The Effect of Diabetes Mellitus on Costs and Length of Stay in Patients with Peripheral Arterial Disease Undergoing Vascular Surgery

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WHAT THIS PAPER ADDS

This retrospective study describes the economic and clinical impact of diabetes mellitus as a comorbid variable in patients with peripheral arterial disease undergoing lower limb vascular intervention. Few reports from within Australia present the costs of patients with lower limb pathology requiring procedures such as amputation, open bypass, and angioplasty. This paper reflects the impact of diabetes in two major ways: length of stay in hospital and inpatient costs. Each patient journey was mapped individually and all results crosschecked between paper charts, electronic medical records, coding records, and the vascular audit database, capturing an accurate reflection of inpatient costs. The study adds to existing literature and provides one of only a few reports of vascular surgery costs and length of stay from an Australian perspective.

Objective: To determine the impact of diabetes mellitus (DM) and other comorbidities on length of stay (LOS) and costs in patients with peripheral arterial disease (PAD) admitted to a vascular surgical unit.

Methods: A retrospective study was conducted between January 2011 and July 2012 at a tertiary referral hospital in Sydney. Demographic, laboratory, and operative data were obtained from the Australasian Vascular Audit database and hospital diagnostic-related group (DRG) reports. Patients with confirmed PAD with or without DM requiring hospital admission for a diagnosis of claudication, rest pain, ulcer/gangrene, and infection that required lower limb surgical intervention were included. Associations between LOS, surgical procedure, and DRG were explored.

Results: Five hundred and sixty-eight admissions (492 patients) were identified: 292 admissions with PAD and 276 admissions with PAD in conjunction with DM (PADDM). Mean LOS for patients with PAD was 10 $\pm$ 13.7 days compared with 15 $\pm$ 18.2 days for PADDM ($p < .01$; 95% confidence interval 2.7—8.0). LOS and costs were greatest in patients with PADDM undergoing major amputation (37 $\pm$ 13.7 days; US$42,236; $p < .01$). Analysis of variance indicated that the best predictors of LOS were the presence of DM, bypass surgery, amputation, chronic kidney disease (CKD) stage V, infection, and emergency admission. Over 18 months, the estimated total inpatient costs associated with lower limb intervention for PAD with and without DM amounted to US$7,598,597. People with DM incurred greater inpatient costs, averaging US$1,912 more per episode of admission and a total of US$528,029 over 18 months.

Conclusion: The impact of diabetes as a comorbid condition in patients with PAD is significant, both clinically and economically. Factors that predict increased LOS in patients with PAD are DM, bypass surgery, amputation, CKD stage V, infection, and emergency admission.

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INTRODUCTION

From a health economic perspective, the treatment of peripheral arterial disease (PAD) is costly owing to the need for invasive investigations, hospitalization, and surgery.[1] The prevalence of PAD varies depending on the defining criteria and age of the study population, with the age-standardized prevalence estimated at 2—6% for the general population.[2—5] Managing PAD in combination with comorbidities

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such as diabetes mellitus (DM), hypertension (HTN), and hyperlipidemia complicates the expense.[6] To date, there have been no Australian-based studies that have examined the cost of patients with PAD (with or without DM) who require admission and lower limb surgical procedures in a vascular surgery ward. The available research has predominantly been conducted in North American healthcare systems, which are not directly comparable with Australian healthcare systems. Data from European countries that are more reflective of an Australian perspective, in particular the UK, have provided the closest reflection of the problem at large. In one such study by Currie et al., where the cost of inpatient care in people with peripheral vascular disease and foot complications was reported, diagnostic-related group (DRG) codes were utilized to estimate that, over a 4-year period, admissions cost a total of US$9,743,855.

The aim of this study was to determine the cost and length of stay (LOS) in inpatients with PAD undergoing vascular surgical procedures on a lower limb, with a particular focus from an Australian health perspective and the impact of DM as a comorbid variable.

METHODS

Between 1 January 2011 and 7 July 2012 a retrospective cohort analysis was conducted at a tertiary referral hospital in metropolitan Sydney (Liverpool Hospital, NSW, Australia). Patient demographics were obtained through clinical records and hospital laboratory data, and surgical procedure reports were obtained from the Australian and New Zealand Society for Vascular Surgery's Australasian Vascular Audit database (AVU) for patients with a confirmed diagnosis of PAD with and without DM who underwent any form of vascular surgical intervention,[7] including surgeon-performed angiography. The data inputted into the AVU were collected prospectively; however, data for the study were analyzed retrospectively.

Only patients undergoing lower limb interventions were included in the dataset. All surgical procedures and interventional radiographic procedures during the admission for a patient in this sample were undertaken by vascular surgeons. More than one admission might occur for a patient during the study period, and more than one procedure might be performed on a patient during an admission.

DM was confirmed through medical records using current diagnostic guidelines.[8] Glycemic control was identified using glycosylated hemoglobin (HbA1c) readings. Suboptimal glycemic control was defined as an HbA1c $>7\%$.[9] Chronic kidney disease (CKD) was defined using estimated glomerular filtration guidelines.[10]

Amputations were defined to match the Australian-refined DRG coding system (AR-DRG),[11] with major amputations classified as an amputation for circulatory system disorders except the upper limb and toe, and minor amputations classified as upper limb and toe amputations for circulatory system disorders. No upper limb amputation patients were included in the amputation dataset. The clinical diagnosis of infection was based on the Infectious Disease Society of America guidelines for diabetic foot infections,[12] in addition to laboratory and imaging results.

Calculating the associated inpatient costs utilizing clinical coding

Associated inpatient costs were calculated utilizing AR-DRG codes to assign the matching standard New South Wales public hospital cost weight.[11] All values are shown in US$. For each patient, admission and discharge date, principal diagnosis, principal procedure, and comorbidities were extracted and crosschecked between paper and electronic records. The cost of each patient's episode of admission was individually calculated.

The cost for multiple procedures during a single admission was not calculated. Each admission was costed against the highest surgical procedure undertaken. The chief driver of cost in the AR-DRG system is LOS. Therefore, if a patient

Table 1. Peripheral arterial disease (PAD) and PAD with diabetes mellitus (PADDM) figures are quoted in US$. Inpatient costs are based on Australian-refined DRG coding system mapping of individual patient admissions to provide approximate costs for all patients within an intervention group.

Intervention	PAD cost average per patient mapped individually	PAD (group totals)	PADDM average per patient mapped individually	PADDM (group totals)	Total cost
Minor amputation	21,849[a]	196,649	27,068[a]	1,326,377	**1,523,026**
Major amputation	40,195[a]	643,137	42,236[a]	886,979	**1,538,543**
Open bypass	24,727[a]	667,631	20,099[a]	341,701	**943,788**
PTA	11,072[a]	1,699,266	13,853[a]	1,579,310	**3,306,667**
Debridement	14,209[a]	85,257	18,022[a]	144,187	**229,445**
Average total cost	**22,410**[b]	**3,320,033**	**24,256**[b]	**4,278,555**	**7,598,597**
Additional average cost per patient admission					1,912[c]
Additional treatment costs					528,029[d]

Note. PTA = percutaneous angioplasty.
[a] Average cost per patient.
[b] Total average cost per admission regardless of intervention type.
[c] Average additional cost of PADDM per admission against those with PAD only.
[d] Total average additional costs incurred for all admissions of PADDM then those with PAD only over the 18-month study duration.

underwent angioplasty followed by an amputation, the cost of procedure was based on the highest procedure undertaken (amputation). For cost calculations, patients with private health insurance were treated the same as state-funded patients.

Statistical analysis

Statistical analysis was performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Unpaired *t* tests and chi-square tests with and without risk ratio were employed in testing for differences between the cohorts. Censoring of outliers was performed. Analysis of variance (general linear model [GLM]) was used to explore the association between selected variables. For all comparisons and modeling, the level of significance was set at $p < .05$. Data are given as mean ± SD.

RESULTS

Five hundred and sixty-eight admissions were identified for 492 patients, of which 181 admissions were women (32%) with a mean age 69.0 ± 13.9 years; 387 admissions were men (68%) with a mean age 70.0 ± 12.0 years. The cohort was divided into patients with PAD alone (PAD) or PAD and DM (PADDM). Of the 568 admissions, 292 had PAD alone and 276 had PADDM. There was no significant difference between the age and sex of the patients in the PAD and PADDM groups. The mean LOS for patients with PAD was 10 ± 13.7 days compared with 15 ± 18.2 days for patients with PADDM ($p < .01$; 95% confidence interval [CI] 2.70–8.00).

During the study period, 711 surgical procedures were undertaken for the following procedures: amputation, percutaneous transluminal angioplasty (PTA), open bypass, and wound debridement. Over an 18-month period, the cost of the inpatient stay of the total group was $7,598,597 (Table 1).

HTN

The total number of patients with HTN in this study was high (93%), but there was no difference in prevalence between groups (PAD 46%, PDDM 46%).

Presence of infection

In admissions for infection in patients with PADDM, LOS increased by 5 days compared with admissions for infection in patients with PAD alone (PAD 10 days ± 13.8 days vs. PADDM 15 days ± 18 days; $p < .01$; 95% CI 7.97 to −2.71). Regardless of comorbidity, admissions with infection spent 13.0 ± 16.1 days longer in hospital than those without infection ($p < .01$; 95% CI 9.30–15.60).

Of admissions with PADDM, 225/276 (82%) had infection at or during the time of their admission compared with 102/292 (35%) with PAD. Patients with PADDM were 3.3 times more likely to have an infection than patients with PAD alone (risk ratio [RR] 95% CI 2.50–4.20).

Emergency versus elective (planned) admission

Patients admitted as emergency cases spent 6 days longer in hospital than those admitted as elective cases (PAD 10 days ± 13.1 days vs. PADDM 16 days ± 18.5 days; $p < .01$, 95% CI −9.48 to −4.16).

Amputation

Patients with PADDM were three times more likely to have an amputation compared with those with PAD alone (RR 2.9; 95% CI 1.90–4.30). Hospital LOS and cost were greatest in patients undergoing major amputation (PAD 35 days ± 27.6 days, $40,195; PADDM 37 days ± 15.3 days, $42,236), with no significant differences between the groups ($p = .90$; 95% CI −20.23 to 17.05). The inpatient cost for admissions with major amputation over the study period totalled $1,530,116 (PAD $643,187 vs. PADDM $886,979).

Minor amputations also resulted in increased LOS in both cohorts, although this was not significant (PAD 19 days ± 15.3 days, $24,498; PADDM 18 days ± 17.8 days, $25,190; $p = .70$, 95% CI −9.47 to 13.78). Total inpatient-associated costs for this group were $1,523,026 (PAD $196,640 vs. PADDM $1,326,377). The total cost of inpatient care attributable to lower extremity amputation was $3,162,644.

Revascularization

The lowest LOS was recorded for patients having endovascular surgery. Patients with PAD undergoing PTA stayed 6 days ± 10.4 days in hospital (cost $11,072), while those with PADDM requiring the same procedure spent significantly longer in hospital (10 ± 12.4 days, cost $13,853; $p < .01$; 95% CI −6.14 to −1.31).

Patients requiring lower limb revascularization utilizing bypass surgery incurred longer LOSs for both PAD (15 days ± 13.6 days; cost $24,727) and PADDM (18 days ± 13.6 days; cost $20,099) but the difference was not significant ($p = .50$; 95% CI −12.34 to 10.05). Patients undergoing open bypass surgery spent significantly longer in hospital—almost double the length of time as those who had PTA alone (PTA 8 days ± 11.5 days vs. open bypass 15 days ± 13.3 days; $p < .01$).

Kidney disease

Thirty-two admissions (6%) had stage V CKD (defined as an eGFR <15), of which five a had PAD alone; 27 admissions had PADDM. No significance was found between the two groups for LOS (17 days ± 13.7 days vs. 18 ± 15.8 days; $p = .90$; 95% CI −17.39 to 16.78). In those with PADDM and stage V CKD, the presence of stage V CKD was associated with a significantly increased LOS (18 days ± 15.8 days) when compared to those with normal or mildly reduced kidney function (CKD stages 1–2, eGFR >60; 11 days ± 14 days, 95% CI 0.68–11.73; $p < .03$). In those with stage V CKD, 14 underwent amputation (44% of 32 admissions with stage V CKD and 3% of a total 568 admissions), with 12 of

these amputations occurring in those with PADDM ($p < .01$).

Glycemic control

The mean HbA1C for those with PADDM was 8.2%.

Predicting LOS using GLM

The general linear model (GLM) examined the dependent variable of length of stay against independent variables. The significant results are given in Table 2. The independent variables of age and sex were not indicators of increased LOS, while those of infection, emergency admission, amputation, bypass surgery, stage V CKD, and DM were predictors for increased LOS. DM as a comorbidity, independent of other variables, was a significant predictor for increased LOS ($p < .01$).

DISCUSSION

This retrospective cohort analysis estimates the costs and LOS of inpatients with PAD with and without DM who required lower limb surgical intervention by a vascular surgeon. The analysis does not account for any out-of-hospital healthcare costs or any indirect costs. As the total care of cost excludes procedures other than the major procedure accounting for the LOS, the total cost of care associated with a lower limb vascular procedure is likely to be significantly higher.

The methodology for costing used in this study is that currently used to fund public hospitals in New South Wales, Australia, and presents a realistic representation of inpatient costs, even though estimated rather than directly calculated from a dedicated costing study. In the analyses, each patient's admission was mapped utilizing AR-DRG codes and New South Wales cost-weights. While the AR-DRG coding system reflects the whole inpatient experience, and is periodically updated to match changes in clinical practice, the accuracy of cost-weights can become degraded over time, which is the major weakness in the system. In this instance, health cost estimates account for LOS (accommodation, pathology tests, drugs, imaging costs), cost of procedures, clinical occasions of service, and comorbid conditions (drugs, pathology costs, etc.) that complicate medical care.

Research that relies on the AR-DRG clinical code system to estimate healthcare costs has encountered significant issues related to data integrity.[13,14] Coding may be performed by trained, nonmedical coders using discharge summaries and clinical records, which are often incomplete or poorly reflect all of a patient's relevant diagnoses. In this study, these problems were avoided by allocating AR-DRG codes for each admission only after manually cross-referencing all of the data from the AVU database against the relevant paper and electronic medical records. Known diagnoses in an admission are assigned by both trained nonmedical coders and medical staff.

LOS may vary depending on the ability to transfer stable patients who undergo major amputation from a tertiary surgical bed into a rehabilitation unit or community setting for prosthetic rehabilitation. Only patients not capable of managing at home with walking aids and wheelchairs are transferred for inpatient prosthetic rehabilitation at Liverpool Hospital. It is possible that the LOS was extended for some patients while they were waiting for a rehabilitation bed. The hospital is supported by high-risk foot clinics, wound clinics, and a community nursing office providing domiciliary care of complex wounds, including V.A.C. dressings (KCI Medical, Kidlington, UK). Patients were discharged when their condition could be safely managed in the community.

This study makes no distinction in analysis between elective admissions and unplanned/emergency admissions. The groups in this study are selected on the basis that the patients underwent a vascular procedure on the lower limb by a surgeon, and excludes those who were admitted to a vascular surgical ward and who did not undergo a vascular procedure. The reason for admission was not rigorously subcategorized, as this would add unduly to the complexity of the results without affecting the major conclusions. The study includes multiple admissions and procedures for patients, as this does not affect the major conclusions regarding total costs, which are predominantly driven by bed-day cost estimates.

The findings are consistent with previous reports that patients with PAD, with or without DM, consume a large proportion of hospital resources.[15,16] In contrast to patients with PAD, patients with PADDM spent nearly twice as long in hospital (10 days vs. 15 days). This is in agreement with previous reports, with one particular study from the UK reporting similar lengths of stay for patients without DM versus those with DM who were admitted with peripheral vascular disease and diabetes foot disease (15.5 days vs. 8.7 days).[17]

The presence of DM added an average of $1912 per admission. An HbA1c level >7% was associated with 9 days longer in hospital than for patients without DM, a finding consistent with current reporting.[15–19] The major factor explaining the effect of diabetes on LOS and therefore costs is the presence of infection in patients with diabetes. For patients with PADDM, prevention of infection may reduce LOS and perhaps improve hospital outcomes. With the old adage that "prevention is better than cure", increased utilization of specialist multidisciplinary high-risk foot clinics may decrease PADDM-related admissions and thus lower the burden that PADDM places on the healthcare system.

Table 2. Dependent variables associated with increased length of stay (LOS) using general linear modeling.

Variable acting on LOS	*p*
Amputation	<.01
Bypass	<.01
PADDM	<.01
CKD stage V	<.01
Infection	<.01
Emergency admission	<.01

Note. PADDM = peripheral arterial disease with diabetes mellitus; CKD = chronic kidney disease.

LOS in this study was greatest in the major amputation group. Patients with PADDM were three times more likely to undergo amputation than patients with PAD alone. Similar reports on amputation risks in people with PADDM have been reported by Jude et al.,[20] who studied diabetic and nondiabetic patients undergoing arteriography and concluded that patients with PADDM were five times more likely to undergo amputation then people with PAD alone.

Endovascular surgery for the lower extremity improves limb salvage rates when utilized as a first-line approach,[21] with limb salvage rates comparable with those from open bypass surgery. The most common form of surgery undertaken in this study was endovascular intervention. The endovascular procedure of PTA was associated with the lowest LOS in both groups, with LOS almost twice as long for those patients undergoing open bypass surgery.

In summary, this paper is the first to report on the Australian hospital costs associated with inpatients with PAD with or without DM undergoing a vascular surgical procedure. The hospital cost of DM as a comorbid condition in patients with PAD who underwent lower limb surgical interventions is significant. Patients with PADDM stayed significantly longer in hospital and accounted for greater use of hospital resources than patients with PAD alone. Factors that were found to predict increased LOS, apart from DM, were performance of bypass surgery, performance of amputation, CKD stage V, infection, and emergency admission.

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None.

CONFLICT OF INTEREST

None.

REFERENCES

1 Hirsch AT, Hartman L, Town RJ, Virnig BA. National health care costs of peripheral arterial disease in the Medicare population. *Vasc Med* 2008;**13**:209—15.

2 Fowler B, Jamrozik K, Norman P, Allen Y. Prevalence of peripheral arterial disease: persistence of excess risk in former smokers. *Aust N Z J Public Health* 2002;**26**:219—24.

3 Kröger K, Stang A, Kondratieva J, et al. Heinz Nixdorf Recall Study Group. Prevalence of peripheral arterial disease — results of the Heinz Nixdorf recall study. *Eur J Epidemiol* 2006;**21**:279—85.

4 Eraso LH, Fukaya E, Mohler 3rd ER, Xie D, Sha D, Berger JS. Peripheral arterial disease, prevalence and cumulative risk factor profile analysis. *Eur J Prev Cardiol* 2012;**21**:704—11.

5 Félix-Redondo FJ, Fernández-Bergés D, Grau M, Baena-Diez JM, Mostaza JM, Vila J. Prevalence and clinical characteristics of peripheral arterial disease in the study Population Hermex. *Rev Esp Cardiol* 2012;**65**:726—33.

6 Currie CJ, Morgan CL, Peters JR. The epidemiology and cost of inpatient care for peripheral vascular disease, infection, neuropathy and ulcers in diabetes. *Diabetes Care* 1998;**21**:42—8.

7 Australian and New Zealand Society for Vascular Surgery. *Australasian vascular audit*. Available at: http://www.anzsvs.org.au/national-audit/ [accessed 21.07.14].

8 American Diabetes Association. Diagnosis and classification of diabetes mellitus. Position statement. *Diabetes Care* 2012;**35**(Suppl. 1):S64—71.

9 The International Expert Committee. International Expert Committee report on the role of the A1c assay in the diagnosis of diabetes. *Diabetes Care* 2009;**32**:1327—34.

10 National Kidney Foundation. K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Am J Kidney Dis* 2002;**39**:S1—266.

11 Independent Hospital Pricing Authority. *Australian refined diagnosis related groups version 6.x*. Available at: http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/CA25794400122452CA257B280015FF6B/$File/AR-DRG-v6%20x-addendum.pdf [accessed 21.07.14].

12 Lipsky BA, Berendt AR, Comia PB, Pile JC, Peters EJG, Armstrong DG, et al. 2012 Infectious Diseases Society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. *Clin Infect Dis* 2012;**54**:132—73.

13 NSW Government. *Costs of Care Standards 2009/10*. Available at: http://www0.health.nsw.gov.au/policies/gl/2011/pdf/GL2011_007.pdf [accessed 21.07.14].

14 Stone MA, Camosso-Stefinovic J, Wilkinson J, de Lusignan S, Hattersley AT, Khunti K. Incorrect and incomplete coding and classification of diabetes: a systematic review. *Diabet Med* 2010;**27**:491—7.

15 Kristensen T, Laudicella M, Ejersted C, Street A. Cost variation in diabetes care delivered in English hospitals. *Diabet Med* 2010;**27**:949—57.

16 Garg R, Bhutani H, Alyea E, Pendergrass M. Hyperglycemia and length of stay in patients hospitalized for bone marrow transplantation. *Diabetes Care* 2007;**30**:993—4.

17 Ahmann A. Reduction of hospital costs and length of stay by good control of blood glucose levels. *Endocr Pract* 2004;**10**:53—6.

18 Umpierrez GE, Isaacs SD, Bazargan N, You X, Thaler LM, Kitabchi AE. Hyperglycemia: an independent marker of in-hospital mortality in patients with undiagnosed diabetes. *J Clin Endocrinol Metab* 2002;**87**:978—82.

19 Furnary AP, Wu Y, Bookin SO. Effect of hyperglycemia and continuous intravenous insulin infusions on outcomes of cardiac surgical procedures: the Portland Diabetic Project. *Endocr Pract* 2004;**10**:21—33.

20 Jude EB, Eleftheriadou I, Tentolouris N. Peripheral arterial disease in diabetes — a review. *Diabet Med* 2010;**27**:4—14.

21 Faglia E, Mantero M, Caminiti M, Caravaggi C, De Giglio R, Pritelli C, et al. Extensive use of peripheral angioplasty, particularly infrapopliteal, in the treatment of ischaemic diabetic foot ulcers: clinical results of a multicentric study of 221 consecutive diabetic subjects. *J Intern Med* 2002;**252**:225—32.