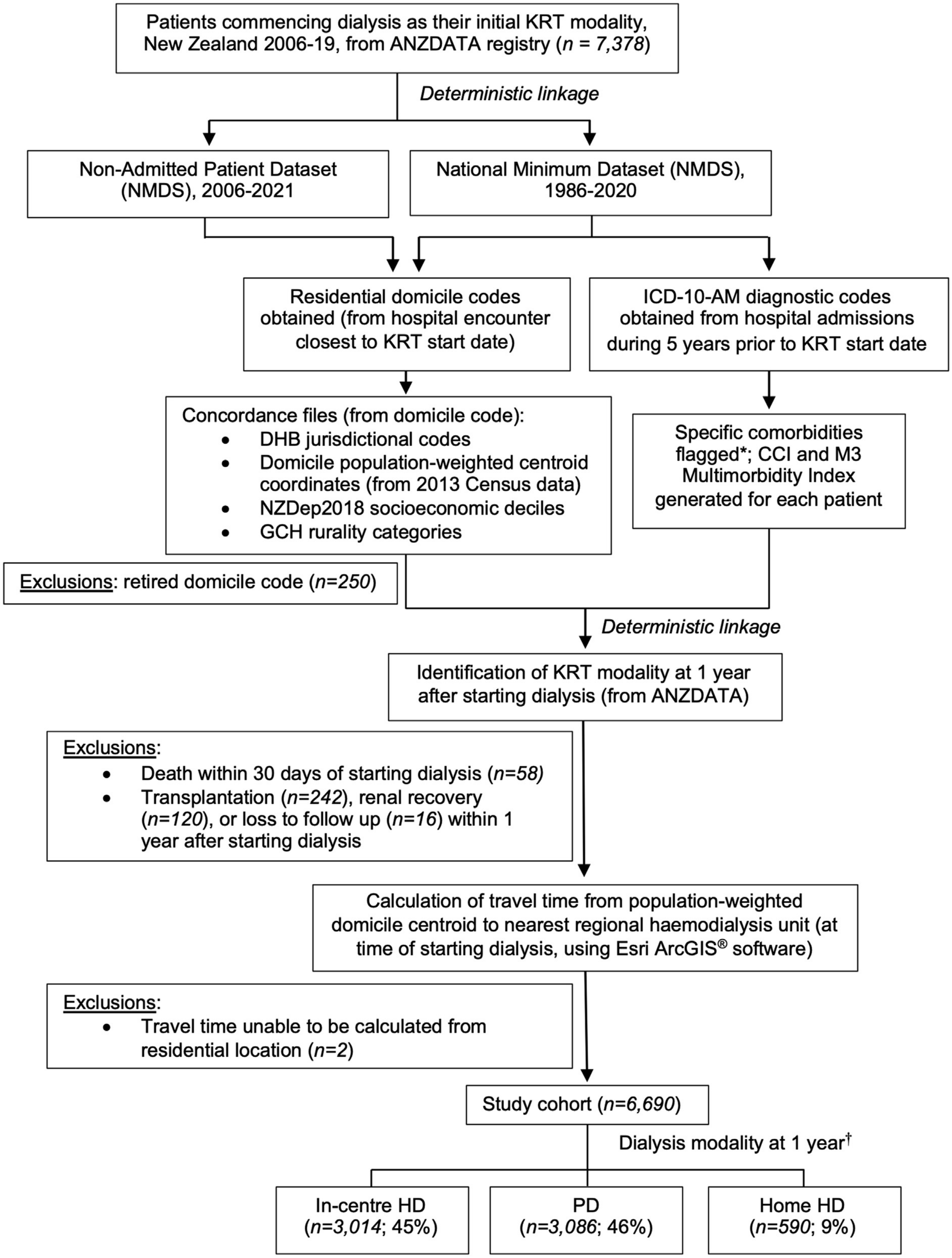

Figure 1. Flow diagram of inclusion criteria, data linkage, and analysis. ANZDATA, Australia and New Zealand Dialysis and Transplant Registry; CCI, Charlson Comorbidity Index; DHB, District Health Board; ESKD, end-stage kidney disease; HD, hemodialysis; ICD-10-AM, International Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification; KRT, kidney replacement therapy; M3 Index, M3 Multimorbidity Index; PD, peritoneal dialysis. *Diabetes mellitus, chronic lung disease, coronary artery disease, peripheral vascular disease, cerebrovascular disease, cancer. †For patients who died within 1 year of starting dialysis, the final dialysis modality before death was recorded as the dialysis modality at 1 year (in-center HD: $n = 353$, PD: $n = 195$, home HD: $n = 11$).

Table 1. Characteristics of patients commencing dialysis in New Zealand from 2006 to 2019, by dialysis modality at 1 year (data are *n* (%) unless otherwise specified)

Characteristics	Dialysis modality at 1 yr after commencing dialysis: In-center hemodialysis ($n = 3014$)		Dialysis modality at 1 yr after commencing dialysis: Home-based dialysis (peritoneal dialysis or home hemodialysis) ($n = 3676$)		Total ($N = 6690$)	
One-way driving time (mins)						
To nearest hemodialysis unit, median (IQI)	12	(8–24)	17	(9–37)	14	(8–31)
< 10	1156	(52)	1069	(48)	2225	(100)
10–19	912	(48)	976	(52)	1888	(100)
20–29	368	(45)	441	(55)	809	(100)
≥ 30	578	(33)	1190	(67)	1768	(100)
One-way travel distance (km)						
To nearest hemodialysis unit, median (IQI)	7	(4–21)	10	(5–39)	8	(4–30)
Year of kidney failure, *n* (%)						
2006–2010	919	(42)	1275	(58)	2194	(100)
2011–2015	1051	(45)	1283	(55)	2334	(100)
2016–2019	1044	(48)	1118	(52)	2162	(100)
Region, *n* (%)						
Northern	1744	(57)	1337	(43)	3081	(100)
Te Manawa Taki	458	(29)	1119	(71)	1577	(100)
Central	662	(52)	601	(48)	1263	(100)
Te Waipounamu	150	(20)	619	(80)	769	(100)
Sex, *n* (%)						
Female	1245	(47)	1428	(53)	2673	(100)
Male	1769	(44)	2248	(56)	4017	(100)
Age at kidney failure in yrs, *n* (%)						
< 45	442	(39)	695	(61)	1137	(100)
45–54	605	(43)	794	(57)	1399	(100)
55–64	846	(46)	975	(54)	1821	(100)
65–74	774	(47)	883	(53)	1657	(100)
≥ 75	347	(51)	329	(49)	676	(100)
Ethnicity[a], *n* (%)						
European	868	(37)	1465	(63)	2333	(100)
Māori	1039	(46)	1208	(54)	2247	(100)
Pacific	865	(59)	605	(41)	1470	(100)
Asian	214	(39)	339	(61)	553	(100)
Other ethnicity	19	(30)	45	(70)	64	(100)
Unknown	9		14		23	
Socioeconomic quintile[b], *n* (%)						
1–2 (least disadvantaged)	170	(36)	308	(64)	478	(100)
3–4	299	(42)	418	(58)	717	(100)
5–6	399	(40)	596	(60)	995	(100)
7–8	691	(46)	806	(54)	1497	(100)
9–10 (most disadvantaged)	1455	(48)	1548	(52)	3003	(100)
Rurality, *n* (%)						
Rural	429	(34)	816	(66)	1245	(100)
Urban	2585	(47)	2860	(53)	5445	(100)
Charlson Comorbidity Index, *n* (%)						
0–1	785	(35)	1481	(65)	2266	(100)
2+	2214	(50)	2178	(50)	4392	(100)
Unknown	15		17		32	
M3 Multimorbidity Score						
Median (IQI)	1.0	(0.5–1.6)	0.7	(0.3–1.2)	0.8	(0.4–1.4)
Unknown	19		20		39	
Late referral, *n* (%)						
No	2418	(44)	3140	(56)	5558	(100)
Yes	558	(52)	510	(48)	1068	(100)
Unknown	130		83		213	
Body mass index, *n* (%)						
Underweight	47	(39)	73	(61)	120	(100)

(Continued on following page)

Table 1. (Continued) Characteristics of patients commencing dialysis in New Zealand from 2006 to 2019, by dialysis modality at 1 year (data are *n* (%) unless otherwise specified)

Characteristics	Dialysis modality at 1 yr after commencing dialysis: In-center hemodialysis ($n = 3014$)		Home-based dialysis (peritoneal dialysis or home hemodialysis) ($n = 3676$)		Total ($N = 6690$)	
Normal	506	(37)	866	(63)	1372	(100)
Overweight	715	(39)	1113	(61)	1828	(100)
Obese	1616	(51)	1541	(49)	3157	(100)
Unknown	130		83		213	
Cause of kidney failure, *n* (%)						
Diabetes	1699	(50)	1729	(50)	3428	(100)
Glomerulonephritis	455	(36)	811	(64)	1266	(100)
Hypertension or renal artery disease	265	(40)	400	(60)	665	(100)
Polycystic kidney disease	85	(33)	175	(67)	260	(100)
Reflux nephropathy	30	(29)	73	(71)	103	(100)
Other	351	(50)	355	(50)	706	(100)
Uncertain diagnosis	117	(48)	127	(52)	244	(100)
Not reported	12		6		18	

IQI, interquartile interval; KRT, kidney replacement therapy; NZDep2018, New Zealand Index of Deprivation 2018.
[a]Categorized based on Stats NZ ethnic groups, using total response ethnicity.
[b]Categorized using NZDep2018 score, based on residential domicile.
Northern region: Northland, Waitemata, Auckland, Counties Manukau District Health Boards (DHBs).
Te Manawa Taki region: Waikato, Lakes, Bay of Plenty, Tairawhiti, Taranaki DHBs.
Central region: Whanganui, Hawke's Bay, MidCentral, Wellington, Hutt Valley, Wairarapa DHBs.
Te Waipounamu region: Nelson-Marlborough, Canterbury, West Coast, South Canterbury, Southern DHBs.

hemodialysis cohort (11 [IQI: 8–18] minutes; $P < 0.001$). Assuming 3 hemodialysis sessions per week, the median weekly driving time for rurally located patients was estimated to be 4.5 (IQI: 2.8–6.2) h/wk and driving distance to be 331 (IQI: 209-459) km/wk.

The Hemodialysis Capacity Pressure Index ranged from 0.78 (in the Auckland region, 2006–2010) to 4.20 (in the Wellington region, 2006–2010), with a higher result indicating greater capacity limitation in that region at that time. In Supplementary Figure S3, we show the index results for each dialysis region, including changes over time with establishment of new hemodialysis units.

Trends in Driving Time and In-Centre Hemodialysis Rate

Twelve new hemodialysis units were established in NZ from 2006 to 2019, including 2 at existing sites (Figure 2). Median one-way patient driving time to the nearest hemodialysis unit at dialysis commencement decreased from 17.5 (IQI: 9.6–37.4) minutes to 11.6 (IQI: 7.1–22.4) minutes over the study period (Supplementary Figure S4A). This reduction in estimated driving time was apparent in intervention dialysis regions (where a new unit location opened during the study period) but not in control regions (Supplementary Figure S4B).

An inverse relationship was observed between driving time and the proportion of patients receiving in-center hemodialysis (Supplementary Figure S5), with substantial regional variation. Rates of in-center hemodialysis were consistently lower in Te Waipounamu and Te Manawa Taki health regions than in Northern and Central regions, including among patients living in close proximity (within a 20-min drive) of a hemodialysis unit (Supplementary Figure S6).

Predicting Dialysis Modality

Predictors of receiving in-center hemodialysis at 1 year after dialysis commencement, after adjustment using multiple logistic regression analysis, are shown in Figure 3 and Supplementary Table S2. Patients were significantly less likely to receive in-center hemodialysis (compared with home-based dialysis) at 1 year if their estimated one-way driving time was more than 20 minutes to the nearest hemodialysis unit, if living in Te Manawa Taki or Te Waipounamu health regions, or if living in a dialysis region experiencing greater local hemodialysis capacity pressure. In contrast, older age, Māori or Pacific ethnicity, obesity, multimorbidity, late referral, and dialysis commencement in 2016 to 2019 were independently associated with an increased likelihood of in-center hemodialysis. Model fit statistics are provided in Supplementary Table S3 and Supplementary Figure S7. Supplementary Figures S8 and S9 include statistically significant interaction terms between region, driving time and year category, indicating that the relationship between service design and dialysis modality is complex and varies with place and time.

Geospatial Mapping

Interactive dialysis maps (https://tinyurl.com/assetnzdialysis) were developed for 3 time brackets

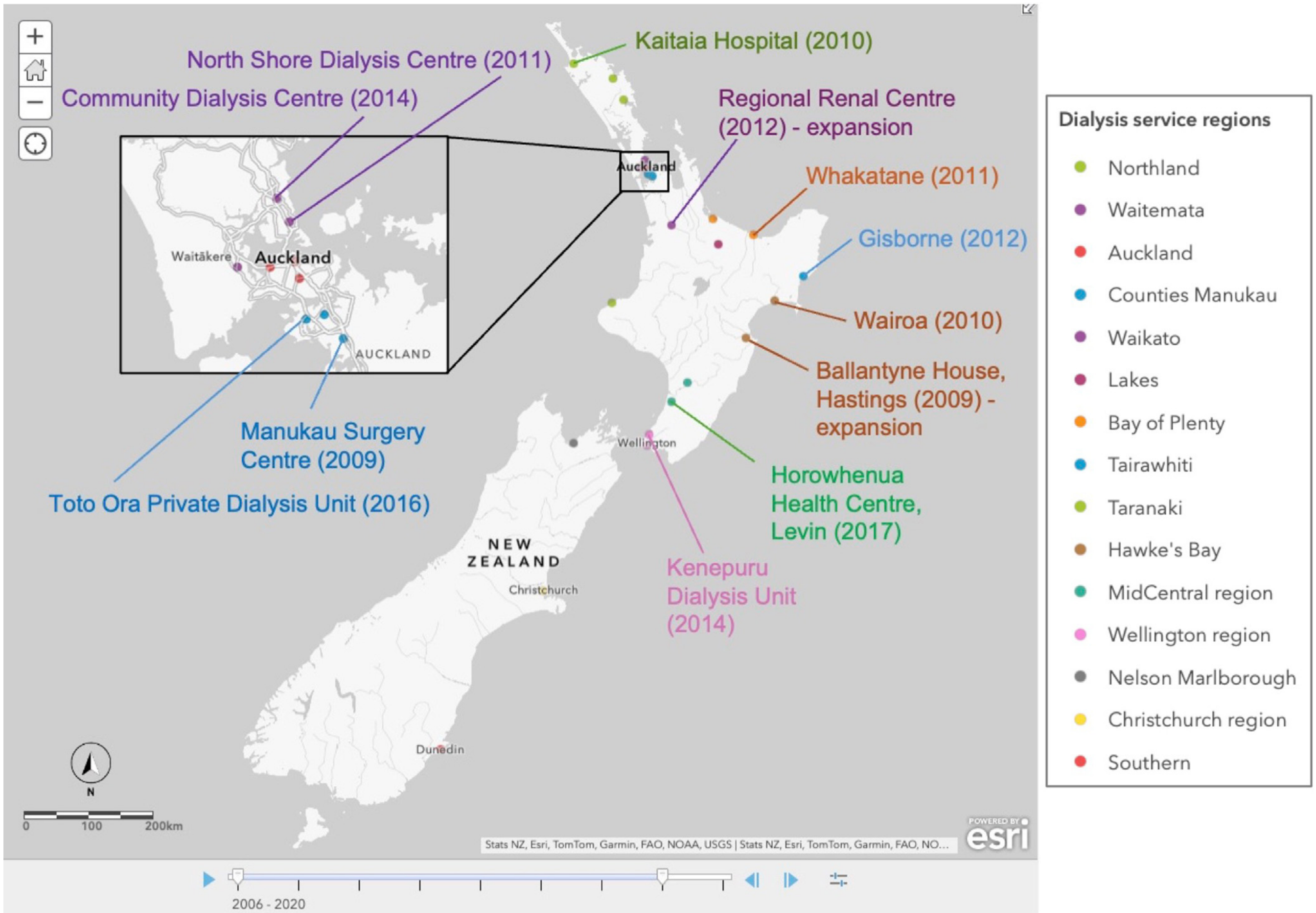

Figure 2. Map of in-center hemodialysis unit locations in New Zealand, 2006 to 2019. Units that were newly established or underwent major expansion during the study period are labelled. Each color corresponds to a dialysis service region.

(2006–2010, 2011–2015, and 2016–2019). In Figure 4, we provide a snapshot of maps for 2016 to 2019. In Figure 4a, we show the geographic distribution of dialysis patients. In Figure 4b–d, we highlight incremental regional differences in the Hemodialysis Capacity Pressure Index (highest in Bay of Plenty: 2.71 new patients per chair and Christchurch region: 2.34 new patients per chair), in-center hemodialysis rates (highest in Northland: 71% and Auckland: 69%) and estimated travel time burden (by domicile) respectively.

DISCUSSION

This population-based data linkage study examined dialysis service provision in NZ from 2006 to 2019, integrating travel time data as an indicator of patient convenience and quality of life. We found that rural patients face an extensive burden of travel time to receive in-center hemodialysis treatment when compared with urban patients. Furthermore, travel time and local hemodialysis unit capacity were independent predictors of patients' dialysis modality, demonstrating the importance of health service design in shaping patient care. Māori or Pacific ethnicity was independently associated with receiving in-center hemodialysis, consistent with previous studies demonstrating reduced access to home-based dialysis for these patient groups. Our web-based interactive maps present epidemiological data in a user-friendly format to support equitable renal service planning.

In this study we observed that the median estimated travel time to the nearest hemodialysis unit was 4-fold higher for dialysis recipients living in rural areas (45 [IQI: 28–62] mins) than in urban areas (11 [IQI: 8–18] mins). Patients living further from a hemodialysis unit were independently less likely to be managed with in-center hemodialysis at 1 year after starting dialysis (OR: 0.62 [95% CI: 0.53–0.73] for a driving time ≥ 30 mins; reference category < 10 mins). This finding is consistent with previous research.[34] However, in our study a considerable proportion of rural patients (34%) received in-center hemodialysis at 1 year despite the extensive travel time involved. Increased travel time to dialysis has been associated with financial hardship,[35] decreased

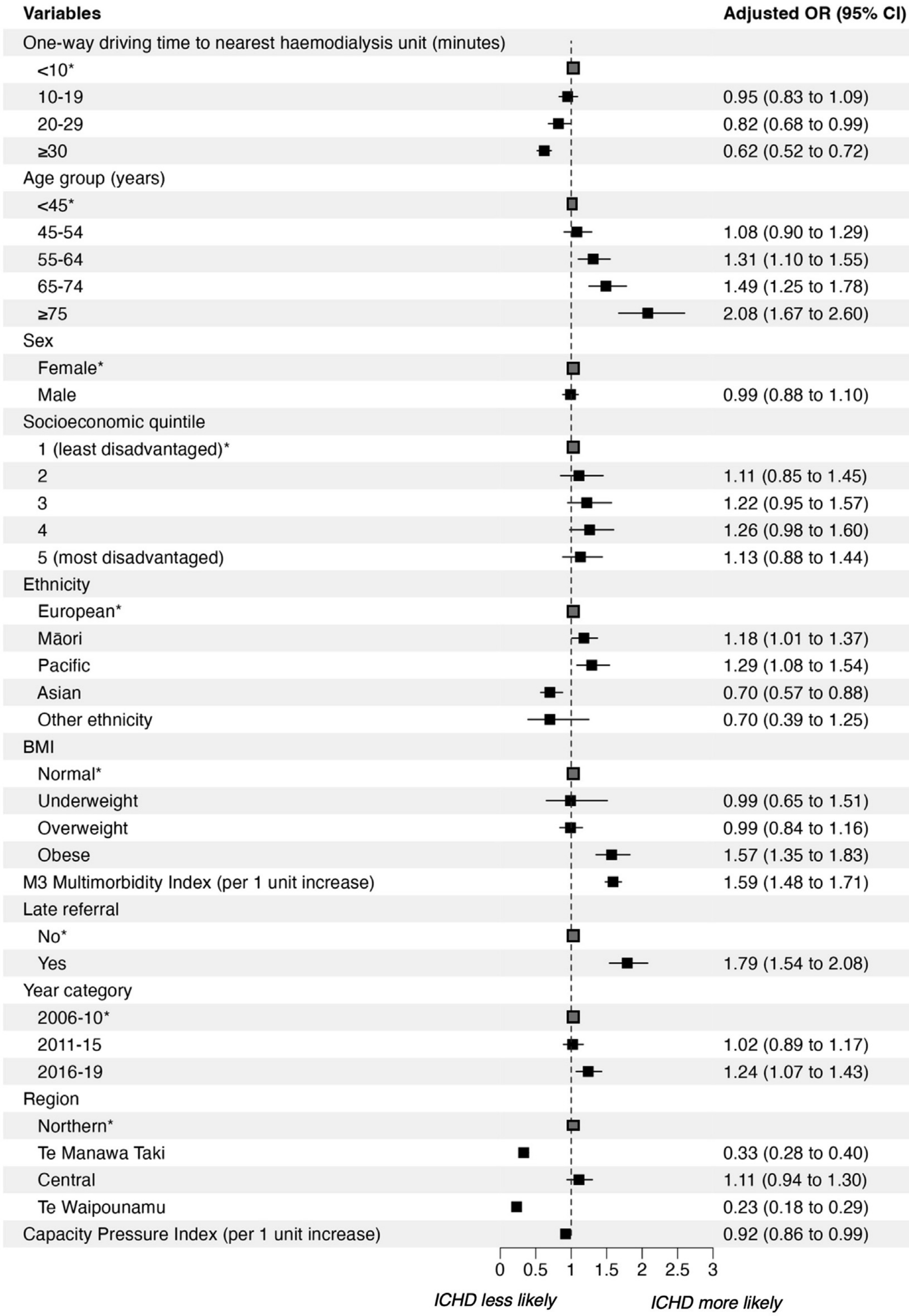

Figure 3. Forest plot of adjusted odds ratios for receiving in-center hemodialysis (compared with home-based dialysis) at 1 year after dialysis commencement, Aotearoa New Zealand, 2006 to 2019 ($N = 6690$). BMI, body mass index; ICHD, in-center hemodialysis. *reference category.

health-related quality of life, and increased mortality risk.[6] These disparities are likely to be exacerbated by reduced access to kidney transplantation in remote areas.[36] Geospatial analysis has similarly demonstrated that rural adolescents are less likely to access oral health services in NZ, with those at greatest oral health risk being geographically underserved.[37] Living more remotely from care may challenge service delivery, though the underlying expectation of the publicly funded healthcare system is that all New Zealanders have equal access to the care they require. Our results emphasize the need to address deficiencies in broader healthcare access and delivery in rural and remote areas.[38]

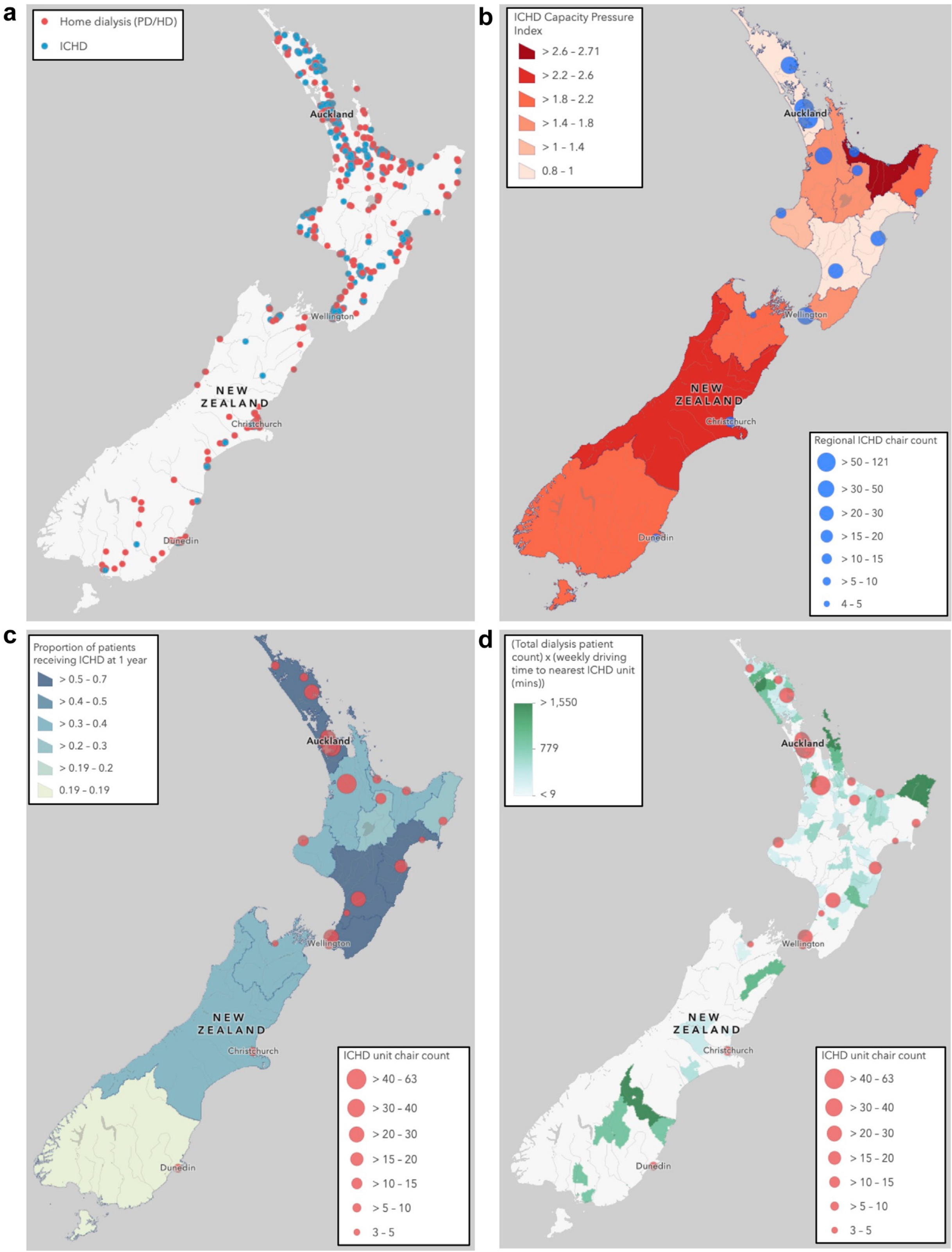

Figure 4. Dialysis mapping of Aotearoa New Zealand, 2016 to 2019. (a) Residential location (by domicile population-weighted centroid) of incident dialysis patients and dialysis modality at 1 year. (b) In-center hemodialysis capacity pressure, by DHB dialysis region. Blue bubbles indicate hemodialysis chair count per region. (c) Proportion of incident dialysis patients receiving in-center hemodialysis at 1 year, by DHB dialysis region. Red bubbles indicate hemodialysis unit locations and chair counts. (d) Potential weekly burden of driving time (to the nearest hemodialysis unit), by domicile region. Red bubbles indicate hemodialysis unit locations and chair counts.DHB, District Health Board.

Innovation is necessary to reduce the burden of travel time to dialysis, particularly for patients living in rural areas. Potential solutions include improving access to home-based dialysis training, establishment of further small satellite hemodialysis units in key rural locations,[39] mobile dialysis units (as successfully implemented in remote Australia),[40] and assisted home dialysis services.[41] The interactive maps developed during this project highlight priority locations for these services (Figure 4d). For example, for neighboring rural North Island domiciles (details suppressed to maintain patient privacy), there were a total of 15 dialysis recipients at the end of 2019. Thirteen of these patients were receiving in-center hemodialysis, with a minimum combined weekly driving time of 39 hours. Placement of a satellite or mobile hemodialysis unit in this area may have substantial benefits for these individuals' quality of life and employment potential, as well as reducing healthcare–related transport costs and carbon emissions. Geospatial mapping could allow health service leaders to objectively compare potential dialysis unit sites, including identifying areas of need where patients may be disempowered to advocate for local infrastructure. Next steps include validating the mapping through usage in health service planning, with formal feedback and evaluation.

We found that patients living in a dialysis region experiencing greater hemodialysis unit capacity pressure were independently less likely to be treated with in-center hemodialysis (OR: 0.94 [95% CI: 0.90–0.99] for every 1-point increase in the Hemodialysis Capacity Pressure Index). This result is consistent with previous qualitative research indicating that modality decisions may be influenced by resource constraints, such as availability at a dialysis centre.[9] Capacity shortages can also result in suboptimal hemodialysis quality (including by offering patients < 3 treatments/wk, treatment cancellations, staff shortages, shortened treatments, and overnight dialysis shifts),[2] with additional health and lifestyle burdens that were not captured in our study.

Goal-directed dialysis care requires availability of adequately resourced dialysis services.[8] However, our maps demonstrate that development of new facilities tends to be reactive, in response to established capacity constraints. Delays to subsequent service expansion can have negative repercussions for patient care.[2] With the number of people requiring dialysis in NZ anticipated to further dramatically increase over coming years,[42] a shift to proactive, equitable national service planning is needed. We identified increasing age, Māori and Pacific ethnicity, multimorbidity, and obesity as independent, patient-level predictors of receiving in-center hemodialysis. A valuable next step would involve modelling of future dialysis demand based on these variables, and incorporating regional demographic projections, chronic kidney disease prevalence data, and health economic assessment.

We found that Māori (OR: 1.18 [95% CI: 1.01–1.54]) or Pacific ethnicity (OR: 1.29 [95% CI: 1.08–1.54]) was independently associated with a higher likelihood of receiving in-center hemodialysis, when compared with European ethnicity. This is consistent with previous studies demonstrating that Māori patients in NZ have poorer access to home-based dialysis,[43] and occurs on a background of persistent broader inequities in health outcomes for Māori and Pacific peoples in NZ.[44] Contributing factors may include inadequate information provision about home-based dialysis options,[45] peer influence, and individual physician preference[9] in settings with a high proportion of Māori or Pacific patients because spatial clustering of ethnicity groups occurs within NZ.[46] Our findings provide further evidence of the need for interventions to improve access to home-based dialysis, particularly for Māori and Pacific peoples, including early referral to nephrology services for patients requiring KRT. The Caring for Australians and New Zealanders with Kidney Impairment guidelines provide recommendations for health services to deliver best practice care to Māori affected by chronic kidney disease[47]; further resources are needed to specifically support Pacific patients in NZ.

Our study demonstrates how geospatial techniques can be used to highlight population groups that are disadvantaged in accessing optimal, patient-centered dialysis care. Patients' travel time is an important contributor to "time toxicity" (the time-related burden that patients experience while seeking healthcare)[48] and reduced quality of life for patients receiving dialysis but is uncommonly included in renal services research. We estimated patients' minimum travel time to dialysis using routinely collected linked administrative health data and demonstrated a linear association with in-center hemodialysis rates. Combined with the development of interactive health service maps, this methodology provides a "proof of concept" for contemporary renal service planning that can be replicated in other jurisdictions internationally.

The Hemodialysis Capacity Pressure Index used in this study assumes that every new dialysis recipient is treated with in-center hemodialysis. Therefore, the rate of home-based dialysis and renal transplantation in each region are not factored into regional Index calculations. The Index could be adapted to simulate the effect of changing the dialysis modality breakdown in each region when starting treatment.

Limitations of this study include an assumption that patients are travelling to their nearest hemodialysis unit for treatment. Previous Australian research found that less than half of urban patients were receiving treatment at their nearest hemodialysis unit,[5] therefore our results may underestimate the true travel burden. A small proportion of patients may travel from work instead of home to a hemodialysis centre.[49] We also assumed travel by car, but other modes of transport may include bus, train, and patient shuttles. However, data on employment status and individuals' modes and routes of transport are not available. Patient shuttles follow a set route to collect several patients from their homes, making multiple stops to accommodate all passengers. These alternative transport services are likely to result in longer travel times, disproportionately affecting patients of lower socioeconomic status because of lower rates of car ownership.[50] The driving times reported in this study should therefore be considered an estimate of patients' minimum travel burden.

Other limitations include the use of domicile population-weighted centroids as a proxy for residential address. This may have resulted in miscalculation of travel time and nearest hemodialysis unit for some individuals, particularly in rural areas with geographically large domicile zones. Residential domiciles were obtained from the hospital admission date temporally closest to the date of dialysis commencement. Therefore, travel time may be overestimated if patients subsequently relocated to be closer to a hemodialysis unit. Relocation for dialysis can have profound psychosocial impacts on patients[51] and understanding relocation rates is an important area for further local research.

We recommend future analysis of renal supportive care practices in NZ, including regional variation and the impact of rurality. This may provide further insights into the regional differences in dialysis modality practices observed in this study and identify gaps and opportunities for holistic kidney failure service provision.

This study provides an explanatory model for the increasing in-center hemodialysis rates in NZ and presents geospatial mapping tools to inform renal resource allocation that is targeted at areas of greatest need, supporting delivery of individualized care. The results provide a foundation for national modelling of future renal services, incorporating regional demographic projections and economic analysis.

DISCLOSURE

All the authors declared no competing interests.

ACKNOWLEDGMENTS

For assistance with establishing the linked data platform, we thank ASSET Investigators: Ian Dittmer, John Irvine, Ben Beaglehole, John Kearns, Curtis Walker, Heather Dunckley, Merryn Jones, Patrick Kelly, Rachel Cutting, Kate Wyburn, and Melanie Wyld. We thank the Australia and New Zealand Dialysis and Transplant Registry for providing data to ASSET for this work and the New Zealand Ministry of Health for facilitating data linkage. We also acknowledge James Stanley and Diana Sarfati at the University of Otago for sharing their M3 Multimorbidity Index R code.

Funding

This project was supported by funding from the Ross Bailey Nephrology Trust. JMB was supported by a National Health and Medical Research Council (NHMRC) Postgraduate Scholarship (ID 2031401). JMB also acknowledges the support provided during the course of this research by the Australian Academy of Science's Douglas and Lola Douglas Scholarship. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the funding organization.

DATA AVAILABILITY STATEMENT

The data are not currently publicly available owing to privacy restrictions imposed by the University of Sydney Human Research Ethics Committee. Further inquiries regarding the data can be directed to the corresponding author or info@assetkidneyresearch.org.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Figure S1. Flow diagram: calculation of median time from dialysis commencement to reaching a stable dialysis modality.

Figure S2. Example map of driving time and distance calculations from population-weighted centroids to nearest hemodialysis unit - Waikato District Health Board dialysis region 2006 to 2019.

Figure S3. Hemodialysis Capacity Pressure Index, per dialysis region category, 2006 to 2019.

Figure S4. (A) Trend in one-way patient driving time to the nearest hemodialysis unit, New Zealand, 2006 to 2019. (B) Trend in one-way patient driving time to the nearest hemodialysis unit in control and intervention regions, New Zealand, 2006 to 2019.

Figure S5. Proportion of dialysis patients receiving in-center hemodialysis (at 1 year), by driving time in New Zealand, 2006 to 2019.

Figure S6. Number of dialysis patients, by dialysis modality and driving time, in each health region of New Zealand from 2006 to 2019.

Figure S7. Hosmer-Lemeshow plot for multiple logistic regression model of receiving in-center hemodialysis at 1 year after dialysis commencement, New Zealand, 2006 to 2019.

Figure S8. Forest plot of adjusted odds ratios for receiving in-center hemodialysis at 1 year, with interaction term between region and driving time, 2006 to 2019.

Figure S9. Forest plot of adjusted odds ratios for receiving in-center hemodialysis at 1 year, with interaction term between region and year category, 2006 to 2019.

Table S1. District Health Board (DHB) dialysis region categories.

Table S2. Logistic regression results: unadjusted and adjusted odds ratios for receiving in-center hemodialysis at 1 year after dialysis commencement, New Zealand, 2006 to 2019.

Table S3. Assessment of model fit statistics for multiple logistic regression model of receiving in-center hemodialysis at 1 year after dialysis commencement, New Zealand, 2006 to 2019.

STROBE Checklist.

REFERENCES

1. ANZDATA 46th Annual Report 2023. Australia and New Zealand Dialysis & Transplant Registry. Accessed June 10, 2024. https://www.anzdata.org.au/report/anzdata-46th-annual-report-2023-data-to-2022/
2. Chapter 5: Adults on in-Centre Haemodialysis (ICHD) in the UK at the End of 2021. UK Kidney Association 25th Annual Report. Accessed June 10, 2024. https://ukkidney.org/sites/renal.org/files/CHAPTER%205%20ICHD_2023_Final%20for%20book_0.pdf
3. United States renal data system. *End Stage Renal Disease. Chapter 1: Incidence, Prevalence, Patient Characteristics, and Treatment Modalities.* USRDS annual data report 2022. National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. Accessed June 10, 2024. https://usrds-adr.niddk.nih.gov/2022/end-stage-renal-disease/1-incidence-prevalence-patient-characteristics-and-treatment-modalities
4. Aotearoa New Zealand haemodialysis infrastructure survey 2023. Kidney Health New Zealand, Renal Services, Hauora a Toi Bay of Plenty, Te Whatu Ora and Renal Services, Waitematā, and Te Whatu Ora. Accessed June 10, 2024. https://www.kidney.health.nz/resources/files/picker/khnz-dialysis-capacity-report-2023-04-30-final-compressed.pdf
5. McDonald SP, Ullah S, Dansie K, et al. The burden of travel-time and distance traveled for hemodialysis patients in Australian major city areas. *Kidney Int Rep*. 2023;8:1105–1108. https://doi.org/10.1016/j.ekir.2023.02.1077
6. Moist LM, Bragg-Gresham JL, Pisoni RL, et al. Travel time to dialysis as a predictor of health-related quality of life, adherence, and mortality: The Dialysis Outcomes and Practice Patterns Study (DOPPS). *Am J Kidney Dis*. 2008;51:641–650. https://doi.org/10.1053/j.ajkd.2007.12.021
7. Jung HY, Jeon Y, Park Y, et al. Better Quality of Life of peritoneal dialysis compared to hemodialysis over a two-year Period after Dialysis Initiation. *Sci Rep*. 2019;9:10266. https://doi.org/10.1038/s41598-019-46744-1
8. Chan CT, Blankestijn PJ, Dember LM, et al. Dialysis initiation, modality choice, access, and prescription: conclusions from a Kidney Disease: improving Global Outcomes (KDIGO) Controversies Conference. *Kidney Int*. 2019;96:37–47. https://doi.org/10.1016/j.kint.2019.01.017
9. Morton RL, Tong A, Howard K, Snelling P, Webster AC. The views of patients and carers in treatment decision making for chronic kidney disease: systematic review and thematic synthesis of qualitative studies. *BMJ*. 2010;340:c112. https://doi.org/10.1136/bmj.c112
10. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2024 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int*. 2024;105:S117–S314. https://doi.org/10.1016/j.kint.2023.10.018
11. Riehl-Tonn VJ, Ahmed SB. Care of older persons with kidney failure: incorporating values, preferences, … and dialysis? *Ann Intern Med*. 2024;177:1281–1282. https://doi.org/10.7326/M24-0890
12. Kliger AS, Finkelstein FO. Can we improve the quality of life for dialysis patients? *Am J Kidney Dis*. 2009;54:993–995. https://doi.org/10.1053/j.ajkd.2009.09.005
13. Living better with CKD – improving the quality of life of CKD patients on dialysis across Europe, European Kidney Health Alliance. 2021. Accessed June 10, 2024. https://ekpf.eu/wp-content/uploads/2021/10/Living-better-with-CKD—-improving-the-quality-of-life-of-CKD-patients-on-dialysis-across-Europe-.pdf
14. The ISN joins the discussion on improving quality of life during dialysis at European roundtable; 2022. International Society of Nephrology. Accessed September 6, 2024. https://www.theisn.org/blog/2022/10/03/the-isn-joins-the-discussion-on-improving-quality-of-life-during-dialysis-at-european-roundtable/
15. van der Willik EM, Hemmelder MH, Bart HA, et al. Routinely measuring symptom burden and health-related quality of life in dialysis patients: first results from the Dutch registry of patient-reported outcome measures. *Clin Kidney J*. 2021;14:1535–1544. https://doi.org/10.1093/ckj/sfz192
16. Cutting RB, Webster AC, Cross N, et al. AcceSS and Equity in Transplantation (ASSET) New Zealand: protocol for population-wide data linkage platform to investigate equity in access to kidney failure health services in New Zealand. *PLoS One*. 2022;17:e0273371. https://doi.org/10.1371/journal.pone.0273371
17. Dialysis units. Kidney Health New Zealand. Accessed June 10, 2024. https://www.kidney.health.nz/contacts/dialysis-unit-contact-information/
18. Google. Google Maps. Accessed September 9, 2024. https://www.google.com/maps
19. GIS Online - Configure time settings (Map Viewer). ArcGIS: Esri's comprehensive geospatial platform. 2024. Accessed October 3, 2024. https://doc.arcgis.com/en/arcgis-online/create-maps/configure-time-mv.htm

20. Ethnic group (grouped total responses). Stats NZ DataInfo+. Updated 2021. Accessed October 3, 2024. https://datainfoplus.stats.govt.nz/item/nz.govt.stats/b0598e2e-ff27-42c8-8641-9d5aad1c89f4
21. Ministry of Health NZ. *Domicile Code V3 2013 map*. Accessed October 3, 2024. https://www.arcgis.com/home/item.html?id=0c8489a23d0848c594e1dc5b041cce73
22. Common Code Tables - Domicile code table. Health New Zealand – Te whatu ora. Accessed June 10, 2024. https://www.tewhatuora.govt.nz/our-health-system/data-and-statistics/nz-health-statistics/data-references/code-tables/common-code-tables#domicile-code-table
23. University of Otago. Rural-urban classification for NZ health research and policy - downloads - Concordance files. 2021. Accessed January 23, 2025. https://rhrn.nz/gch/resources
24. Socioeconomic deprivation indexes: NZDep and NZiDep, Department of public health. University of Otago; 2018. Accessed June 10, 2024. https://www.otago.ac.nz/wellington/departments/publichealth/research-groups-in-the-department-of-public-health/hirp/socioeconomic-deprivation-indexes-nzdep-and-nzidep-department-of-public-health
25. AU 2013 suppression. ArcGIS Online. Updated February 9, 2022. Accessed June 10, 2024. https://www.arcgis.com/home/item.html?id=f52327016dc944aa9f7a4ad3f831af04
26. Publications, reports and data; 2024. University of Canterbury Te Taiwhenua o te Hauorao, GeoHealth Laboratory. Accessed September 6, 2024. https://www.canterbury.ac.nz/research/about-uc-research/research-groups-and-centres/te-taiwhenua-o-te-hauora-geohealth-laboratory/publications–reports-and-data
27. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373–383. https://doi.org/10.1016/0021-9681(87)90171-8
28. Stanley J, Sarfati D. The new measuring multimorbidity index predicted mortality better than Charlson and Elixhauser indices among the general population. *J Clin Epidemiol*. 2017;92:99–110. https://doi.org/10.1016/j.jclinepi.2017.08.005
29. How to calculate the driving time between locations in ArcGIS Online Map Viewer Classic; 2022. ArcGIS: Esri's comprehensive geospatial platform. Accessed June 10, 2024. https://support.esri.com/en-us/knowledge-base/how-to-calculate-the-driving-time-between-locations-in–000028840
30. Kiani B, Bagheri N, Tara A, Hoseini B, Hashtarkhani S, Tara M. Comparing potential spatial access with self-reported travel times and cost analysis to haemodialysis facilities in North-Eastern Iran. *Geospat Health*. 2018;13. https://doi.org/10.4081/gh.2018.703
31. RStudio Team. RStudio. Integrated Development Environment for R. Version 2023.03.0. RStudio, PBC. Accessed January 22, 2025. https://www.rstudio.com
32. Regional map. Health New Zealand – Te whatu ora. 2024. Accessed September 9, 2024. https://www.tewhatuora.govt.nz/corporate-information/about-us/health-new-zealand-boundaries/
33. NZ District Health Board boundaries – generalized. Eagle Technology Group Ltd (NZ Esri Distributor). Updated on April 20, 2020. Accessed October 3, 2024. https://hub.arcgis.com/datasets/bab0ff4386eb4522b87d9cda6883f178_0/explore
34. Little J, Irwin A, Marshall T, Rayner H, Smith S. Predicting a patient's choice of dialysis modality: Experience in a United Kingdom renal department. *Am J Kidney Dis*. 2001;37:981–986. https://doi.org/10.1016/s0272-6386(05)80014-9
35. Scholes-Robertson NJ, Gutman T, Howell M, et al. Clinicians' perspectives on equity of access to dialysis and kidney transplantation for rural people in Australia: A semi-structured interview study. *BMJ Open*. 2022;12:e052315. https://doi.org/10.1136/bmjopen-2021-052315
36. Birrell JM, Webster AC, Cross N, et al. Geographic variation in kidney failure and transplantation in Aotearoa New Zealand: A population-based data linkage study. *Nephrology (Carlton)*. 2024;29:941–954. https://doi.org/10.1111/nep.14409
37. Lee JJM, Schluter OJ, Hodgett M, Deng B, Hobbs M. Adolescents and oral health service utilization in Canterbury, New Zealand: A geospatial cross-sectional study. *Community Dent Oral Epidemiol*. 2023;51:388–398. https://doi.org/10.1111/cdoe.12858
38. Marek L, Hills S, Campbell M, et al. Slipping under the radar: worsened health outcomes in semi-urban areas of New Zealand. *N Z Med J*. 2020;133:121–125.
39. Willis CE, Watson JD, Casson K, Doherty CC, Telford AM, Brown JH. Locations for renal services–patient satisfaction surveys. *Ulster Med J*. 1998;67:110–114.
40. Conway J, Lawn S, Crail S, McDonald S. Indigenous patient experiences of returning to country: a qualitative evaluation on the Country Health SA Dialysis bus. *BMC Health Serv Res*. 2018;18:1010. https://doi.org/10.1186/s12913-018-3849-4
41. Reddy YNV, Kearney MD, Ward M, et al. Identifying major barriers to home dialysis (the IM-HOME study): findings from a national survey of patients, care partners, and providers. *Am J Kidney Dis*. 2024;84:567–581.e1. https://doi.org/10.1053/j.ajkd.2024.04.007
42. Transforming lives and saving money: The golden opportunity of kidney transplants and the system changes needed to lift the numbers. NZ Institute of Economic Research (NZIER) report to Kidney Health NZ. Accessed October 3, 2024. https://www.nzier.org.nz/hubfs/Public%20Publications/Client%20reports/transforming_lives_and_saving_money_final_report_5_november_2021.pdf
43. Huria T, Palmer S, Becker L, Williman J, Pitama S. Inequity in dialysis related practices and outcomes in Aotearoa/New Zealand: A Kaupapa Maori analysis. *Int J Equity Health*. 2018;17:27. https://doi.org/10.1186/s12939-018-0737-9
44. Aotearoa New Zealand Health Status Report 2023. Health New Zealand – Te Whatu Ora. Accessed October 3, 2024. https://www.tewhatuora.govt.nz/assets/Publications/Health-status-reports/HNZ-TWO-Health-Status-Report_FULL.pdf
45. Davis P, Lay-Yee R, Dyall L, et al. Quality of hospital care for Maori patients in New Zealand: Retrospective cross-sectional assessment. *Lancet*. 2006;367:1920–1925. https://doi.org/10.1016/S0140-6736(06)68847-8
46. Marek L, Hills S, Wiki J, Campbell M, Hobbs M. Towards a better understanding of residential mobility and the environments in which adults reside: A nationwide geospatial study from Aotearoa New Zealand. *Habitat Int*. 2023;133. https://doi.org/10.1016/j.habitatint.2023.102762
47. Walker C, Reid S, White C, et al. Management of chronic kidney disease for Maori in Aotearoa New Zealand: a summary of clinical practice guidelines. *N Z Med J*. 2024;137:62–68. https://doi.org/10.26635/6965.6483

48. Gupta A, Eisenhauer EA, Booth CM. The time toxicity of cancer treatment. *J Clin Oncol*. 2022;40:1611–1615. https://doi.org/10.1200/JCO.21.02810

49. Kirkesov L, Carlsen RK, Lund T, Buus NH. Employment of patients with kidney failure treated with dialysis or kidney transplantation-a systematic review and meta-analysis. *BMC Nephrol*. 2021;22:348–364. https://doi.org/10.1186/s12882-021-02552-2

50. Hartley M, Curl A, Crossin R, McKerchar C. Access to primary care services using public transport in Otautahi Christchurch. *N Z Med J*. 2021;134:59–69.

51. Genereux D, Fan L, Brownlee K. The psychosocial and somatic effects of relocation from remote Canadian first nation communities to urban centres on indigenous peoples with chronic kidney disease (CKD). *Int J Environ Res Public Health*. 2021;18:3838. https://doi.org/10.3390/ijerph18073838