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Research Article

Trend Analysis of Lower Limb Amputation and Revascularization Procedures in Australia: 2007-2017

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Abstract

Background: Patients with peripheral arterial disease may be asymptomatic or present with symptoms ranging from intermittent claudication to critical leg ischaemia, which may lead to lower limb amputation. This study aims to investigate the relationship between revascularization procedures and amputations rates in Australia.

Methods: This was a retrospective observational study. Medicare claims via procedure item numbers listed in the Medical Benefits Schedule and available on the Medicare Statistic website were accessed. Population data were extracted from the Australian Bureau of Statistics' database. Data were expressed in per 100 000 population to better reflect the change in population over time, i.e. population based. Regression analysis was used to analyse the trend and correlate variables.

Results: From 2007 to 2017, across all states, there was a 36.98% decline in below knee amputations ($p<0.05$), 39.52% decline in above-knee amputations ($p<0.05$) and a 43.49% rise in revascularization procedures ($p<0.05$).

Conclusion: The increase in revascularisation procedures has been matched by a reduction in major lower limb amputations in Australia. While it is debatable which revascularization procedures are most effective in preventing amputations, the importance of such preventative measures has likely been underestimated.

INTRODUCTION

Peripheral arterial disease (PAD) refers to a manifestation of systemic atherosclerosis. Whilst many patients may be asymptomatic, symptomatic patients can present with benign intermittent claudication or more sinister limb threatening ischaemia. Multiple national and international guidelines reinforce that treatment of PAD requires a comprehensive treatment programme including lifestyle modification, pharmacotherapy and surgical intervention (revascularisation) with the aims of decreasing the risk of cardiovascular events and death, improving exercise ability and quality of life whilst decreasing progression to limb loss [1-3].

In Australia, the most common reason cited for lower limb amputation is calcified arteries in the limb resulting in inadequate blood flow [4] as a result of various co-morbidities such as diabetes, hypertension, hypercholesterolemia, smoking and kidney failure. As amputations result in serious implications on a person's daily activities, vascular surgeons reserve amputations as a last resort and offer patients restoration of physical function by restoring blood flow through revascularization procedures [5,6].

While data is available describing the incidence rate of lower limb amputations and revascularization procedures at a national and state level, there are no studies that describe and analyse any trend between the two procedures [7-9].

We aim to analyse the trend of amputation and revascularization in Australia between 2007 and 2017.

MATERIAL AND METHODS

Study Design

This was a retrospective study with data on major lower limb amputations and revascularisation procedures performed between the calendar year 2007 and 2017. Given that data was obtained from publicly accessible sources, ethics approval was not sought.

Data Source

In Australia, the Medicare Benefits Schedule (MBS) lists by item number services which can be provided my medical practitioners. The principal function of itemising these services is to enable providers to claim a fee for the service. The frequency of claims for specific item numbers can be obtained by year and state from the Medicare statistics website. Amputation and revascularization data were retrieved from the Medicare Australia Statistics website at both national and state level. All 8 states were included, i.e. New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), Western Australia (WA), Tasmania (TAS), Australian Capital Territory (ACT) and Northern Territory (NT).

For amputation procedures, we used the MBS item number 44367 (through the thigh, at knee or below knee amputation). Item number 21232 is the specific item number for initiation of management of anaesthesia for above knee amputations. There is no specific item number for initiation of management of anaesthesia for below knee amputation. Thus, by subtracting the number of 21232 from 44367 we would have the number of through and below knee amputations.

For revascularization procedures, we looked at 22 surgical item numbers as listed in Table 1.

Population data were retrieved from the Australian Demographics Statistics published by the Australian Bureau of Statistics (ABS).

As this study utilised data available online and no personal information from patients were involved, no approval was required from the ethics board.

Data Analysis

Data collected were analysed, and sample characteristics and trends of amputations and revascularization procedure over the years were established. Data were expressed in per 100 000 population to better reflect the change in population over time, i.e. population based. Regression line was established to help

Table 1: MBS Surgical item number.

MBS item number	Surgical item
Open Vascular Procedures	
32708	AORTIC BYPASS FOR OCCLUSIVE DISEASE using a straight non-bifurcated graft
32710	AORTIC BYPASS FOR OCCLUSIVE DISEASE using a bifurcated graft with 1 or both anastomoses to the iliac arteries)
32712	ILIO-FEMORAL BYPASS GRAFTING
32715	AXILLARY OR SUBCLAVIAN TO FEMORAL BYPASS GRAFTING to 1 or both femoral arteries
32718	FEMORO-FEMORAL OR ILIO-FEMORAL CROSS-OVER BYPASS GRAFTING
32739	FEMORAL ARTERY BYPASS GRAvFTING using vein, including harvesting of vein (when it is the ipsilateral long saphenous vein) with above knee anastomosis
32745	FEMORAL ARTERY BYPASS GRAFTING USING VEIN, including harvesting of vein (when it is the ipsilateral long saphenous vein) with distal anastomosis to tibia-peroneal trunk or tibial or peroneal artery
32748	FEMORAL ARTERY BYPASS GRAFTING USING VEIN, including harvesting of vein (when it is the ipsilateral long saphenous vein) with distal anastomosis within 5cms of the ankle joint
32751	FEMORAL ARTERY BYPASS GRAFTING USING SYNTHETIC GRAFT, with lower anastomosis above or below the knee
32754	FEMORAL ARTERY BYPASS GRAFTING, using a composite graft (synthetic material and vein) with lower anastomosis above or below the knee, including use of a cuff or sleeve of vein at 1 or both anastomoses
32757	FFEMORAL ARTERY SEQUENTIAL BYPASS GRAFTING, (using a vein or synthetic material) where an additional anastomosis is made to separately revascularize more than 1 artery - each additional artery revascularized beyond a femoral bypass
33509	AORTIC ENDARTERECTOMY, including closure by suture, not being a service associated with another procedure on the aorta
33512	AORTO-ILIAC ENDARTERECTOMY (1 or both iliac arteries), including closure by suture not being a service associated with a service to which item 33515 applies
33515	AORTO-FEMORAL ENDARTERECTOMY (1 or both femoral arteries) or bilateral ilio-femoral endarterectomy, including closure by suture, not being a service associated with a service to which item 33512 applies
33518	ILIAC ENDARTERECTOMY, including closure by suture, not being a service associated with another procedure on the iliac artery
33521	ILIO-FEMORAL ENDARTERECTOMY (1 side), including closure by suture
33539	ARTERY OF EXTREMITIES, endarterectomy of, including closure by suture
33542	EXTENDED DEEP FEMORAL ENDARTERECTOMY where the endarterectomy is at least 7cms long
Endovascular Procedures	
35300	TRANSLUMINAL BALLOON ANGIOPLASTY of 1 peripheral artery or vein of 1 limb
35303	TRANSLUMINAL BALLOON ANGIOPLASTY of aortic arch branches, aortic visceral branches, or more than 1 peripheral artery or vein of 1 limb, percutaneous or by open exposure, excluding associated radiological services or preparation, and excluding aftercare
35306	TRANSLUMINAL STENT INSERTION, 1 or more stents, including associated balloon dilatation for 1 peripheral artery or vein of 1 limb, percutaneous or by open exposure, excluding associated radiological services or preparation, and excluding aftercare
35309	TRANSLUMINAL STENT INSERTION, 1 or more stents, including associated balloon dilatation for visceral arteries or veins, or more than 1 peripheral artery or vein of 1 limb, percutaneous or by open exposure, excluding associated radiological services or preparation, and excluding aftercare

analyse the trend and correlate variables. Quantitative data were further visually displayed in figures and tables.

RESULTS

National sample characteristics

The national sample characteristics are summarized in Table 2. There were a total of 3 894 claims for below and through knee amputations (BKA), 1,327 for above knee amputations (AKA) and 43,759 for revascularization procedures (RP) performed in Australia from 2007 - 2017. Of those undergoing a BKA, 65.69% were male 74.88% were aged 65 years or older. Of those undergoing an AKA, 62.25% were male and 82.82% were aged 65 years or older. For RP, 62.87% were male and 77.12% were aged 65 years or older.

National population-based amputation and revascularization rate

The breakdown of the national population-based amputation and RP is seen in Table 3. From 2007 to 2017, we observe a change in the population-based BKA from 2.08 amputations per 100 000 population to 1.31 amputations per 100 000 population (-36.98%; $p < .05$). In the same period, the population-based AKA rate changed from 0.77 amputations per 100 000 population to 0.47 amputations per 100 000 population (-39.52%; $p < .05$). For the population-based lower limb amputations (LLA), it changed from 2.86 per 100 000 population to 1.78 per 100 000 population (-37.67%; $p = .05$).

For the population-based RP rate, we observed an increase from 44.56 procedures per 100 000 population to 63.94 procedures per 100 000 population (+43.49%; $p < .05$). For population-based open RP rate, we observed a decrease from 8.18 procedures per 100 000 population to 6.02 procedures per 100 000 population (-26.39%; $p < .05$) and for population-based endovascular RP rate, there is an increase from 36.39 procedures per 100 000 population to 57.92 procedures per 100 000 population (+59.19%; $p < .05$).

Table 2: National sample characteristics.

Below Knee Amputations	**n**	**%**
Total	3 894	100.00
Male	2 558	65.69
Age ≥ 65	2 916	34.31
Above Knee Amputations	**n**	**%**
Total	1 327	100.00
Male	826	62.25
Age ≥ 65	501	37.75
Total Lower Limb Amputations	**n**	**%**
Total	2 567	100.00
Male	1 732	67.47
Age ≥ 65	2 415	94.08
Revascularization Procedures	**n**	**%**
Total	139 587	100.00
Male	87 753	62.87
Age ≥ 65	107 653	77.12

Table 3: Breakdown of procedures from 2007 - 2017.

		Total number			Per 100,000 population				Per 100,000 population
Year	Population*	BKA	AKA	Total number of leg amputation	BKA	AKA	Number of lower limb amputation	Number of revascularizations procedures	Number of revascularizations per 100,000
2007	21 181 000	441	164	277	2.08	0.77	1.31	9 439	44.56
2008	21 644 000	369	120	249	1.70	0.55	1.15	10 209	47.17
2009	22 155 000	408	136	272	1.84	0.61	1.23	11 077	50.00
2010	22 477 400	326	109	217	1.45	0.48	0.97	11 622	51.71
2011	22 485 300	318	131	187	1.41	0.58	0.83	12 015	53.43
2012	22 906 400	349	129	220	1.52	0.56	0.96	12 397	54.12
2013	23 130 900	344	118	226	1.49	0.51	0.98	13 357	57.75
2014	23 625 600	345	89	256	1.46	0.38	1.08	13 466	57.00
2015	23 940 300	354	103	251	1.48	0.43	1.05	13 970	58.35
2016	24 385 600	315	112	203	1.29	0.46	0.83	14 938	61.26
2017	24 770 700	325	116	209	1.31	0.47	0.84	15 839	63.94

The trendlines for amputations and revascularization procedures are shown in Figure 1.

Figure 2 depicts the regression line plotted with the population-based revascularization rate against population based below knee amputation rate which shows an inverse relationship between the two ($p < .05$; $r^2 = .74$) as well as the population-based revascularization rate against population based above knee amputation rate ($p < .05$; $r^2 = .58$); the regression line plotted with the population-based revascularization rate against population based total number of lower limb amputation rate, which shows an inverse relationship between the two ($p < .05$; $r^2 = .57$).

Sample characteristics, by state

In general, proportion of patients who are male, and had BKA ranged from 62.59% (VIC) to 80.00% (NT); had AKA ranged from 55.98% (VIC) to 100% (ACT & NT) and had revascularization procedures ranged from 56.95% (NT) to 67.07% (WA).

Proportion of patients who are ≥ 65 years old and had BKA ranged from 50.00% (NT) to 80.60% (VIC); had AKA ranged from 50% (NT) to 86.41% (QLD); and had RP ranged from 41.72% (NT) to 79.00% (VIC).

Population-based amputation and revascularization rates, by state

The sample characteristics of individual states are summarized in Table 4.

In general, proportion of patients who are male, and had BKB ranged from 62.59% (VIC) to 80.00% (NT); had AKA ranged from 55.98% (VIC) to 100% (ACT & NT) and had RP ranged from 57.02% (NT) to 66.15% (WA).

Proportion of patients who are ≥ 65 years old and had BKA ranged from 50.00% (NT) to 80.60% (VIC); had AKA ranged from 50% (NT) to 86.41% (QLD); and had RP ranged from 44.74% (NT) to 79.64% (VIC).

Figure 3 shows the revascularisation rates per 100 000 population by each state.

Figure 1 Trendline of various procedures per 100000 population over the period 2007 - 2017.

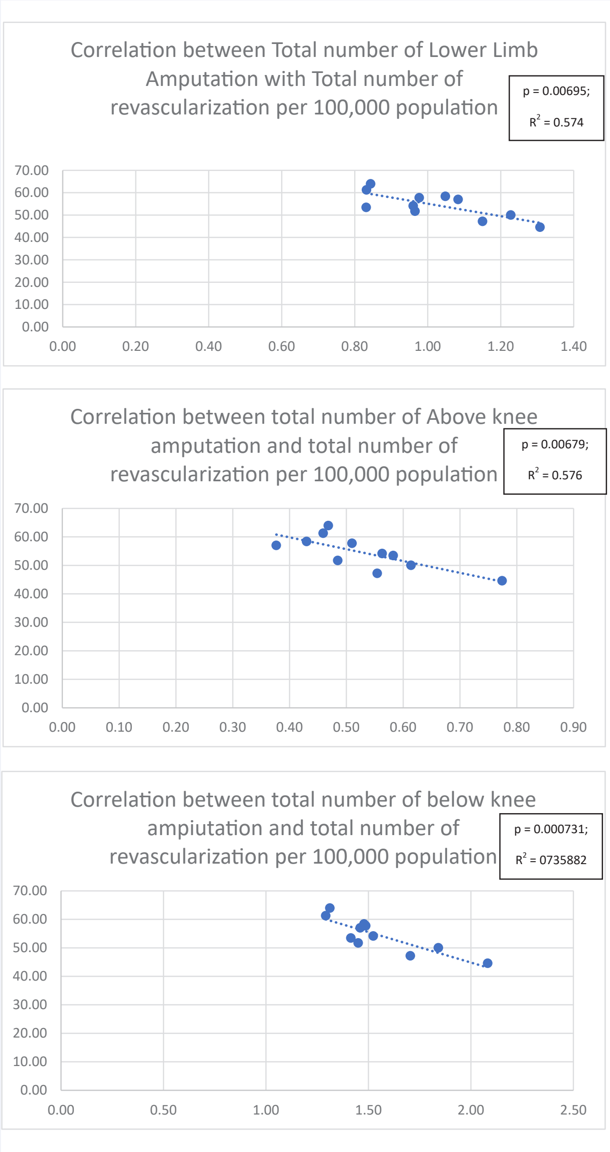

Figure 2 Regression line of various amputation procedures against the total number of revascularizations per 100,000 population.

DISCUSSION

Interpretation

This study analyses the trend of the treatment for PAD in Australia over 11-year period from 2007 to 2017. We observed an inverse relationship between the amputation rate and the revascularization procedures. The BKA rate per 100 000 population has decreased by 7.09% while the AKA rate per 100 000 population has decreased by 18.97% over the last 11 years. We also noticed a significant decrease in total number of LLA per 100 000 population - a drop of 37.67%. During the same time-period, there has been an increase of 43.49% in the use of revascularisation procedures. This relationship is statically strong with a moderate to high r^2 value. We have shown that patients who receive revascularisation procedures are more likely to be male and above the age of 65, thus reinforcing strong risk factors for atherosclerosis. This is coherent with a study done in 2018 [10], attributing sex and age as strong risk factors of PAD [11,12]. For revascularization procedure, we also observe a fall in open procedures and a rise in endovascular procedures. Some studies have suggested that endovascular procedures are likely to confer improved amputation-free survival over long term when compared to open procedures [13], and incur a lower healthcare cost [14]. Several other studies have reported on the pattern of treatment for peripheral artery disease. Tunis et al. studied the pattern of treatment of PAD in Maryland from 1979 to 1989 and found that while there was an increase in RP rate, there was no significant changes in the rate of amputation [15]. Other studies performed in a similar time-periods also demonstrated an increasing trend in the usage of endovascular and open endovascular revascularization procedures but variable amputation rates [16-21].

Nowygrod et al. found that from 1998 to 2003, there was a substantial decrease in the national amputation rate and a sharp

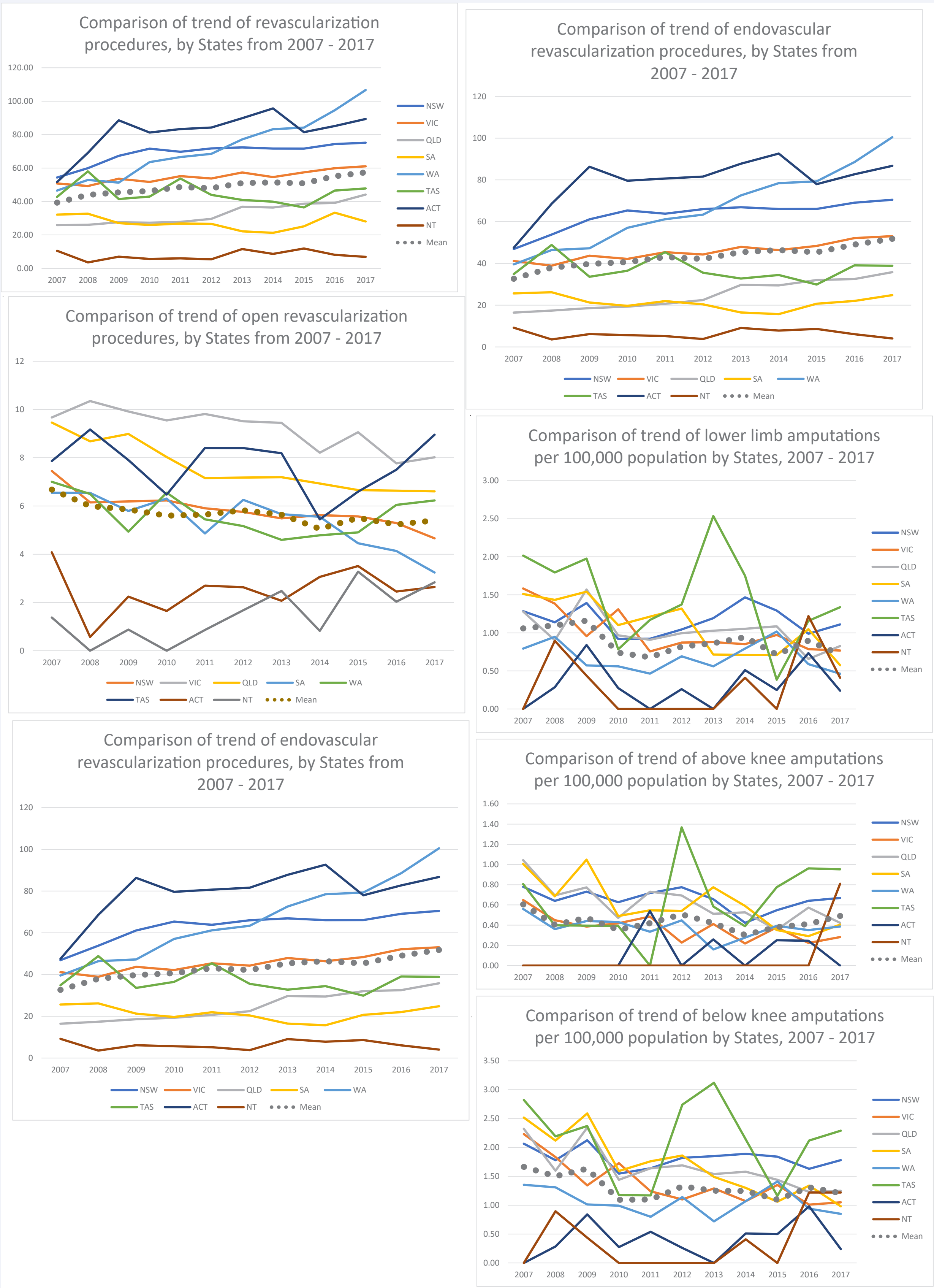

Figure 2 Revascularizations, below knee amputations, above knee amputations and lower limb amputations per 100,000 population, by states, from 2007 to 2017.

Table 4: Sample characteristics, by state and procedures.

Below Knee Amputations	NSW, n (%)	VIC, n (%)	QLD, n (%)	SA, n (%)	WA, n (%)	TAS, n (%)	ACT, n (%)	NT, n (%)
Total	1 473	866	824	307	278	119	17	10
Male	986 (66.94)	542 (62.59)	536 (65.05)	195 (63.52)	193 (69.42)	86 (72.27)	12 (70.59)	8 (80.00)
Age ≥ 65	1 107 (75.15)	698 (80.60)	621 (75.36)	223 (72.64)	112 (59.71)	85 (71.43)	11 (64.71)	5 (50.00)
Above Knee Amputations								
Total	521	234	309	111	99	36	5	2
Male	338 (63.65)	131 (55.98)	196 (63.43)	67 (60.36)	65 (65.55)	22 (61.11)	5 (100)	2 (100)
Age ≥ 65	437 (82.30)	202 (86.32)	267 (86.41)	89 (80.18)	70 (70.71)	29 (80.56)	4 (80.00)	1 (50.00)
Revascularization Procedures								
Total	14 623	13 103	6 563	2 532	5 007	965	851	151
Male	9 379 (64.14)	8 189 (62.50)	4 221 (64.32)	1 584 (62.56)	3 358 (6707)	641 (66.42)	510 (59.93)	86 (56.95)
Age ≥ 65	10 977 (75.07)	10 351 (79.00)	4 689 (71.45)	1 981 (78.24)	3 894 (77.77)	745 (77.20)	520 (61.10)	63 (41.72)

increase in lower limb revascularization procedures [22]. This was further complemented by Rowe et al. who found that there is a significant increase in the use of endovascular procedures with a corresponding decrease in major amputation rates from 1996 to 2005 [23]. As postulated by Rowe et al., the decrease in amputation rate as observed by Nowygrod et al. and Rowe et al. and ourselves may associate with the time period where the benefits of revascularization procedures positively impacted the outcome of patients with PAD and is further fuelled by the rapid improvement in endovascular technology [23]. Despite the general trend of rising revascularization procedures across a national level, when we take a closer look at state levels, it is not hard to find that the trend of revascularization procedures has declined over the years with the exception of SA, QLD, TAS and NT. Conversely, while the general trend of decline in lower limb amputations was observed across the national level, we observe a rising trend for NT and ACT. Dillion et al. also conducted a similar study in regards to the geographic variation of the incidence of LLA in Australia from 2007 - 2012 and found that while the rates are similar across various states, it was higher in NT [24]. Goodney et al. suggested that for areas with poor healthcare access, patients with peripheral arterial disease often present late, resulting in irreversible damage [25]. Interestingly, while NT has been reported to have a disadvantageous local government area given its rural and remote nature, ACT has been reported to have an be an advantageous local government area [26]. There are likely to be other underlying factors that affect the rate of amputation procedures-patient characteristics, ethnicity, co-morbidities and social-economical statuses, which are not examined in this study [27,28].

LIMITATION

Given the observational and retrospective nature of this study, the study findings do not imply causation, and we recognise that our study does not present any direct causative experimental evidence to explain the decrease in amputation rate but correlation. The data presented here are based on claims data and this might account for an under representation of procedures performed.

Our data is also not able to identify the clinical indications for procedures done and hence not able to explain the variation in incidence rate across various states.

Be that as it may, it is evident that with the increase in utilisation of revascularization procedures has been associated with lower rates of major amputation [25].

CONCLUSION

While it is debatable which revascularization procedures are most effective in preventing amputations, the importance of such preventative measures has likely been underestimated and should be closely examined. Future works examining relationships between preventative measures, revascularization, and amputation are necessary to help clinician's better outline the best treatment for decreasing the risk for amputation [29,30]. Future works should also aim to analyse and explain the trend of amputation rates due to other factors- patient characteristics, co-morbidities and socio-economical statuses.

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