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Using Days Alive and Out of Hospital to measure inequities and explore pathways through which inequities emerge after coronary artery bypass grafting in Aotearoa New Zealand: a secondary data analysis using a retrospective cohort

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ABSTRACT

Objectives To describe the use of days alive and out of hospital (DAOH) as a sensitive measure of equity of outcomes after surgery by comparing outcomes after a coronary artery bypass grafts (CABG) operation between Māori and non-Māori patients in Aotearoa New Zealand.

Primary and secondary outcome measures We calculated unadjusted and risk-adjusted DAOH scores at three time points (30, 90 and 365 days) and compare values between Māori and non-Māori using data from the New Zealand Ministry of Health (MoH) over a 9 year period. To assess the impact of different risk factors on differences in outcome, we risk-adjust for multiple factors individually and collectively, to begin to elucidate possible pathways for equity gaps.

Results After our comparisons, Māori patients experienced fewer unadjusted $DAOH_{90}$ at seven out of nine deciles. After risk-adjustment, the differences ranged from 8 days to 0 days when considering different risk factors. The equity gap was widest at the lower deciles and was most reduced after adjusting for the Measuring Multi Morbidity (M3) score. The equity gap widened as the time period extended from 30 to 90 to 365 days.

Conclusion Māori patients who underwent a CABG operation experienced fewer DAOH than non-Māori patients even after adjusting for multiple possible explanatory variables, and this difference increased over time postoperatively. Importantly, our results illustrate the value of DAOH as a sophisticated outcome metric that can reflect the complex and accumulative impacts of disadvantage and discrimination faced by Indigenous peoples both here in New Zealand and worldwide. It has considerable potential to increase our understanding of how and where inequities arise on the entire patient journey.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study uses days alive and out of hospital (DAOH) to measure equity of outcomes after surgery and discusses the advantages of using DAOH (or other) continuous variables over binary variables to measure equity.
⇒ This study compares DAOH measurements before and after risk adjustment between two ethnic groups.
⇒ While we can measure equity differences in DAOH, the clinical impact of a small difference in DAOH between groups is still unclear.

INTRODUCTION

In Aotearoa New Zealand (NZ), approximately 2800 cardiac procedures are performed each year and being of Māori ethnicity or coming from a lower socioeconomic household is associated with poorer outcomes after surgery.[1–5] These outcome differences are partially but not fully explained through observed and lifetime accumulated health disparities. Health system biases and choices made by healthcare providers during the provision of care have been previously hypothesised to contribute to inequities.[6 7]

Generally, perioperative health outcomes in NZ are measured analytically through metrics such as mortality or infection rates.[2 8 9] One-month mortality is the most common metric, but overall perioperative mortality in NZ is low, being 0.6% for general surgery[9] and 1%–2% for cardiovascular procedures.[1] This makes identifying differences between groups difficult, particularly with a relatively small population. Longer term mortality rates, such as 90-day mortality,[10 11] have been suggested as measures, but mortality is a

binary, unidimensional variable, with limited statistical power. Alternate measurement variables to mortality have been suggested in an equity context, for example comparing equity of access by assessing the rates of intervention between population groups.[12 13]

One recent NZ study measured perioperative outcomes through days alive and out of hospital (DAOH), and in a secondary analysis, it was found that, on average, Māori patients experienced 1.1 fewer DAOH than non-Māori.[14] DAOH is a composite outcome metric which has been validated for measuring surgical outcomes alongside other similar metrics, such as 'days at home'.[15–17] As a continuous measurement, DAOH should possess a higher level of information than binary variables, such as mortality or infection rates. Also, DAOH can be considered as a more holistic measure of outcome as it captures the impact of many complications in a single variable. For example, the use of composite measures, over individual outcome metrics, has been shown to increase ordinal rankability of hospitals after surgery and improve future predictions of outcomes.[18 19] This also means DAOH is more reflective of patient experience than mortality. DAOH can easily be calculated from administrative databases[20] and in NZ, the information required to calculate DAOH is maintained in continuously updated national databases, such as the National Minimum Data set (NMDS).[21]

In this paper, we present an analysis of outcomes after coronary artery bypass grafts (CABG) in NZ, measured by DAOH scores. Our paper focuses on the utility of DAOH as a tool for monitoring equity in outcomes for Māori as the Indigenous people (tangata whenua) of NZ, and our work reflects Māori rights to equitable health outcomes reaffirmed by both the United Nations Declaration of the Rights of Indigenous peoples[22] and the Treaty of Waitangi.[23] As discussed by Sandiford *et al*,[13] analysis at a system level is required to understand and change the root causes of inequity. In this work, we aimed to demonstrate how DAOH can be used as a tool to measure inequities in outcomes after CABG, and how DAOH as a more complete variable than mortality can identify opportunities for interventions to address these.

METHODS

This study follows the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) guidelines (an extension of the STrengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines)[24] (see online supplemental additional file 1) and the CONSIDER statement[25] (see online supplemental additional file 2).

We conducted a secondary analysis of routinely collected data from the NZ MoH. All patients in the NMDS 18 years of age or over who had undergone an isolated CABG operation between 1 January 2013 and 31 December 2021 were included. Patients who had a concomitant valve operation were excluded. Only a patients first CABG operation in our study period was included. A CABG operation was identified as an admission which included an Australian Classification of Health Interventions (ACHI) code for CABG as defined in online supplemental appendix 1. These operations were all classified as severity 5 on a 1–5 scale for operative severity based on the system developed by Pasternak,[26] which has been modified for use in NZ and used in previous work.[2 3 5] The cohort was divided into Māori and non-Māori for analysis using MoH prioritised ethnicity codes.[27] Therefore, any patient with multiple ethnicity codes where one is Māori was counted as a Māori patient in the analysis.

Data were sourced from the NMDS, which contains hospital admissions and aspects of surgical care from all public hospitals and most private hospitals in NZ and has been continuously updated since 1999[21] with patients linked to the NZ Births and Deaths registry for mortality information. The NMDS captures every patient admission that lasts longer than 3 hours, and patients can be tracked across hospitals through their unique National Health Index (NHI) numbers.[28] The NMDS also contains demographic information about patients, such as their age, self-reported ethnicity, their domicile code (allowing for geographic analysis of their socioeconomic position)[29] and some comorbidity information.

The primary outcome for this study was days alive and out of hospital at 90 days ($DAOH_{90}$). Secondary outcomes measured included days alive and out of hospital at 30 and 365 days ($DAOH_{30}$ and $DAOH_{365}$). The CABG operation was considered to happen on day 1, so to calculate DAOH, we remove 1 day from the total of all the days spent in hospital or dead during the follow-up period. This means the maximum result possible was equal to one less than the total follow-up period. Patients who were not discharged during the follow-up period or who died in hospital were given zero. Patients who were discharged to home but then died during the follow-up period were given a score reflecting their time spent at home.

This study was framed from a Kaupapa Māori Research positioning, which acknowledges that Māori health outcomes are directly tied to the unequal distribution of the social determinants of health[30] and the historical (and contemporary) impacts of colonialism.[31] This study incorporated a Kaupapa Māori Research positioning via: a collaborative team including senior Māori public health researchers and clinicians; a commitment to a structural analysis that critiqued system responsiveness to Māori within the context of CABG inequities; a rejection of victim-blame or cultural deficit analyses; ensuring high-quality ethnicity data collection and reporting and the use of appropriate methods to investigate Māori health inequities within the study design and data analysis.[32]

All comparisons were conducted between Māori and non-Māori. We calculated unadjusted DAOH scores for the deciles of the DAOH distribution (0.1–0.9 inclusive) at three time points (30, 90 and 365 days). A decile represents the threshold below which X% of the individual patient values lie: for example, 10% of patients' scores lie below the 0.1 decile.

$DAOH_{90}$ values were subsequently calculated after risk adjustment using direct risk standardisation.[33] This method has been used previously with DAOH data[14] and was chosen over direct standardisation for risk factors as it adjusts for non-comparability of groups arising from differences in their expected outcomes rather than their characteristics. This allows many risk factors to be included in the adjustment process without requiring impracticably large sample sizes. Furthermore, the overall risk distribution is adjusted rather than the scores of individual patients.

Risk was adjusted using seven different combinations of potential confounding variables. The reason for the number of factors and the models chosen is that our hypothesis is that differences in DAOH would decrease after adjustment, but not disappear entirely. The 'baseline' model included age and sex. Accounting for age is particularly important given the difference in population age structure between Māori and non-Māori (with the Māori population being considerably younger than the non-Māori population).[34] Prespecified factors were then added to our baseline model, which may possess explanatory ability for inequities. Each factor was added on its own, that is, non-sequentially, to test for any changes in the adjusted differences between groups. These factors were at deprivation level as measured by NZDep18 Deprivation Index, which provides an area-based measure of material deprivation,[35] acuity of admission, American Society of Anaesthesiologists (ASA) score[36] and the Measuring Multimorbidity Index Score (M3 score)[37 38] and rurality (as measured by the Geographic Classification of Health (GCH2018)[39]). Then, all variables were included in a fully-adjusted model. At each stage, DAOH values were calculated for each time point for each adjustment model. This generated a total of 189 adjusted $DAOH_{90}$ value comparisons between Māori and non-Māori (seven models * nine deciles * three time periods) and 27 unadjusted comparisons. Equivalent calculations were undertaken for $DAOH_{30}$ and $DAOH_{365}$. The full results are available in online supplemental material.

These models are as follows:

Baseline—Age+sex

Model 2—Baseline+NZDep18

Model 3—Baseline+rurality

Model 4—Baseline+ASA

Model 5—Baseline+acuity

Model 6—Baseline+M3 score

Full model—Baseline+rurality+ASA+acuity+ M3 score+NZDep18

Every adjustment model was constructed using quantile regression for the median quantile of the patients' logit-transformed DAOH scores. The scores are logit-transformed to keep the modelled values within the DAOH boundaries, that is, 0–30, 0–90 and 0–365. Quantile regression on the untransformed data has the potential to produce quantile estimates outside the explicit DAOH boundaries, such as 91 or −1 for $DAOH_{90}$. Age was handled as a continuous variable and M3 score was modelled with a restricted cubic spline to reflect its non-linear association with overall health. All other variables were handled as factors.

All statistical analyses were conducted in R V.4.2.1[40] using Rstudio 2022.07.1+554.[41] The survey package was used, V.4.1–1,[42] for analysis and generating data points and confidence limits and ggplot2 for our graphs[43] and data manipulated using data.table, V.1.14.2[44] and the tidyverse package, V.1.3.2.[45]

As it is mandatory to report the date of death in NZ, all mortality outcomes were assumed to have been reported. All patients in NZ can be uniquely identified through their NHI number, allowing reliable capture of readmissions. For our risk models, some data were missing for rurality (3.8%), ASA (21.5%) and NZDep18 (5.1%). As it is assumed that data were not missing at random, patients with missing data were labelled as 'missing' and included in the model to minimise possible bias.

Patient and public involvement

Patients and the public were not involved in the design or conduct of this study. But as is usual in NZ, we have consulted with Māori in our study design by presenting our plan at the Taia te Hauora Māori health research advisory group. We have also included senior Māori health experts in our team.

RESULTS

We extracted data from the NMDS on a total of 11 774 eligible patients, of whom 1373 (11.6%) were Māori. Demographic and other information on these patients is presented in table 1.

Table 2 shows unadjusted $DAOH_{90}$ scores at nine deciles for Māori and non-Māori patients undergoing CABG operations and the differences between their scores. Māori patients experienced fewer unadjusted $DAOH_{90}$ at seven out of nine deciles (0.1–0.7 inclusive) across the $DAOH_{90}$ distribution. The differences were larger at lower deciles and reduced as the deciles got higher. The largest difference was at the 0.1 decile (5.8 days) and the smallest was at the 0.7 decile (1 day). There was no difference between Māori and non-Māori patients at the 0.8 or 0.9 deciles.

After adjustment, Māori patients continued to experience fewer $DAOH_{90}$ at various deciles than non-Māori; these differences were most marked at the lower deciles of the DAOH distribution and decreased as the deciles increased. The largest differences after adjustment were at the 0.1 decile, ranging from 8 days for models 1, 4 and 5 to 2 days in the sixth model. The smallest differences were for the 0.8 and 0.9 deciles where 6/7 models showed no differences after adjustment. Model 5 showed a 1 day difference at the 0.8 decile. At the median, differences after adjustment ranged from 3 days to 1 day, with 5/7 models showing a difference of 2 days. Importantly, all models showed a difference between ethnic groups after adjustment at the 0.5 decile, implying no combination of

Table 1 Demographic details of patients included in the study (Māori, non-Māori)

	Māori	non-Māori	Total
Total N	1373	10401	11774
Age			
<50	147 (11%)	547 (5%)	694
50–65	716 (52%)	3834 (37%)	4550
65–74	429 (31%)	4198 (40%)	4627
75+	81 (6%)	1822 (18%)	1903
Sex			
F	361 (26%)	1817 (17%)	1903
M	1012 (74%)	8584 (83%)	9596
NZDep18 deprivation level (note—1 is least deprived, 10 is most deprived)			
1–2	71 (5%)	1604 (15%)	1675
3–4	118 (9%)	1883 (18%)	2001
5–6	202 (15%)	2120 (20%)	2322
7–8	304 (22%)	2133 (21%)	2437
9–10	655 (48%)	2028 (19%)	2683
Missing	23 (2%)	633 (6%)	656
Acuity of admission			
Acute	455 (33%)	3618 (35%)	4073
Scheduled	918 (67%)	6783 (65%)	7701
Rurality (GCH2018) Urban 1 (U1) is most urban to Rural 3 (R3) most rural			
U1	544 (40%)	5765 (55%)	6309
U2	381 (28%)	1948 (19%)	2329
R1	220 (16%)	1416 (14%)	1636
R2	148 (11%)	676 (6%)	824
R3	66 (5%)	106 (1%)	172
Missing	14 (1%)	490 (5%)	504
M3 score			
<0.5	719 (52%)	6940 (67%)	7659
0.5–1	417 (30%)	2376 (23%)	2793
1–2	218 (16%)	995 (10%)	1213
2+	19 (1%)	90 (1%)	109
ASA score			
<3	14 (1%)	126 (1%)	140
3	387 (28%)	3451 (33%)	3838
4	644 (47%)	4531 (44%)	5175
5	6 (0%)	24 (0%)	30
Missing	322 (23%)	2269 (22%)	2591
Mortality			
30 day	3.2%	1.8%	2.0%
90 day	3.4%	2.2%	2.4%
One year	6.2%	4.0%	4.5%
In-hospital mortality	4.5%	2.7%	2.9%
Length of stay (days)			
Lower quartile	7	7	7
Median	11	10	10
Upper quartile	17	15	16
Readmission rates			
30 day	1.5%	1.4%	1.4%
90 day	6.5%	4.1%	4.4%
One year	13.6%	12.5%	12.7%

NZDep18 is the New Zealand index of deprivation 2018 and GCH2018 is the Geographic Classification of Health 2018, both are location-based indicators of access and/or deprivation. M3 is the Measuring Multi Morbidity score and ASA is the American Society of Anesthesiologists score, both are measures for a patient's health.
ASA, American Society of Anesthesiologists.

adjustment variables could account for the ethnic differences between 'average' patients.

Looking at the average across all deciles, the models incorporating the M3 score showed the highest average reduction in differences, with the sixth model (baseline+M3 score) having the lowest average difference, followed by the seventh model incorporating all factors and then the second model (baseline+NZDep18) with 0.78, 1 and 1.9 days, respectively. All other models had an average difference across the deciles of more than 2 days. The average unadjusted difference across deciles was 2.1 days (table 2), meaning that the baseline model, the model including ASA and the model including acuity actually increased the differences after adjustment. At the median, 5/7 models showed a difference of 2 days after adjustment, with the two models incorporating the M3

Table 2 Unadjusted days alive and out of hospital after 90 days $DAOH_{90}$ at nine quantiles of the DAOH distribution between Māori and non-Māori patients following a coronary artery bypass graft

Quantile	Māori	non-Māori	Diff. (days)	All patients
0.1	59.2	65	5.8	62
0.2	67	71	4	69
0.3	71	74	3	73
0.4	74	76	2	76
0.5	77	79	2	78
0.6	79	81	2	80
0.7	81	82	1	81
0.8	82	82	0	82
0.9	83	83	0	83

The 'diff' column shows the absolute difference between Māori and non-Māori patients at that chosen decile.
DAOH, days alive and out of hospital.

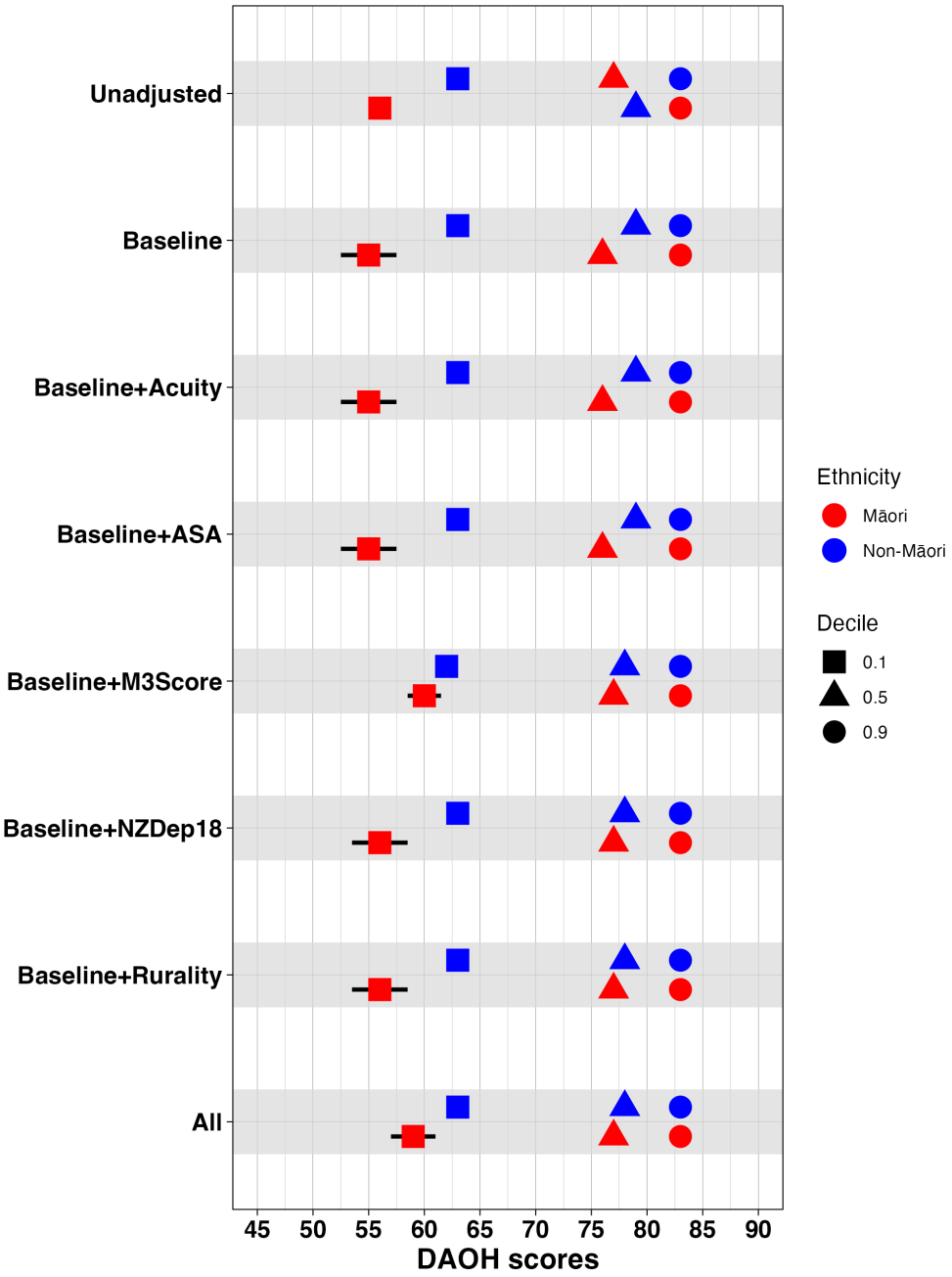

Figure 1 A forest plot of $DAOH_{90}$ at three selected deciles 0.1, 0.5 and 0.7, which illustrates differences between Māori and non-Māori patients before and after adjustment for a variety of covariates. Each point represents the average DAOH score at one decile for either Māori (blue) or non-Māori (red) patients. The whiskers on the boxes show a 95% CI. The baseline model included age and sex only, and these factors were also included in all subsequent models. DAOH, days alive and out of hospital.

score showing a 1 day difference after adjustment. The differences at a selected subset of the deciles (0.1, 0.5 and 0.9) are shown in figure 1, while table 3 shows the complete set of results.

Comparing outcomes across three time periods ($DAOH_{30}$, $DAOH_{90}$ and $DAOH_{365}$), there was a difference in fully adjusted DAOH outcomes between Māori and non-Māori patients at deciles 0.1 to 0.5 inclusive (table 4). At the 0.6 and 0.7 decile, there was a difference only at two of the three time periods. For all deciles where differences were observed, they were greatest at the $DAOH_{365}$ time period.

DISCUSSION

In this cohort, Māori patients who underwent CABG experienced worse outcomes as measured using DAOH than non-Māori patients after adjusting for multiple possible explanatory variables. The equity gap was greatest for patients already experiencing the worst outcomes (ie,

Table 3 Risk-adjusted days alive and out of hospital at 90 days ($DAOH_{90}$) values at three deciles of the distribution after adjusting for selected confounding factors

Decile/model	Adjustment covariates	Māori	non-Māori	Diff. (days)
M1				
0.1	Age+Sex	59 (57.0–61.0)	65 (64.5–65.5)	6
0.5	Age+Sex	76 (75.5–76.5)	79 (78.5–79.5)	3
0.9	Age+Sex	83 (82.5–83.5)	83 (82.5–83.5)	0
M2				
0.1	Age+Sex+NZDep18	60 (58.5–61.5)	65 (64.5–65.5)	5
0.5	Age+Sex+NZDep18	77 (76.5–77.5)	79 (78.5–79.5)	2
0.9	Age+Sex+NZDep18	83 (82.5–83.5)	83 (82.5–83.5)	0
M3				
0.1	Age+Sex+GCH2018	59 (57.0–61.0)	65 (64.5–65.5)	6
0.5	Age+Sex+GCH2018	77 (76.5–77.5)	79 (78.5–79.5)	2
0.9	Age+Sex+GCH2018	83 (82.5–83.5)	83 (82.5–83.5)	0
M4				
0.1	Age+Sex+ASA	59 (57.0–61.0)	65 (64.5–65.5)	6
0.5	Age+Sex+ASA	77 (76.5–77.5)	79 (78.5–79.5)	2
0.9	Age+Sex+ASA	83 (82.5–83.5)	83 (82.5–83.5)	0
M5				
0.1	Age+Sex+Acuity	59 (57.0–61.0)	65 (64.5–65.5)	6
0.5	Age+Sex+Acuity	76 (75.5–76.5)	79 (78.5–79.5)	3
0.9	Age+Sex+Acuity	83 (82.5–83.5)	83 (82.5–83.5)	0
M6				
0.1	Age+Sex+M3Score	62 (60.5–63.5)	65 (64.5–65.5)	3
0.5	Age+Sex+M3Score	78 (77.5–78.5)	79 (78.5–79.5)	1
0.9	Age+Sex+M3Score	83 (82.5–83.5)	83 (82.5–83.5)	0
M7				
0.1	All covariates	61 (59.5–62.5)	65 (64.5–65.5)	4
0.5	All covariates	78 (77.5–78.5)	79 (78.5–79.5)	1
0.9	All covariates	83 (82.5–83.5)	83 (82.5–83.5)	0

A decile represents the values at which 1X% of the patients scored above. Adjustment covariates lists the variables which have been included in the adjustment model. Māori and non-Māori give the $DAOH_{90}$ values for those patients at that decile. The 'diff' column shows the difference in days as measured by $DAOH_{90}$ between non-Māori and Māori patients. The full set of results are available in online supplemental table 1. *NZDep18 is the New Zealand index of deprivation 2018 and GCH2018 is the Geographic Classification of Health 2018, both are location-based indicators of access and/or deprivation. M3 is the Measuring Multi Morbidity score and ASA is the American Society of Anesthesiologists score, both are measures for a patient's health*.

those at the lower deciles of the DAOH distribution). After accounting for age and sex, the inequity of outcomes between these groups was larger, while the equity gap was smallest after adjusting for a large range of comorbidities, as measured by the M3 score. At the median, even after adjusting $DAOH_{90}$ for age, sex, household deprivation, rurality and comorbidities, Māori patients experienced 1 day fewer alive and at home than their non-Māori counterparts. This is consistent with previous work looking at $DAOH_{90}$ between patients in NZ.[14]

Some previous studies have focused only on median DAOH values.[15 16 20] Our results show that the median value might fail to convey how differences are amplified in the lower tail of the distribution or how they disappear in the upper end of the distribution. For an operation such as CABG, an extremely good outcome requires nearly everything to go right for the patients. However, a wide variety of complications can extend hospital stay, lead to readmission or an untimely death. Our results suggest that Māori may experience more complications than non-Māori, and that when such complications occur, the impact is worse for Māori. The M3 score measures the ongoing health impact of a range of health conditions, and provides some indication of patients' pre-existing burden of disease. Māori and non-Māori have different median M3 scores (0.47 and 0.37, respectively) indicating

Table 4 Differences in DAOH between Māori and non-Māori patients across three time periods after adjusting for seven different covariates (sex, age, acuity, ASA, deprivation level, rurality and M3 score)

	$DAOH_{30}$ (complement)			$DAOH_{90}$ (complement)			$DAOH_{365}$ (complement)		
Decile	Māori	non-Māori	Diff.	Māori	non-Māori	Diff.	Māori	non-Māori	Diff.
0.1	2 (28)	6 (24)	4	61 (29)	65 (25)	4	334 (31)	339 (26)	5
0.2	9 (21)	11 (19)	2	69 (21)	70 (20)	1	342 (23)	345 (20)	3
0.3	13 (17)	14 (16)	1	72 (18)	74 (16)	2	346 (19)	349 (16)	3
0.4	15 (15)	16 (14)	1	75 (15)	76 (14)	1	349 (16)	351 (14)	2
0.5	18 (12)	19 (11)	1	78 (12)	79 (11)	1	351 (14)	353 (12)	2
0.6	20 (10)	21 (9)	1	80 (10)	80 (10)	0	354 (11)	355 (10)	1
0.7	21 (9)	22 (8)	1	81 (9)	82 (8)	1	356 (9)	356 (9)	0
0.8	22 (8)	22 (8)	0	82 (8)	82 (8)	0	357 (8)	357 (8)	0
0.9	23 (7)	23 (7)	0	83 (7)	83 (7)	0	358 (7)	358 (7)	0

DAOH represents time spent alive and out of hospital and in brackets we are showing the complement, which is the time spent dead or in hospital for each time period calculated by taking the maximum of the DAOH period less the DAOH score.
DAOH, days alive and out of hospital.

a higher burden of disease for Māori. This is reflected by the fact that adjusting for the M3 score closes the equity gap the most.

These findings have policy implications for the health system. To reduce inequity, a focus on the 'average' patient or even on the majority of patients may net lower gains than a more intense push to improve outcomes for those currently doing the worst (those at the lower deciles). The ability to investigate DAOH as a continuous variable in this way is an obvious strength in any equity focused research when compared with comparisons made using metrics such as mortality, and allows for a more complete story to be told. By leveraging the continuous nature of the data, we gain an improved understanding of the equity differences at alternate tails of our distributions and how these feed into the overall systemic differences. Investigating differences at the median of the DAOH distributions only, or binary variables such as mortality rates, hides important information about patients in the tails. Thus, the very poor results of certain patients, such as those with a high M3 score (many comorbidities), may be hidden by the inflation of the average by those scores at the higher ends of our distribution.

The equity gap increased with time. The largest differences were observed for $DAOH_{365}$, with no difference between $DAOH_{90}$ and $DAOH_{30}$ (2 days at $DAOH_{365}$ vs 1 day for $DAOH_{90/30}$) at the median. We hypothesise that worse outcomes at the longer time period reflect ongoing problems with health system interactions for Māori and experiences of systematic racism in those interactions,[46] leading to more readmissions, higher mortality and less days spent alive and at home. Indeed, the remaining equity gaps after risk adjustment at all time periods and all deciles will be directly tied to the unequal distribution of the social determinants of health for Māori[47] alongside the historical (and contemporary) impacts of colonialism.[48] This is supported by the equity gap widening between Māori and non-Māori at $DAOH_{365}$ for multiple deciles compared with $DAOH_{90/30}$. The increase in this gap may reflect an ongoing gap between need for greater care and access to the care needed or the ongoing impact of comorbidities on patients' overall quality of life. The level of care offered to Māori patients may not be equal to that offered to other patients or Māori patients may experience more barriers when accessing care than non-Māori patients,[49–52] leading to equity gaps extending over time.

A limitation of our study is the reliance on administrative data. This means data about some other potential drivers of variation, for example operative complications or other clinical complications not recorded, are not available. Our study is also limited to those who have been captured in our observational data set; however, the NMDS captures 99% of hospital admission in NZ, including those in private, so we are unlikely to have missed many CABG operations.[21] While we have tried to establish which factors could be impacting the outcome differences through our adjustment models, this data represent correlations only, and further work could try to understand, in more depth, the drivers of outcome differences through more systematic analysis of causality. We have followed our patients out to 1 year postoperatively; however, given that the equity gap was seen to be widening with time, further analysis using a longer data set may be beneficial but was not possible with our data. Further analysis should also consider quality of life or patient-reported outcome measures. The clinical impact or significance of differences in DAOH is still unclear, and this is an important limitation of this study and more work is needed in this area and should include discussion of patient preferences. Economically, a stay at Waitematā DHB (NZ's largest DHB) is estimated to cost $1587 per night,[53] taking our median value of 2 days difference between the groups for $DAOH_{365}$, this amounts to an extra cost of $2 579 248 over the period our data captured

for Māori patients even after fully adjusting our data. It is worth considering that some patients may actually benefit from slightly longer in hospital, particularly those who experience material deprivation or who live rurally where returning to hospital in the case of complications is difficult. More research on patient preferences and understanding of DAOH as a measure of outcomes would be valuable. Previous work has shown that summary measures of outcomes, such as DAOH, are considered useful by patients.[54] Future work should continue to involve Indigenous communities in the development of these tools and the application of them to important research problems. While this study has focused on Māori patients, the methods can generalise to studies looking at equity differences between other groups.

In conclusion, we have added to evidence of inequity in perioperative outcomes after CABG in NZ and have shown that this inequity remains after extensive risk adjustment and is amplified for those patients who experience poor outcomes. Importantly, this work has also illustrated the strengths of DAOH as a metric in equity research. DAOH is a sophisticated metrics that can reflect the complex and accumulative impacts of disadvantage and discrimination faced by Indigenous peoples both here in NZ and worldwide. It has considerable potential to increase our understanding of how and where inequities arise on the entire patient journey. We hope that our study will lead to increased uptake of this variable in clinical and outcome focused research. In our view, future work with DAOH should lean into its strengths by looking at values across the whole distribution and carefully consider what differences at areas of the distribution beyond the median may imply for patients.

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Ethics approval This study involves human participants and was approved by Auckland Health Research Ethics Committee, reference AH24430. Due to the size of the data set used and the historical nature of the data, it was not possible to obtain informed consent.

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