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ORIGINAL RESEARCH

Evolving Trends in Carotid Endarterectomy and Stenting in Australia: A 15-Year Analysis in the Post-CREST Era

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Background: Stroke remains a leading cause of mortality in Australia. Over the past three decades, carotid endarterectomy (CEA) has been the gold standard for stroke prevention in patients with symptomatic high-grade carotid stenosis. Carotid artery stenting (CAS) has emerged as a minimally invasive alternative, particularly for high-risk surgical candidates. This study aims to evaluate national trends in CEA and CAS in Australia over a 15-year period, reflecting evolving practices in the post-CREST era.

Methods: A population-level retrospective trend analysis was conducted using Australian Institute of Health and Welfare Procedures Data Cubes to identify CEA and CAS procedures performed between 2009 and 2023. Population-adjusted incidence rates were calculated using data from the Australian Bureau of Statistics. Simple linear regression analysis was used to assess changes in procedure rates overtime.

Results: A total of 41,845 carotid interventions were performed during the study period, with males accounting for 70.47% of procedures. CEA comprised the majority of interventions (78.86%), while CAS accounted for 21.14%. The population-adjusted incidence of CEA declined significantly by 0.346 procedures per 100,000 people annually ($p < 0.001$), consistent across all age groups and genders. Conversely, CAS incidence increased modestly by 0.061 procedures per 100,000 people annually ($p = 0.044$), with the most significant rise observed in patients aged 60–69 years.

Conclusion: This study highlights significant changes in carotid revascularisation practices in Australia, with a marked decline in revascularisation procedures overall, primarily driven by a significant decline in CEA overtime. CAS showed a modest but significant increase over the study period. These findings align with global trends, reflecting the impact of improved medical management, shifting clinical guidelines, and the growing role of minimally invasive techniques. Future research should investigate the clinical outcomes and indications associated with these trends to optimise patient selection and refine management strategies for carotid artery disease.

Keywords: carotid endarterectomy, carotid artery stenting, stroke prevention, australian trends

Introduction

Stroke is a leading cause of mortality in Australia, accounting for 4.4% of all deaths in 2022.[1] Carotid artery stenosis is a significant contributor to ischaemic stroke, responsible for approximately 20% of acute ischaemic stroke cases.[2]

Over the past three decades, interventions for stroke prevention have undergone significant evolution. Several landmark trials have shaped the current practice of carotid interventions. In the 1990s, randomised controlled trials such as North American Symptomatic Carotid Endarterectomy Trial (NASCET) and European Carotid Surgery Trial (ECST) established carotid endarterectomy (CEA) as the gold standard for stroke prevention in patients with symptomatic, high grade carotid stenosis.[3,4] Additionally, the Asymptomatic Carotid Atherosclerosis Study (ACAS) demonstrated the benefit of CEA over medical therapy in selected patients with asymptomatic carotid stenosis.[5]

In recent years, carotid artery stenting (CAS) has emerged as an alternative to CEA for the management of carotid artery stenosis. The Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE)

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trial found that CAS demonstrated similar long term stroke prevention outcomes with fewer peri-operative cardiac complications compared to CEA.[6] This validated CAS as a safe and effective option in high-risk surgical candidates, facilitating its adoption in clinical practice. This was followed by the Carotid Revascularisation Endarterectomy vs Stenting Trial (CREST), which found no significant difference between CAS and CEA in the composite outcomes of stroke, myocardial infarction (MI), or death.[7] However, subgroup analyses highlighted a higher peri-procedural stroke risk with CAS and a higher peri-procedural MI risk with CEA. Transcarotid artery revascularisation (TCAR) – a newer hybrid technique combining direct carotid access with flow reversal for embolic protection, has also been introduced as a potential treatment option, though it had not been implemented in Australia during the study period to the best of our knowledge.

Alongside these procedural developments, improvements in medical therapy, including the widespread use of statins, antiplatelet agents, and aggressive risk factor modification have also influenced revascularisation rates by reducing the overall burden of atherosclerotic disease.[8,9]

Management strategies for carotid artery stenosis differ substantially between symptomatic and asymptomatic disease. In patients with symptomatic carotid stenosis, carotid revascularisation has been shown to significantly reduce the risk of recurrent stroke and remains an important component of secondary stroke prevention.[3,4] In contrast, the benefit of revascularisation in asymptomatic carotid stenosis is more nuanced and has evolved with improvements in contemporary medical therapy and risk factor modification.[10] These differences are important when interpreting population-level trends in carotid revascularisation over time.

We hypothesised that CAS utilisation has increased over time, coinciding with a decline in the rates of CEA. International trends have certainly demonstrated an increasing utilisation of CAS, often accompanied by a decline in CEA rates.[11] One Australian study from 2017, that examined outcomes and trends in carotid revascularisation found a steady decline in both CEA and CAS over an 8-year period.[12] The aim of this study was to evaluate national trends in CEA and CAS over a more extensive 15-year period, providing a broader perspective on these evolving practices in the post-CREST era.

Methods

Australian Institute of Health and Welfare (AIHW) Procedures Data Cubes from the National Hospitals Data Collection were used to extract data relating to carotid endarterectomy (MBS code 33500) and carotid artery stenting (MBS code 35307) procedures. No additional inclusion or exclusion criteria were required, as no other procedures are captured under these MBS codes.

The AIHW National Hospital Data Collection contains publicly available, aggregated data with no identifiable patient information. The establishment of AIHW data collections has been approved by the AIHW Ethics Committee. In accordance with the *National Statement on Ethical Conduct in Human Research (NHMRC, 2023), Section 5.1.17*, research using publicly available, non-identifiable data is exempt from additional Human Research Ethics Committee review; therefore, separate institutional ethics approval was not required for this study.

The AIHW National Hospital Morbidity Database captures admitted patient care episodes from all public and private hospitals in Australia. Procedures are coded using the Australian Classification of Health Interventions (ACHI) within the ICD-10-AM framework and are subject to standardised national coding practices and routine data quality assurance processes.

Statistical Analysis

Descriptive statistics were used to present the incidence rates of CEA and CAS, broken down by age and sex. To determine population-adjusted incidence, rates were calculated per 100,000 individuals using annual data from the Australian Bureau of Statistics (ABS) for each demographic group. Simple linear regression analysis was employed to assess changes in the population-adjusted incidence of these procedures over time, with year as the independent variable. This approach was selected as the dataset consisted of annual aggregated observations without seasonal or high-frequency variation; therefore, more complex time-series methods (eg. ARIMA) were not applicable. Model assumptions of linearity, normality, homoscedasticity, and influential outliers were assessed using residual plots, Q–Q plots, and Cook's distance. All assumptions were adequately met, confirming the suitability of the linear model for these data.

Results were expressed as the annual change per 100,000 individuals (β), accompanied by 95% confidence intervals. Statistical significance was defined as a p-value less than 0.05. Data analysis was conducted using IBM SPSS Statistics (version 29.0.2.0),[13] while figures were created using GraphPad Prism 8 (Dotmatics, Boston, MA, USA).

Results

There were 41,845 carotid interventions performed in Australia between 2009 and 2023 (Table 1). The majority of these procedures (70.47%) were conducted in males, with the largest proportion (39.65%) occurring in individuals aged 70–79 years (Table 1). Of the interventions, CEA accounted for the majority (78.86%), while CAS comprised the remaining 21.14% (Table 1).

Since 2009, there has been a significant decline in overall carotid interventions, primarily driven by a marked reduction in CEA procedures (Table 1 and Figure 1). The total number of carotid revascularisation procedures declined from 2901 in 2009 to 2554 in 2023, representing an overall reduction of approximately 12% over the study period (data not shown). There was an overall reduction of 28 carotid revascularisation procedures per year (Table 1).

In 2009, 2,376 CEAs were performed, accounting for 81.9% of all carotid interventions. By 2023, this number had decreased to 1,783, representing only 69.8% of carotid interventions and corresponding to an overall reduction in CEAs of approximately 25% over the study period (data not shown). The population-adjusted incidence of CEA declined significantly by 0.346 procedures per 100,000 people annually (Table 2). This downward trend was consistent across all age groups and both genders throughout the study period (Table 2, Figures 2 and 3). The unadjusted incidence indicates a reduction of 47 CEA procedures per year during the study period (Table 1).

In contrast, the incidence of CAS increased modestly but significantly, with an annual rise of 0.061 procedures per 100,000 people (Table 2). Patients aged 60–69 exhibited the most notable increase, with an annual growth of 0.118 CAS procedures per 100,000 people. In contrast, older age groups demonstrated no significant change over the study period, including patients aged 70–79 years ($\beta = -0.021$, $p = 0.845$) (Table 2). No statistically significant trends were observed in other age groups or among genders (Table 2, Figures 2 and 3). The unadjusted incidence indicates an increase of 19.7 CAS procedures per year during the study period (Table 1).

Table 1 Cumulative Population Characteristics and Simple Linear Regression of Incidence with Year as the Independent Variable

	N	%	β	SE	95% CI	p-Value
Sex						
Male	29,488	70.47	−16.875	3.608	−24.67 to −9.08	<0.001
Female	12,357	29.53	−11.189	2.42	−16.42 to −5.96	<0.001
Age (years)						
20–59	4928	11.78	−2.225	1.535	−5.54 to 1.09	0.171
60–69	11,331	27.08	−14.682	2.127	−19.28 to −10.09	<0.001
70–79	16,590	39.65	−3.989	3.184	−10.87 to 2.89	0.232
>80	8996	21.5	−7.168	1.547	−10.51 to −3.83	<0.001
CEA	33,000	78.86	−47.768	4.607	−57.72 to −37.82	<0.001
CAS	8845	21.14	19.704	4.398	10.20 to 29.21	<0.001
Total	41,845	100	−28.064	5.282	−39.48 to −16.65	<0.001

Notes: β, regression coefficient representing the change in incidence over time.
Abbreviations: SE, standard error; CI, confidence interval.

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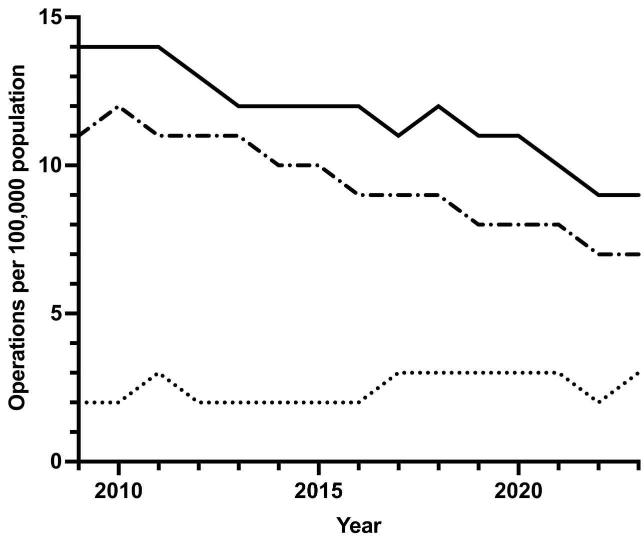

Figure 1 Incidence of CEA and CAS per 100,000 population from 2009 to 2023. The solid line represents the total carotid revascularisations (CEA and CAS combined), the dash-dot line represents CEA, and the dotted line represents CAS.

Discussion

The aim of this study was to describe national trends in carotid revascularisation in the post CREST era. We found a steady decline in the overall incidence of carotid revascularisation procedures over the 15-year study period. This was primarily driven by a significant decline in the incidence of CEA despite a modest but significant increase in the incidence of CAS.

These findings reflect broader global trends in carotid revascularisation. Cole et al in 2019 reported a similar significant decline in carotid revascularisation procedures in the US, driven predominantly by a marked reduction in CEA rates.[14] Notably, CAS rates remained relatively stable over their 5-year study period. Johal et al (2019) from the United Kingdom (UK) similarly documented an overall decline in CEA procedures among both symptomatic and asymptomatic patients.[15] In both studies, CAS rates remained relatively stable, indicating that the decline in CEA was not offset by a corresponding increase in CAS procedures.[15]

In contrast, Murtijaja et al evaluated trends in CEA and CAS in Australia over an 8-year period (2010–2017) and reported declining trends in both procedures.[12] The findings from our study, which demonstrated an increasing trend in

Table 2 Simple Linear Regression of Population Adjusted Incidence of CEA and CAS Procedures Performed From 2009 to 2023 by Age and Sex

	CEA				CAS			
	β	SE	95% CI	p	β	SE	95% CI	p
Total	−0.346	0.023	−0.397 to −0.296	<0.001	0.061	0.027	0.002 to 0.120	0.044
Male	−0.429	0.045	−0.527 to −0.330	<0.001	0.054	0.034	−0.19 to 0.126	0.136
Female	−0.218	0.025	−0.272 to −0.163	<0.001	0.046	0.027	−0.013 to 0.106	0.114
Age 20 to 59	−0.093	0.018	−0.132 to −0.054	<0.001	0	0	0	1
Age 60 to 69	−1.079	0.073	−1.235 to −0.922	<0.001	0.118	0.040	0.031 to 0.204	0.011
Age 70 to 79	−2.236	0.149	−2.558 to −1.914	<0.001	−0.21	0.108	−0.254 to 0.211	0.845
Age over 80	−0.754	0.224	−1.237 to −0.271	0.005	0.154	0.135	−0.138 to 0.445	0.276

Notes: β represents the annual change per 100,000 population.
Abbreviations: SE, standard error; CI, confidence interval.

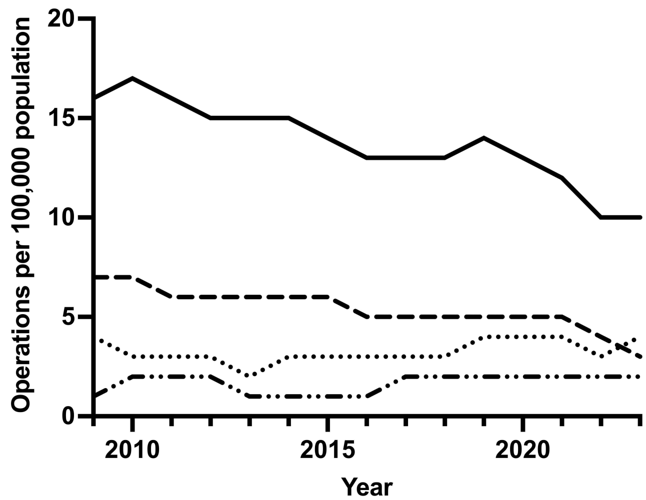

Figure 2 Incidence of CEA and CAS in males and females per 100,000 population from 2009 to 2023. The solid line represents CEA in males, the dashed line represents CEA in females, the dotted line represents CAS in males, and the dash–dot line represents CAS in females.

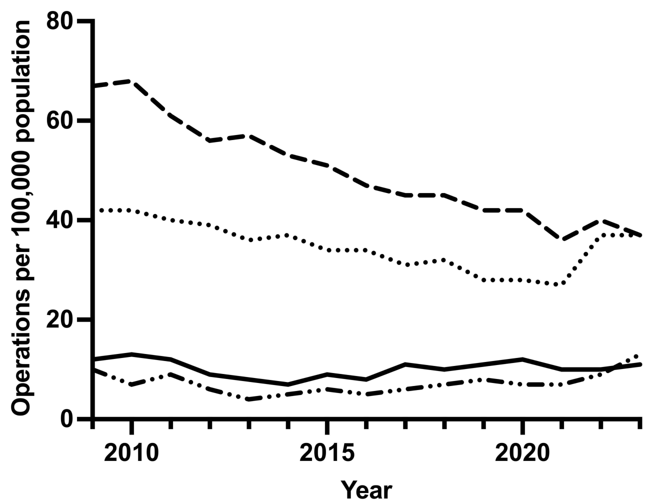

Figure 3 Incidence of CEA and CAS by age group per 100,000 population from 2009 to 2023. The dashed line represents CEA in patients aged 70–79 years, the dotted line represents CEA in patients aged ≥80 years, the solid line represents CAS in patients aged 70–79 years, and the dash–dot line represents CAS in patients aged ≥80 years.

CAS over the longer, 15-year timeframe, differ from this observation. This discrepancy however, may be attributed to differences in study design, as our analysis included all carotid revascularisation procedures performed by both vascular surgeons and interventionalists, while Murtijaja et al focused exclusively on procedures performed by vascular surgeons and their outcomes. By extending the observation period to 15 years and including data from all operators (including interventionalists), this study not only confirms the global trend of declining CEA but also reveals a distinct increasing trend for CAS in Australia over the longer term, differing from earlier national studies, which may reflect the continued evolution of technology and clinical practice in recent years.

These national procedural trends provide valuable insights into how evidence from landmark trials such as CREST is translated into real-world clinical practice across different healthcare systems. Population-level analyses from different countries therefore contribute important comparative data to the international literature, helping to contextualise how evolving clinical guidelines, technological advancements, and healthcare structures influence the adoption of carotid revascularisation strategies.

The decline in CEA rates in Australia over the 15-year study period may be attributed to several factors. First, primary prevention of stroke has improved through aggressive medical management and risk factor modification over the past three decades which may have reduced the number of patients presenting with symptomatic carotid artery stenosis or asymptomatic patients with high grade carotid artery stenosis. Indeed, several studies have found a decline in strokes related to large artery atherosclerosis over time.[16–18] Secondly, recent studies, such as Stent Protected Angioplasty in Asymptomatic Carotid Artery Stenosis Trial (SPACE-2), have demonstrated the efficacy of optimal medical therapy in reducing stroke risk, further challenging the traditional dominance of CEA in asymptomatic patients.[19] More recent evidence has reinforced this shift, with a contemporary meta-analysis and an expert review demonstrating that modern best medical therapy can achieve very low rates of stroke in patients with asymptomatic carotid stenosis, supporting a more selective approach to revascularisation in lower-risk patients.[10,20] Consistent with this, Cole et al found an increase in symptomatic patients undergoing both CEA and CAS, despite an overall decline in the rates of these procedures overtime suggesting that the observed overall decline in CEA may be at least in part attributed to fewer interventions performed on asymptomatic patients[14] Johal et al also found that the observed decline in CEA was more pronounced in asymptomatic patients[15] Thus, the shifting clinical guidelines around management of asymptomatic carotid artery stenosis may have influenced practice patterns leading to a reduction CEA in asymptomatic patients. Indeed, recommendations from the American Heart Association (AHA) and European Society for Vascular Surgery (ESVS) emphasise a more conservative approach to managing asymptomatic carotid stenosis, reserving revascularisation for selected high-risk patients. This paradigm shift may explain the uniform decline in CEA across all age groups and genders observed in our study.

The modest increase in CAS utilisation may reflect its growing role as a minimally invasive alternative, particularly for patients considered high-risk for open surgery. This shift is supported by findings from the CREST trial, which demonstrated comparable long-term outcomes between CAS and CEA in appropriately selected patients. The observed increase in CAS utilisation among individuals aged 60–69 years may further suggest a growing preference for endovascular revascularisation strategies in relatively younger patients with lower operative risk and longer life expectancy. Advances in endovascular technology, together with increasing clinician familiarity with CAS, may also have contributed to the gradual expansion of its use during the study period.[13]

These trends may have implications for vascular surgical training and the maintenance of procedural expertise. Changes in procedural volumes may influence trainee exposure and the development of technical proficiency in carotid revascularisation. The observed decline in CEA procedures may reduce operative experience in open carotid surgery, while the modest increase in CAS highlights the growing importance of endovascular training and infrastructure to support minimally invasive revascularisation approaches. More broadly, these evolving procedural patterns may also influence healthcare resource allocation and workforce planning.

Limitations

This study has several limitations. First, detailed data regarding the indications for CEA and CAS were not available, which limited our ability to perform subgroup analyses, such as distinguishing trends in symptomatic versus asymptomatic patients. Understanding whether the decline in CEA is primarily due to reduced interventions in asymptomatic patients would provide deeper insights. Similarly, data on the clinical indications for the increasing number of CAS procedures would help elucidate whether this trend reflects broader adoption of CAS in high-risk or symptomatic patients. Another limitation in this study is the lack of clinical outcome data. Evaluating outcome data could help determine whether shifts in clinical practice has resulted in better overall health outcomes for patients. Additionally, regional variations in procedural practice across Australian states and territories could not be assessed due to the aggregated nature of the dataset, which may mask local differences in clinical practice and service delivery. Finally, as with all administrative datasets, there is potential for miscoding or classification errors in procedure coding. However, given the large sample size and the national scope of the AIHW dataset, such errors are expected to have minimal impact on the overall trends observed.

Conclusion

This study highlights significant national trends in carotid revascularisation in Australia over the past 15 years, marked by a steady decline in CEA rates and a modest increase in CAS. These findings align with international trends and reflect the impact of evolving clinical guidelines, advances in medical management, and the growing role of minimally invasive endovascular techniques.

The declining reliance on CEA suggests improved stroke prevention strategies and a shift toward more conservative management of asymptomatic carotid stenosis. The modest rise in CAS highlights its emerging role in modern practice, particularly for high-risk surgical candidates.

It should be noted that the present study describes procedural utilisation trends and does not assess clinical outcomes following carotid revascularisation. Future research should examine clinical indications, outcomes, and cost-effectiveness to better inform patient selection strategies in carotid revascularisation, health policy, and resource allocation. Understanding these evolving procedural trends may help guide future service planning, training requirements, and resource allocation within vascular surgery services.

Disclosure

The authors report no conflict of interests in this work.

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