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Estimating the economic impact of acute coronary syndrome in New Zealand over time (ANZACS-QI 64): a national registry-based cost burden study

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ABSTRACT

Objectives To estimate the changes in costs associated with acute coronary syndrome (ACS) admissions in New Zealand (NZ) public hospitals over a 12-year period.

Design A cost-burden study of ACS in NZ was conducted from the NZ healthcare system perspective.

Setting Hospital admission costs were estimated using relevant diagnosis-related groups and their costs for publicly funded casemix hospitalisations, and applied to 190 364 patients with ACS admitted to NZ public hospitals between 2007 and 2018 identified from routine national hospital datasets. Trends in the costs of index ACS hospitalisation, hospital admissions costs, coronary revascularisation and all-cause mortality up to 1 year were evaluated. All costs were presented as 2019 NZ dollars.

Primary outcome measures Healthcare costs attributed to ACS admissions in NZ over time.

Results Between 2007 and 2018, there was a 42% decrease in costs attributed to ACS (NZ$7.7 million (M) to NZ$4.4 M per 100 000 per year), representing a decrease of NZ$298 827 per 100 000 population per year. Mean admission costs associated with each admission declined from NZ$18 411 in 2007 to NZ$16 898 over this period (p<0.001) after adjustment for key clinical and procedural characteristics. These reductions were against a background of increased use of coronary revascularisation (23.1% (2007) to 38.1% (2018)), declining ACS admissions (366–252 per 100 000 population) and an improvement in 1-year survival post-ACS. Nevertheless, the total ACS cost burden remained considerable at NZ$237 M in 2018.

Conclusions The economic cost of hospitalisations for ACS in NZ decreased considerably over time. Further studies are warranted to explore the association between reductions in ACS cost burden and changes in the management of ACS.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Hospital admissions costs for acute coronary syndrome (ACS) were estimated using relevant diagnosis-related groups, and their costs for publicly funded casemix hospitalisations.
⇒ It was possible to estimate the clinical and cost burden attributed to ACS in New Zealand at the national level using routine national hospital datasets.
⇒ A key limitation to our analysis was that the weighted average costs of relevant diagnosis-related groups were applied to each ACS hospitalisation, in lieu of direct patient-level costs.
⇒ It was not possible to estimate potential cost savings specifically attributable to reductions in mortality, morbidity or readmissions not related to repeat ACS admissions.

INTRODUCTION

Acute coronary syndrome (ACS) contributes to considerable mortality and morbidity in New Zealand. However, studies have shown significant temporal reductions in the risk of mortality and complications following ACS in New Zealand.[1 2] Over the 10-year period from 2006 to 2016, the incidence of all-cause mortality, recurrent myocardial infarction (MI), heart failure, stroke and major bleeding events occurring 1 year following an ACS event had decreased significantly.[1] Additionally, the incidence of ACS admissions occurring in public hospitals across New Zealand reduced from 685 to 424 per 100 000 in the same period.[2] Such improvements have been attributed to ongoing advancements in the treatment and management of ACS, including medical therapy, revascularisation and primary and secondary prevention measures. Furthermore, the establishment of the All-New Zealand Acute Coronary Syndrome Quality Improvement programme (ANZACS-QI) in 2011 has also contributed to improved patient outcomes through benchmarking and support of evidence-based management of ACS.[3 4] We had recently published an economic evaluation of ANZACS-QI, and found that there were considerable costs attributed to MI readmissions and deaths over a 4-year period.[4] However, to date, no study has evaluated the cost of ACS in New Zealand, nor the decline in these with the decreasing burden of ACS over time. Therefore, in this study, we sought to estimate the costs of hospital admissions

for ACS in New Zealand, from the perspective of the public healthcare system, as well as trends in these costs.

METHODS

Data

In New Zealand, almost all acute hospital care is provided by public hospitals. Data pertaining to hospital admissions are captured in routinely collected national administrative datasets and linked to the ANZACS-QI database using an encrypted National Health Index number.[3 5] For the purposes of this study, admissions for all ACS patients aged 20 years or older to New Zealand public hospitals occurring in the period between 1 January 2007 and 31 December 2018 were identified.

International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10) codes were used to identify the following ACS subgroups: non-ST elevation MI (NSTEMI) (I21.4 and I22.2), ST-elevation MI (STEMI) (I21.0–I21.3, I22.0, I22.1, I22.8 and I22.9), unstable angina (UA) and 'MI unspecified' (I21.9).[4] Patients were excluded from the analysis if they were not residents in New Zealand, or if hospital length of stay (LOS) exceeded 8 weeks.[1 2] Hospital LOS greater than 8 weeks were likely attributed to non-ACS comorbidities, resulting in an overestimation of admissions costs through undue weight in statistical analyses.[6] For the purposes of this study, all ACS admissions for each patient in a calendar year were included in the analyses. In each calendar year, the first ACS admission for a patient was considered the 'index' admission, with subsequent ACS admissions being considered as repeat ACS admissions for a patient if they occurred in the same calendar year.

The key outcome of interest was the cost attributed to ACS admissions in New Zealand over time. This includes trends in total ACS admission costs, as well as index ACS admission costs and trends in costs attributed to repeat ACS admissions occurring within 1 year of an index admission. The ACS cost per 100 000 population per year was estimated using the total costs attributed to ACS in the numerator, and population projections in the denominator.[7] ACS hospitalisations for which percutaneous coronary intervention (PCI) and/or coronary bypass grafting (CABG) were performed were defined as revascularisation events.[2] Inpatient LOS, and revascularisation and all-cause mortality up to 30 days postdischarge were available for the whole study population. All-cause mortality occurring from 31 days to 1 year were available for index ACS hospitalisations occurring between 2007 and 2017.[1] The cost for each hospital admission for ACS was estimated using relevant diagnosis-related groups (DRGs), and their costs for publicly-funded casemix hospitalisations in 2018/2019 sourced as a separate dataset from the New Zealand Ministry of Health.[8] The following DRGs were considered: F05A, F05B, F06A and F06B for CABG; F10A and F10B for acute MI (AMI) with PCI; F15A, F15B, F16A and F16B for non-AMI PCI; F41A and F41B for AMI with angiography; F42A–F42C for non-AMI angiography; F60A and F60B for AMI admissions without angiography; and F72A and F72B for UA admissions without angiography. To estimate the per-diem cost of an admission, the estimated DRG cost was divided by the average LOS associated with each DRG in the supplied DRG data. The weighted average cost per diem for the DRGs associated with an AMI/UA admission with or without CABG/PCI/angiography was then estimated, and applied to the LOS estimated for each admission in the ANZACS-QI dataset. As DRGs represent a relative measure of resources use for each episode of care, patient-level cost components cannot be assessed separately. The derivation of hospital admission costs associated with AMI and UA with or without CABG/PCI or angiography, is summarised in online supplemental Table A1 of the Appendix. As DRG data from the New Zealand Ministry of Health for the period 2018/2019 was used, all costs are presented as New Zealand dollars (NZ$), referenced to the period 2018/2019 to reflect the DRG dataset.

Statistical analyses

Univariate linear regression analyses were performed to estimate the trend in total ACS costs over time. Multivariable generalised linear regression modelling (GLM), with log-link and gamma distribution, was used to evaluate trends in index and repeat hospital admission costs to overcome positively skewed cost data.[9] Multivariable models were adjusted using the following covariates: age group (20–44, 45–59, 60–69, 70–79 and >80 years), sex, ethnicity, socioeconomic deprivation and ACS subtype. For socioeconomic deprivation, the New Zealand Deprivation Index (NZDep2013), which provides area-based estimates of relative socioeconomic deprivation, was divided into quintiles.[10] The average change in cost outcomes per year was presented as β-coefficients for GLMs and linear regression models, with corresponding 95% CIs. Multivariable logistic regression analyses or GLMs were also performed to explore trends in patient all-cause mortality for index ACS admissions, and patient LOS and revascularisation practices across all ACS admissions (the results for which are presented in online supplemental Table A5 and A6 in the Appendix). All statistical analyses were performed using Stata statistical analysis software V.14.2 (StataCorp), and the significance level was set at $p<0.05$.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research

RESULTS

Tables 1 and 2 present the trends in patient baseline and clinical characteristics, and patient outcomes over time, respectively. A more detailed table of patient trends over time is presented in online supplemental Table A2 of the Appendices.

Table 1 Patient baseline and clinical characteristics over time

Variable	Year 2007 (N=18 595)	2012 (N=15 957)	2018 (N=14 548)
Age (years) (mean (SD))	71.4 (13.5)	71.8 (13.5)	71.0 (13.4)
Male	10 830 (58.2%)	9612 (60.2%)	8995 (61.8%)
Ethnicity			
European/other	15 711 (84.5%)	12 969 (81.3%)	11 218 (77.1%)
Asian	204 (1.1%)	267 (1.7%)	417 (2.9%)
Indian	346 (1.9%)	500 (3.1%)	498 (3.4%)
Pacific	565 (3.0%)	625 (3.9%)	700 (4.8%)
Māori	1769 (9.5%)	1596 (10.0%)	1715 (11.8%)
NZ DEP (quintile)*			
1	2298 (12.4%)	2085 (13.1%)	2144 (14.3%)
2	2847 (15.3%)	2644 (16.6%)	2579 (17.3%)
3	3778 (20.4%)	3141 (19.7%)	2846 (19.6%)
4	4833 (26.0%)	3990 (25.1%)	3453 (23.7%)
5	4801 (25.9%)	4071 (25.6%)	3510 (24.1%)
Missing	38 (0.2%)	26 (0.2%)	16 (0.1%)
ACS			
UA	5380 (28.9%)	3921 (24.6%)	3148 (21.6%)
NSTEMI	9861 (53.0%)	8767 (54.9%)	7707 (53.0%)
STEMI	2523 (13.6%)	2639 (16.5%)	2713 (18.7%)
MI unspecified	831 (4.5%)	630 (4.0 %)	980 (6.7%)
Angiography	6131 (33.0%)	7506 (47.0%)	7950 (54.7%)
Revascularisation	4297 (23.1%)	5156 (32.3%)	5538 (38.1%)
PCI	3143 (18.4%)	4152 (26.0%)	4690 (32.2%)
CABG	907 (4.9%)	1034 (6.5%)	868 (6.0%)

Data are presented as mean (SD) or n (%).
*First quintile represents the least deprived and fifth quintile the most deprived.
ACS, acute coronary syndrome; CABG, coronary artery bypass graft; DEP, deprivation; MI, myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; UA, unstable angina.

A total of 190 364 ACS hospitalisations were captured in the period from 2007 to 2018. The number of ACS hospitalisations in a calendar year declined from 440 per 100 000 population in 2007 to 298 per 100 000 population in 2018: index ACS hospitalisations declined by 31% (366 per 100 000 in 2007 to 252 per 100 000 in 2018) and repeat ACS hospitalisations by 45% (74 per 100 000 in 2007 to 41 per 100 000 in 2018). Compared with 2007, the proportion of patients aged >80 years was lower (30% in 2018 vs 32.9% in 2007) and there were a greater proportion of males hospitalised for ACS (62% in 2018 vs 58% in 2007). Furthermore, compared with 2007, more STEMI hospitalisations occurred in 2018 (19% vs 14%). LOS decreased from a median of 5 days (IQR: 3–9 days) in 2007 to 4 days (IQR: 2–7 days) in 2018.

Table 3 summarises the trend in total hospital costs in total and stratified by ACS subgroup for index ACS cases, as well as the trend in total hospital costs for repeat ACS admissions over time per 100 000 population. Trends in the absolute cost burden attributed to ACS are presented in Table A3 of the Appendices.

In line with the declining number of ACS hospitalisations, the cost attributed to ACS decreased by 42% (NZ$7.7 million (M) in 2007 to NZ$4.4 M per 100 000 population in 2018). Over this 12-year period, admission costs per 100 000 population reduced annually by NZ$298 827 (β-coefficient: −NZ$0.3 M, 95% CI −NZ$0.30 M to −NZ$$0.30 M) (p<0.001). Index hospitalisations attributed to UA and NSTEMI comprised the majority of the costs, with reductions in the total costs attributed to UA of NZ$65 763 (β-coefficient: −0.07 M; 95% CI: −NZ$0.07 M to −NZ$0.07 M) (p<0.001) per 100 000 population per year and NZ$134 744 (β-coefficient: −NZ$0.13 M; 95% CI −NZ$0.13 M to −NZ$0.13 M) (p<0.001) for NSTEMI hospitalisations per 100 000 population per year driving the annual reduction in hospital costs. Repeat ACS

Table 2 Patient outcomes over time

Variable	Year 2007 (N=18 595)	2012 (N=15 957)	2018 (N=14 548)
LOS (median, IQR)	5.0 (3.0–9.0)	4.0 (2.0–8.0)	4.0 (2.0–7.0)
Clinical event in hospital			
Heart failure	4054 (21.8%)	2869 (18.0%)	2559 (17.6%)
Stroke	331 (1.8%)	246 (1.5%)	200 (1.4%)
Mortality			
0–30 days	1844 (9.9%)	1566 (9.8%)	1348 (9.3%)
31 days to1 year	2220 (11.9%)	1756 (11.0%)	1178 (8.1%)
Repeat ACS admissions *	3123 (16.8%)	2774 (17.4%)	1987 (13.7%)

*Repeat admissions occurring within 1 year of an index admission.
ACS, acute coronary syndrome; LOS, length of stay.

hospitalisations declined from NZ$1.3 M to NZ$407 947 per 100 000 population over this period; that is, a decrease of NZ$78 893 per 100 000 population (β-coefficient: −0.08 M; 95% CI: −0.08 M to −0.08 M) (p<0.001), per year.

Figure 1 presents the trend in mean index hospitalisation costs and procedural costs over time, as estimated using multivariable GLMs. Additional details pertaining to trends in procedural costs, as stratified by sex and ACS-subtype, are presented in Table A4 of the Appendices.

Over a 12-year period, the adjusted mean hospitalisation cost reduced from NZ$18 500 (95% CI NZ$18 230 to NZ$18 701) in 2007 to NZ$17 019 (95% CI NZ$16 818 to NZ$17 220) in 2018, corresponding to an adjusted mean annual decrease of 0.97% (β-coefficient: −0.01 95% CI −0.01 to −0.01) (p<0.001) in hospitalisations costs (figure 1 and online supplemental Table A4 in the Appendices). When stratified by sex and ACS subtype, the greatest decrease in admissions costs occurred in females with NSTEMI (β-coefficient: −0.02, 95% CI −0.02 to −0.02) (p<0.001) and in patients with STEMI ACS (β-coefficient: −0.02, 95% CI −0.02 to −0.01) (p<0.001) (see Online supplemental Appendix). Costs attributed to revascularisation or angiography declined over time, with the greatest decline in procedural costs observed for patients treated with PCI or managed with angiography alone (see Online supplemental Appendix).

Table 4 summarises the change in adjusted mean admissions costs for repeat ACS admissions occurring within one calendar year from index ACS, assessed using multivariable GLM.

As with index ACS admission costs, adjusted mean admission costs for repeat ACS admissions declined over time from NZ$15 258 (95% CI NZ$14 867 to NZ$15 649) in 2007 to NZ$12 554 (95% CI NZ$12 156 to NZ$12 952) in 2018, corresponding to an annual mean reduction of 2% (β-coefficient: −0.02, 95% CI −0.02 to −0.01) (p<0.001). As with index ACS admissions, the greatest reduction in adjusted mean repeat ACS admission costs were observed among patients with STEMIs and NSTEMIs.

Table 3 Cost burden attributed to ACS hospitalisations over time per 100 000 population

Population	Cost (NZ$M) 2007	Cost (NZ$M) 2018	β-coefficient (NZ$M)	95% CI (NZ$M)	R^2	P value
Index admissions						
UA	1.5	0.7	−0.07	−0.07 to −0.07	0.87	<0.001
NSTEMI	3.6	2.1	−0.13	−0.13 to −0.13	0.95	<0.001
STEMI	1.1	0.8	−0.02	−0.02 to −0.02	0.76	<0.001
MI unspec	0.2	0.2	0.00	−0.00 to 0.00	0.00	0.569
Total	6.3	3.9	−0.22	−0.22 to −0.22	0.93	<0.001
Repeat ACS admissions*	1.3	0.4	−0.08	−0.08 to −0.08	0.86	<0.001
Total	7.7	4.4	−0.30	−0.30 to −0.30	0.95	<0.001

*Repeat admissions occurring within 1 year of an index admission.
M, millions; MI, myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; NZD, New Zealand dollars; STEMI, ST-elevation myocardial infarction; UA, unstable angina; unspec, unspecified.

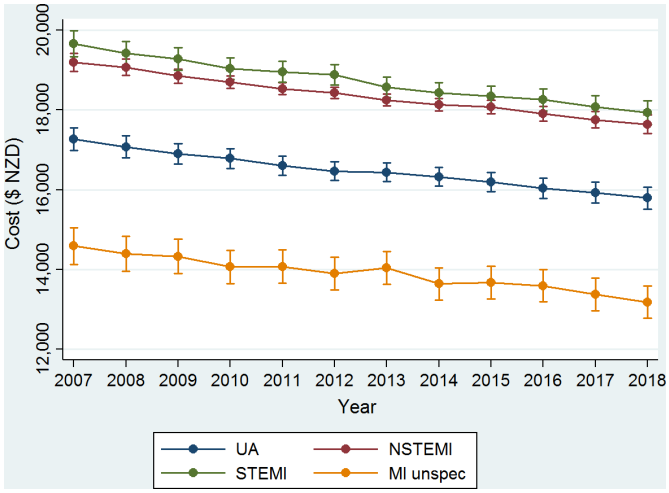

Figure 1 Trend in adjusted[a] mean procedural costs over time. [a]Adjusted for age, sex, ethnicity and NZ deprivation quintile. MI, myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; NZ, New Zealand; NZD, New Zealand dollars; STEMI, ST-elevation myocardial infarction; UA, unstable angina; unspec, unspecified.

DISCUSSION

To the best of our knowledge, our study is the first to evaluate the costs attributed to ACS in New Zealand. Between 2007 and 2018, there was a 42% decrease in costs attributed to all ACS (NZ$7.7 M to NZ$4.4 M per 100 000 per year), representing an annual decrease of NZ$298 827 per 100 000 population. The decline in costs is likely attributed to a similar decline in ACS admissions over this same period. There was a 31% decline in total index ACS hospitalisations (366 to 252 per 100 000 population) and a 45% decline (74 to 41 per 100 000 population) in repeat ACS admissions occurring within 1 year of an index hospitalisation; that is, the total number of ACS admissions in a calendar year declined from 440 to 298 per 100 000 population. Nevertheless, the total ACS cost burden remained considerable at NZ$237 M in 2018, with NSTEMI and UA patients contributing to a considerable proportion of the total costs.

There were reductions in hospitalisation costs across most ACS subgroups, with the exception of the 'MI unspecified' group. This is likely attributable to reductions in LOS for patients with ACS, as hospital LOS is a known driver of hospitalisation cost.[6 11] Significant reductions in patient LOS were observed over time across patients managed with CABG, PCI or angiography. A recent study using routine national hospitalisation data estimated that mean LOS decreased from 7.8 days in 2006 to 6.7 days in 2016 in New Zealand.[6] Our analyses were in line with the reduction in LOS observed over time; that is, the reduction in mean LOS was consistent across patients with NSTEMI, STEMI and UA and most pronounced for patients with NSTEMI and STEMI ACS after adjustment for key confounding factors.[6] Furthermore, the considerable reduction in LOS and costs for NSTEMI and STEMI patients may coincide with the greater likelihood of these patients being managed with PCI over time.[2] Increases in the use of a routine invasive strategy have been previously associated with reduced patient LOS[2] and we found that overall hospitalisation costs were greatly reduced for patients managed with PCI or angiography. The greater uptake of revascularisation procedures was in line with similar studies using data from the ANZACS-QI programme[1 2 6]

Reassuringly, there was also a decline in patient mortality after index ACS admission over time. Although patient demographic characteristics remained relatively stable over time, the proportion of patients with STEMI increased. The observed trends in patient mortality, LOS, revascularisation practices and costs may be attributed to greater efficiency in ACS management and treatment over time.[1 12–14] The significant reduction in patient mortality, coupled with reductions in patient hospitalisation costs over time for NSTEMI—which comprise over 50% of the ACS population—emphasises the considerable cost–benefit attributed to greater efficiency in management of ACS patients. Our analysis highlights the impact of ongoing advancements in the medical and invasive management of ACS, as well as improved public health strategies, in reducing the cost and disease burden of ACS.[1 4]

A key strength for our study was the identification of all publicly admitted index ACS hospitalisations through data linkage of national health datasets. ACS admissions in New Zealand are predominantly captured in the public

Table 4 Trends in repeat ACS admission costs over time

Population	Repeat admissions ($ NZD) (adjusted mean, 95% CI)*		β-coefficient (95% CI)	% Change	P value
	2007	2018			
UA	$15 983 ($15 241–$16 725)	$14 029 ($13 187–$14 871)	−0.01 (−0.02 to −0.00)	−1.42	0.004
NSTEMI	$15 063 ($14 551–$15 573)	$11 897 ($11 398–$12 137)	−0.02 (−0.03 to −0.02)	−2.23	<0.001
STEMI	$14 890 ($13 719–$16 061)	$12 721 (11 501–$13 940)	−0.02 (-0.03 to −0.00)	−1.91	0.008
MI unspec	$11 671 ($9859–$13 482)	$11 580 ($9979– $13 181)	0.00 (−0.02 to 0.02)	−0.18	0.900
Total	$15 258 ($14 867–$15 649)	$12 554 ($12 156–$12 952)	−0.02 (−0.02 to −0.01)	−1.89	<0.001

*Adjusted for age, sex, ethnicity, NZ deprivation quintile and ACS subtype.
MI, myocardial infarction; NSTEMI, non ST-elevation myocardial infarction; NZD, New Zealand dollars; STEMI, ST-elevation myocardial infarction; UA, unstable angina; unspec, unspecified.

hospital system, with private admissions being rare.[2] Hence, it was possible to estimate the clinical and cost burden attributed to ACS in New Zealand at the national level.

A key limitation to our analysis was that the weighted average costs of relevant DRGs were applied to each ACS hospitalisation, in lieu of direct patient-level costs. DRGs are broad categories, within which there can be a varied range of types of hospitalisations. As such, it was not possible to capture the cost impact of changes in clinical practice occurring at the patient level, including the uptake of radial access PCI and improved pharmacological management over time.[12 15] Furthermore, it was not possible to estimate potential cost savings specifically attributable to reductions in mortality, morbidity or readmissions not related to repeat ACS.[1 2 4] It is likely that the reduction in patient cost and disease burden was underestimated, as prior studies using ANZACS-QI data have also shown considerable reductions in heart failure.[1] Additionally, DRG data do not capture the management of ACS beyond discharge, including pharmaceutical management. Hence, there is considerable uncertainty around the reduction in costs of ongoing therapy attributed to reductions in ACS admissions over time.[16] Similarly, it was not possible to explore the impact of adherence to ongoing pharmacological treatments following ACS, which is associated with reductions in recurrent ACS and morbidity, and subsequently, reduced costs.[12 14 16] Ultimately, the estimation of admissions costs using DRG data limited the extent to which changes in clinical practice contributed to reductions in admissions costs.[15] Nevertheless, DRG costs are commonly used to reflect hospitalisation costs, as well as in casemix funding.[15] Another limitation is that ICD-10 codes were used to define ACS hospitalisations, angiography, PCIs and CABGs within the national datasets, and there may have been inaccuracy in coding.[1 2] However, a high level of agreement has been demonstrated between national hospitalisation datasets and the ANZACS-QI programme for both ACS diagnoses and coronary procedures.[17]

CONCLUSIONS

The costs of hospitalisations for ACS in New Zealand are considerable, but decreasing over time, despite patient demographic and clinical characteristics remaining stable over time. Further studies are warranted to explore the association between reductions in the cost burden of ACS and improved management of ACS, facilitated through ongoing health systems monitoring and benchmarking through ANZACS-QI.

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Contributors PL had full access to all of the data in this study and takes responsibility for the integrity of the data and accuracy of the data analysis. PL, AK, YJ, EZ and DL were responsible for the study concept and design, the acquisition, analysis and interpretation of data and drafting of the manuscript. All authors provided critical revision of the manuscript for important intellectual content. PL is the guarantor of this paper.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

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