In-Hospital Outcomes and Trends of Endovascular Intervention vs Surgical Revascularization in Octogenarians With Peripheral Artery Disease

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It is unknown whether endovascular intervention (EVI) is associated with superior outcomes when compared with surgical revascularization in octogenarian. National Inpatient Sample (NIS) database was used to compare the outcomes of limb revascularization in octogenarians who had surgical revascularization versus EVI. The NIS database's information on PAD patients ≥80-year-old who underwent limb revascularization between 2002 and 2014 included 394,504 octogenarian patients, of which 184,926 underwent surgical revascularization (46.9%) and 209,578 underwent EVI (53.1%). Multivariate analysis was performed to examine in-hospital outcomes. Trend over time in limb revascularization utilization was examined using Cochrane-Armitage test. EVI group had lower odds of in-hospital mortality (adjusted odds ratio [aOR]: 0.61 [95% CI: 0.58 to 0.63], myocardial infarction (aOR: 0.84 [95% CI: 0.81 to 0.87]), stroke (aOR: 0.93 [95% CI: 0.89 to 0.96]), acute kidney injury (aOR: 0.79 [95% CI: 0.77 to 0.81]), and limb amputation (aOR: 0.77 [95% CI: 0.74 to 0.79]) compared with surgical group ($p < 0.001$ for all). EVI group had higher risk of bleeding (aOR: 1.20 [95% CI: 1.18 to 1.23]) and vascular complications (3.2% vs 2.7%, aOR: 1.25 [95% CI: 1.19 to 1.30]) compared with surgical group ($p < 0.001$ for all). Within study period, EVI utilization increased in octogenarian patients from 2.6% to 8.9% (ptrend < 0.001); whereas use of surgical revascularization decreased from 11.6% to 5.2% (ptrend < 0.001). In conclusion, the utilization of EVI in octogenarians is increasing, and associated with lower risk of in-hospital mortality and adverse cardiovascular and limb outcomes as compared with surgical revascularization. © 2021 Published by Elsevier Inc. (Am J Cardiol 2021;145:143−150)

The prevalence of peripheral artery disease (PAD) increases with age and is estimated to affect more than 200 million people worldwide.[1] Outpatient and inpatient Medicare data suggest a PAD prevalence of 10% to 14% in the United States.[2] Limb revascularization is commonly performed in patients with intermittent claudication (IC) and critical limb ischemia (CLI).[3] Among patients undergoing endovascular intervention (EVI) for PAD, there is increased interest in identifying factors that are associated with poor outcomes. Similarly, the octogenarian population is rapidly growing and considered to be at higher risk of procedural complications than their younger counterparts during limb revascularization. This procedural risk in octogenarians is often attributed to greater prevalence of comorbidities such as; frailty, low body weight, severely calcified peripheral arterial disease, depressed cardiac function, coronary artery disease, and less tolerance to prolonged courses of dual antiplatelet drugs when compared with younger patients. There are limited data on outcomes of limb revascularization in elderly patients which is a growing population in the current era. In contrast to surgical revascularization where there has been a decrease, EVI is increasingly used to manage PAD patients, but this has not been looked at in patients over 80-year-old. Furthermore, comparative cardiovascular and limb revascularization outcomes in this population associated with endovascular in comparison to surgical revascularization is

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unknown. Therefore, we aimed to examine national trends and in-hospital outcomes of EVI in octogenarian patients with PAD compared with those undergoing surgical revascularization.

Methods

The National Inpatient Sample (NIS) is a publicly available database of hospital discharges in the United States, containing data from approximately 8 million hospital stays that were selected using a complex probability sampling design, and the weighting scheme recommended by the Agency for Healthcare Research and Quality which is intended to represent all discharges from nonfederal hospitals.[4] From 2002 to 2014 and after weighting the data, we used International Classification of Disease, Ninth Edition, Clinical Modification (ICD-9-CM) codes to identify all PAD patients aged ≥80 who had limb revascularization (EVI or surgical revascularization) (Figure 1). We further categorized PAD patients based on clinical presentation into those with IC and CLI. CLI was defined as lower extremity rest pain, ulceration, and/or gangrene due to atherosclerosis of lower extremity arteries. CLI was also identified by the presence of codes for lower extremity chronic ulceration, osteomyelitis, and/or cellulitis along with primary diagnosis codes for PAD. A list of ICD-9-CM diagnosis codes used to identify the PAD population are included in Supplemental Table 1. EVI was defined as angioplasty, atherectomy, and/or stenting of lower limb vessels.[5] Surgical revascularization was identified using ICD-9-CM procedure codes for open bypass, endarterectomy of lower limb arteries, incision and/or resection of lower limb arteries. Patients who had both EVI and surgical revascularization were excluded from the study. A list of ICD-9-CM procedure codes used to identify limb revascularization is included in Supplemental Table 1. This approach has been used by a previous NIS database study to accurately identify patients with PAD and CLI undergoing limb revascularization procedures.[6] This study involved the analysis of de-identified data and was exempt from institutional review boards approval.

Data were retrieved retrospectively. Baseline patient-level characteristics included demographics (age, gender, race, primary expected payer, median household income for patient's zip code), clinical presentation (IC vs CLI), and relevant co-morbidties (smoking, dyslipidemia, diabetes mellitus, hypertension, atrial fibrillation, coronary artery disease, carotid artery disease, prior myocardial infarction (MI), prior percutaneous coronary intervention (PCI), prior coronary artery bypass grafting, congestive heart failure, prior stroke and/or transient ischemic attack, renal failure, valvular disease, coagulopathy, hypothyroidism, chronic lung disease, pulmonary circulation disorder, fluid and electrolytes disorder, liver disease, neurologic disorder, anemia and metastatic cancer). Hospital-level characteristics were census region, bed size, and teaching status. Co-morbidties were identified using the Clinical Classification Software codes provided by the Healthcare Cost and Utilization Project and the Elixhauser Co-morbidity Index, and ICD-9-CM codes.[7] A list of ICD-9-CM codes and Clinical Classification Software codes used to identify co-morbidties is included in Supplemental Table 2.

The primary outcome was all-cause in-hospital mortality. Secondary outcomes included acute MI, stroke, major bleeding, major vascular complications (injury to blood vessel, accidental puncture, injury to retroperitoneum, other vascular complications, or any vascular complications requiring surgery), acute kidney injury (AKI), major amputation and hospital length of stay (LOS). Major bleeding was defined as hemorrhage leading to hemodynamic instability or requiring blood transfusion. A list of ICD-9-CM codes used to define in-hospital outcomes is included in

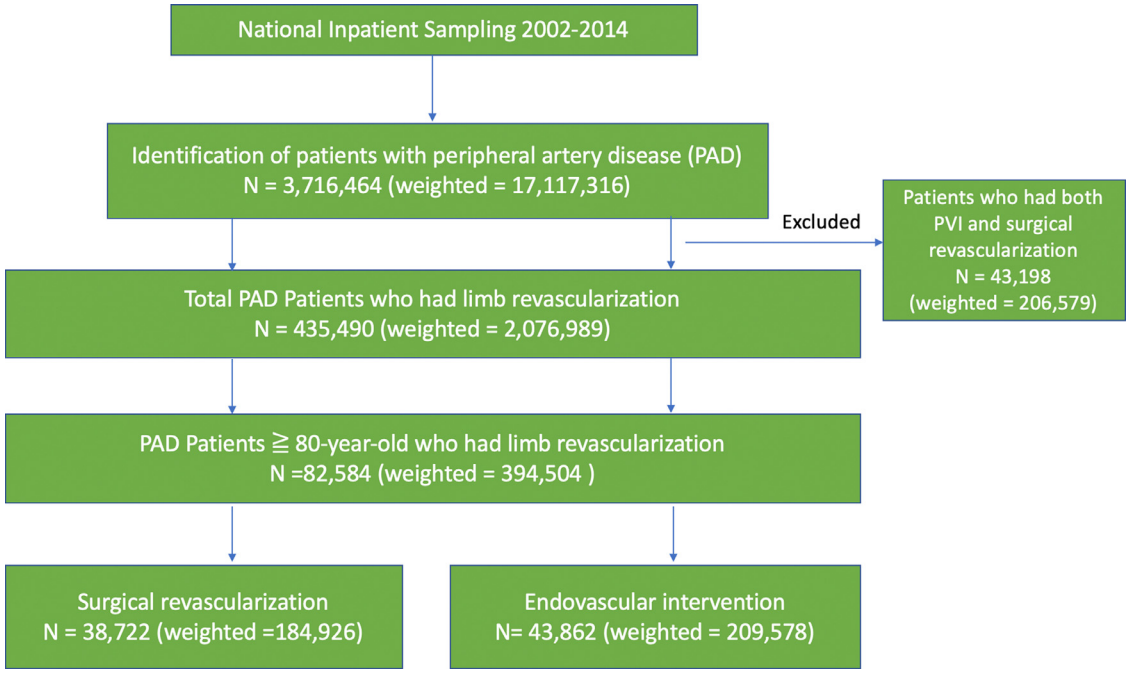

Figure 1. Identification of study population using national inpatient sampling database.

Table 1
Baseline characteristics in octogenarian patients with peripheral artery disease and undergoing limb revascularization

	Surgical group n = 184,926	Endovascular group n = 209,578	p-Value
Age (years)	84.6 ± 3.8	84.6 ± 3.7	0.12
Women	54.7%	56.6%	<0.001
			<0.001
White	82.2%	78.5%	
Black	8.6%	10.1%	
Hispanic	5.6%	7.1%	
Asian or Pacific Islander	1.4%	1.5%	
Native American	0.2%	0.5%	
Other	1.9%	1.3%	
Elective Hospitalization	52.3%	49.1%	<0.001
Primary expected payer			<0.001
Medicare	93.6%	94.2%	
Medicaid	0.8%	0.9%	
Private Insurance	4.7%	4.2%	
Self-Pay	0.3%	0.3%	
No Charge	0.0%	0.0%	
Other	0.5%	0.5%	
Median Household Income (percentile)			<0.001
0 to 25	21.3%	25.8%	
26 to 50	25.7%	25.1%	
51 to 75	25.3%	24.2%%	
76 to 100	27.7%	25.0%	
Bed Size			<0.001
Small	9.7%	10.7%	
Medium	23.5%	23.2%	
Large	66.7%	66.1%	
Location/Teaching Status			<0.001
Rural	6.8%	6.3%	
Urban Nonteaching	42.7%	43.2%	
Urban Teaching	50.4%	50.5%	
Hospital Region			<0.001
Northeast	24.2%	21.2%	
Midwest	23.3%	25.3%	
South	33.1%	35.7%	
West	19.4%	17.8%	
Clinical presentation			
Intermittent claudication	11.6%	18.5%	<0.001
CLI	49.8%	49.9%	0.60
Other	38.6%	35.2%	<0.001
Co-morbidties			
Smoker	6.0%	5.1%	<0.001
Dyslipidemia	32.4%	38.1%	<0.001
DM, Uncomplicated	21.6%	23.2%	<0.001
DM, Complicated	8.3%	11.4%	<0.001
Hypertension	73.2%	73.8%	<0.001
AF	33.5%	24.0%	<0.001
CAD	9.0%	21.2%	<0.001
Prior MI	9.6%	8.2%	<0.001
Prior PCI	5.2%	6.7%	<0.001
Prior CABG	12.8%	13.4%	<0.001
Congestive heart failure	12.4%	10.2%	<0.001
Carotid artery disease	3.1%	2.5%	<0.001
Prior stroke/TIA	4.5%	4.8%	<0.001
Renal failure	18.3%	25.0%	<0.001
Valvular disease	5.2%	4.4%	<0.001
Coagulopathy	4.9%	3.4%	<0.001
Hypothyroidism	13.4%	13.3%	0.86
Chronic Lung Disease	22.8%	19.9%	<0.001
Pulmonary circulation disorders	1.4%	1.3%	0.83
Fluid and Electrolytes Disorders	19.4%	16.0%	<0.001
Liver Disease	0.5%	0.4%	<0.001
Neurological Disorders	6.7%	5.9%	<0.001
Deficiency Anemia	19.9%	20.6%	<0.001
Chronic Blood Loss Anemia	2.1%	1.4%	<0.001
Metastatic Cancer	0.6%	0.5%	<0.001

Values are expressed as mean ± SD for continuous variables or percentages for categorical variables. CLI = critical limb ischemia; IC = intermittent claudication; DM = diabetes mellitus; AF = atrial fibrillation; CAD = coronary artery disease; MI =myocardial infarction; PCI = percutaneous coronary intervention; CABG = coronary artery bypass grafting; TIA = transient ischemic attack.

Supplemental Table 2. We also examined temporal changes in limb revascularization (endovascular and surgical) utilization and in-hospital outcomes among octogenarian patients with PAD who had limb revascularization.

Continuous variables were expressed as weighted mean values ± standard deviation (normal distribution) or median with interquartile range (non-normal distribution), and categorical variables were expressed as percentages. Continuous variables were compared using the unpaired Student *t* test or Mann-Whitney *U* test as appropriate while the chi-square test was used to compare categorical variables. Weighted values of patient level observations were generated to produce a nationally representative estimate of the entire United States population of hospitalized patients. Univariable and multivariable logistic regressions were used to estimate the odds of in-hospital outcomes between groups (endovascular vs surgical). The regression models were adjusted for demographics (age, race, and gender), patients' insurance, socioeconomic status, hospital characteristics, clinical presentation, and all co-morbidities listed in Table 1. Odds ratios (ORs) and 95% confidence intervals (CIs) were used to report the results of regression models. Interaction between clinical presentation (IC or CLI) revascularization strategy and in-hospital outcomes was tested using multivariable regression analysis. Linear regression models were used to assess the LOS. Log transformation of LOS was done to adjust for positively skewed data. Sensitivity analysis was performed by stratifying the cohort by IC and CLI and evaluating in-hospital outcomes in each group. Trend over time in limb revascularization utilization and in-hospital outcomes was examined using Cochrane-Armitage test. p-value of less than 0.05 was considered statistically significant. SPSS version 25 software (IBM Corp, Armonk, New York) was used for all statistical analyses.

Results

Of 394,504 octogenarian patients who had limb revascularization from 2002 to 2014, 184,926 underwent surgical revascularization (46.9%), and 209,578 underwent EVI (53.1%). Baseline characteristics for both groups are

summarized in Table 1. Mean age was similar between both surgical and endovascular groups (84.6 ± 3.8 vs 84.6 ± 3.7, p = 0.12). Compared with surgical group, patients who had EVI were more likely to be women, African American, and Hispanic and less likely to be white (p < 0.001 for all). Elective admissions were less frequent in patients who had EVI (49.1% vs 52.3%, p < 0.001). The prevalence of CLI was similar between both groups; whereas, IC was more prevalent in patients who had EVI (p < 0.001). The prevalence of dyslipidemia, diabetes (complicated and uncomplicated), hypertension, coronary artery disease, prior PCI, prior coronary artery bypass grafting surgery, prior stroke and/or transient ischemic attack, renal failure, deficiency anemia, and metastatic cancer was higher among endovascular patients; whereas, smoking, atrial fibrillation, carotid artery disease, prior MI, congestive heart failure, valvular disease, coagulopathy, chronic lung disease, fluid and electrolytes disorders, neurological disorders, liver disease, chronic blood loss anemia, and metastatic cancer were more prevalent in surgical patients (p < 0.001 for all). The prevalence of hypothyroidism (p = 0.86) and pulmonary circulation disorders (p = 0.83) was similar between both groups.

Among octogenarian patients who underwent limb revascularization, EVI utilization increased in octogenarian patients from 2.6% to 8.9% (p trend < 0.001); whereas, use of surgical revascularization decreased from 11.6% to 5.2% (ptrend < 0.001) during the course of the study. (Figure 2). There was linear increase in mortality (5% to 7.5%), major bleeding (4% to 7.7%), vascular complications (2.4 to 6.4%), and major amputation (4.1% to 8.6%) in octogenarian

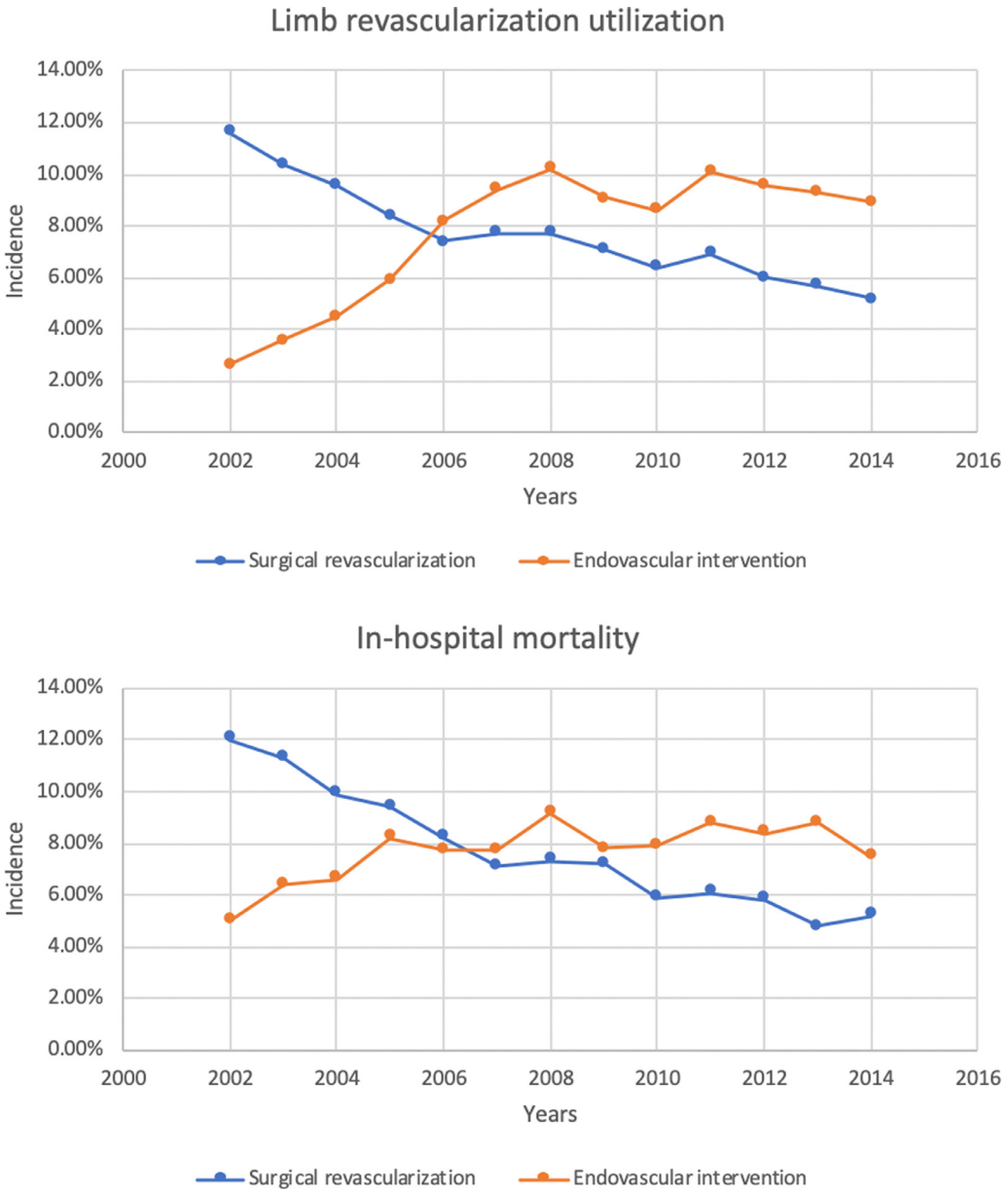

Figure 2. Trend of endovascular intervention and surgical revascularization procedures among octogenarian patients (top). Annual rate of in-hospital mortality among octogenarian patients with peripheral artery disease and undergoing limb revascularization (bottom). p_{trend} <0.001 for all trends

Figure 3. Annual rate of in-hospital outcomes among octogenarian patients with peripheral artery disease and undergoing limb revascularization. p_{trend} <0.001 for all trends.

patients who had EVI; whereas, in-hospital mortality (12% to 5.2%), major bleeding (10.5% to 6.2%), vascular complications (8% to 4.7%), and major amputation (12.1% to 5%) decreased overtime in octogenarian patients who had surgical revascularization (ptrend < 0.001 for all). There was linear increase in AKI in octogenarian patients who had both EVI and surgical revascularization. (Figures 2 and 3)

Compared with surgical revascularization, EVI was associated with lower risk of in-hospital mortality (3.0% vs 5.8%, adjusted OR: 0.61 [95% CI: 0.58 to 0.63] and shorter length of hospital stay (median LOS= 4 days; Interquartile range [IQR] (1-9) vs 6 days; [IQR] (4-11); p < 0.001). Endovascular group had lower rates of MI (3.7% vs 4.7%, adjusted OR: 0.84 [95% CI: 0.81 to 0.87]), stroke (7.9% vs 8.1%, adjusted OR: 0.93 [95% CI: 0.89 to 0.96]), acute kidney injury (10.3% vs 11.0%, adjusted OR: 0.79 [95% CI: 0.77 to 0.81]), and limb amputation (3.3% vs 4.1%, adjusted OR: 0.77 [95% CI: 0.74 to 0.79] compared with surgical group. However, EVI group had higher rates of bleeding (9.7% vs 9.1%, adjusted OR: 1.20 [95% CI: 1.18 to 1.23] and vascular complications (3.2% vs 2.7%, adjusted OR: 1.25 [95% CI: 1.19 to 1.30] compared with surgical group. (Table 2). Due to significant interaction between clinical presentation, revascularization strategy and in-hospital outcomes in this cohort, subgroup analysis was performed in patients with IC and CLI separately.

In subgroup analysis of patients with IC, EVI was associated with lower risk of in-hospital mortality (0.7% vs 1.4%, adjusted OR: 0.52 [95% CI: 0.43 to 0.63] compared with surgical revascularization. The incidence of stroke (5.8% vs 6.7%, adjusted OR: 0.87 [95% CI: 0.81 to 0.94], AKI (3.6% vs 4.7%, adjusted OR: 0.72 [95% CI: 0.65 to 0.80], and major amputation (0.2% vs 0.4%, adjusted OR: 0.38 [95% CI: 0.27 to 0.54] was lower in endovascular patients compared with surgical group. However, the incidence of major bleeding (8.9% vs 5.2%, adjusted OR: 1.34 [95% CI: 1.28 to 1.40] and vascular complications (4.0% vs 1.8%, adjusted OR: 2.70 [95% CI: 2.36 to 3.07] was higher in octogenarian patients who had EVI compared with surgical revascularization. There was no difference in the rate of MI between both groups (2.1% vs 1.9%, adjusted OR: 0.998 [95% CI: 0.87 to 1.14] (Table 3).

In subgroup analysis of patients with CLI, EVI was associated with lower risk of in-hospital mortality (3.1% vs 4.0%, adjusted OR: 0.71 [95% CI: 0.67 to 0.75] compared with surgical revascularization. The incidence of MI (2.7% vs 4.0%, adjusted OR: 0.68 [95% CI: 0.65 to 0.72] stroke (7.6% vs 8.4%, adjusted OR: 0.92 [95% CI: 0.86 to 0.98], AKI (12.7% vs 10.4%, adjusted OR: 0.96 [95% CI: 0.93 to 0.995], and major amputation (5.3% vs 5.5%, adjusted OR: 0.85 [95% CI: 0.82 to 0.89] was lower in endovascular patients compared with surgical group. However, the incidence of major bleeding (9.0% vs 7.3%, adjusted OR: 1.30 [95% CI: 1.25 to 1.30] and vascular complications (2.7% vs 1.3%, adjusted OR: 2.11 [95% CI: 1.95 to 2.27] was higher octogenarian patients who had EVI compared with surgical revascularization. (Table 4).

Discussion

In this study of 429,178 octogenarian patients with PAD and patients who underwent limb revascularization in the United States from 2002 to 2014, we report the following findings: (1) Within the study period, the observed increase of EVI utilization in octogenarian patients was associated with increase in adverse in-hospital outcomes following

Table 2
In-hospital outcomes in octogenarian patients with peripheral artery disease and undergoing limb revascularization

	Surgical group n = 184,926	Endovascular group n = 209,578	p-value	Interaction p-value (CLI * revasc strategy)	Interaction p-value (IC * revasc strategy)
In-hospital mortality					
%	5.8%	3.0%		< 0.001	< 0.001
Unadjusted OR (95% CI)	Ref.	0.51 (0.49-0.53)	< 0.001		
Adjusted OR (95% CI)	Ref.	0.61 (0.58-0.63)	< 0.001		
Myocardial infarction					
%	4.7%	3.7%		< 0.001	< 0.001
Unadjusted OR (95% CI)	Ref.	0.78 (0.75-0.81)	< 0.001		
Adjusted OR (95% CI)	Ref.	0.84 (0.81-0.87)	< 0.001		
Stroke					
%	8.1%	7.9%		0.18	< 0.001
Unadjusted OR (95% CI)	Ref.	0.97 (0.95-0.99)	0.007		
Adjusted OR (95% CI)	Ref.	0.93 (0.89-0.96)	< 0.001		
Vascular complications					
%	2.7%	3.2%		0.230	< 0.001
Unadjusted OR (95% CI)	Ref.	1.21 (1.16-1.25)	< 0.001		
Adjusted OR (95% CI)	Ref.	1.24 (1.19-1.30)	< 0.001		
Major bleeding				< 0.001	< 0.001
%	9.1%	9.7%			
Unadjusted OR (95% CI)	Ref.	1.08 (1.06-1.11)	< 0.001		
Adjusted OR (95% CI)	Ref.	1.20 (1.18-1.23)	< 0.001		
Acute kidney injury				< 0.001	< 0.001
%	11.0%	10.3%			
Unadjusted OR (95% CI)	Ref.	0.93 (0.91-0.95)	< 0.001		
Adjusted OR (95% CI)	Ref.	0.79 (0.77-0.81)	< 0.001		
Amputation				< 0.001	< 0.001
%	4.1%	3.3%			
Unadjusted OR (95% CI)	Ref.	0.79 (0.77-0.82)	< 0.001		
Adjusted OR (95% CI)	Ref.	0.77 (0.74-0.79)	< 0.001		

Adjusted for demographics (age, gender, race), hospital characteristics (region, bed size, teaching status), clinical presentation (intermittent claudication vs critical limb ischemia), and all co-morbidities listed in Table 1. Interaction was tested between clinical presentation, revascularization strategy and in-hospital outcomes. OR = odds ratio; IC = intermittent claudication; CLI = critical limb ischemia; revasc - revascularization

EVI; (2) EVI was associated with lower risk of in-hospital mortality, lower rates of MI, AKI, and major amputation, but higher rates of major bleeding and vascular complications, and shorter length of hospital stay compared with surgical revascularization; (3) these adverse outcomes were seen in patients presenting with IC as well as CLI.

The upward trend in EVI utilization we found among octogenarian patients was observed in prior studies that looked at limb revascularization in all age groups.[8,9] Although EVI was associated with lower mortality and adverse events when compared with surgical revascularization, the temporal increase in EVI utilization was associated with increase in complications rates over time. Brosi et al reported comparable rates of limb salvage in octogenarians who had EVI and surgical revascularization; however, 30-day peri-operative mortality was much lower in the endovascular cohort as compared with the surgical cohort.[10] It is known that surgical revascularization is associated with high perioperative mortality with rates ranging from 2% to 6%.[11-13] EVI offer critical advantages such as: less invasive revascularization, moderate sedation, lower cardiac stress, infection rates, and shorter hospital stays.[14,15]

Improvements in medical care have resulted in higher number of aging populations which could present a challenge to the vascular specialist as they often present with advanced and complex PAD and are associated with higher healthcare cost.[16] Prior study showed higher rates of major complications following EVI in octogenarian patients compared with patients below the age of 80.[17] However, they did not look at the outcome of EVI versus surgery in patients aged 80 or above. In the current analysis, EVI was associated with lower rates of mortality and complications except for vascular complications and major bleeding which were more frequent in EVI when compared with surgical revascularization. The presence of vascular calcification and loss of endothelial function in aging vessels render them more challenging for EVI and may result in higher rates of vascular complications and bleeding.[18]

Despite advances in imaging and interventional techniques and technologies, we found worsening rates of complications over the course of study. This could be due to worse risk profile and more complex cases performed using EVI. Therefore, accurate peri-procedural risk assessment and effective preventive measures in octogenarian patients undergoing EVI are needed to reduce major bleeding, vascular complications and AKI in the perioperative phase. For instance, radial access to minimize bleeding risk, culprit-only intervention, less use of thrombolytics and glycoprotein IIb and/or IIIa inhibitors, less contrast volume, appropriate pre and after EVI hydration, staged interventions, discussing goal of cares with the patients and their families, and careful patient selection for high risk and long

Table 3
In-hospital outcomes in octogenarian patients with intermittent claudication and undergoing limb revascularization

	Surgical group n = 21,541	Endovascular group n = 45,278	p-value
In-hospital mortality			
%	1.4%	0.7%	
Unadjusted OR (95% CI)	Ref.	0.50 (0.43-0.59)	< 0.001
Adjusted OR (95% CI)	Ref.	0.52 (0.43-0.63)	< 0.001
Myocardial infarction			
%	1.9%	2.1%	
Unadjusted OR (95% CI)	Ref.	1.10 (0.98-1.24)	0.11
Adjusted OR (95% CI)	Ref.	0.998 (0.87-1.14)	0.97
Stroke			
%	6.7%	5.8%	
Unadjusted OR (95% CI)	Ref.	0.87 (0.81-0.92)	< 0.001
Adjusted OR (95% CI)	Ref.	0.87 (0.81-0.94)	< 0.001
Vascular complications			
%	1.8%	4.0%	
Unadjusted OR (95% CI)	Ref.	2.23 (2.00-2.49)	< 0.001
Adjusted OR (95% CI)	Ref.	2.70 (2.36-3.07)	< 0.001
Major bleeding			
%	5.2%	8.9%	
Unadjusted OR (95% CI)	Ref.	1.96 (1.81-2.12)	< 0.001
Adjusted OR (95% CI)	Ref.	1.34 (1.28-1.40)	< 0.001
Acute kidney injury			
%	4.7%	3.6%	
Unadjusted OR (95% CI)	Ref.	0.77 (0.71-0.84)	< 0.001
Adjusted OR (95% CI)	Ref.	0.72 (0.65-0.80)	< 0.001
Amputation			
%	0.4%	0.2%	
Unadjusted OR (95% CI)	Ref.	0.51 (0.38-0.68)	< 0.001
Adjusted OR (95% CI)	Ref.	0.38 (0.27-0.54)	< 0.001

Adjusted for demographics (age, gender, race), hospital characteristics (region, bed size, teaching status), and all co-morbidities listed in Table 1.
OR - odds ratio

Table 4
In-hospital outcomes in octogenarian patients with critical limb ischemia and undergoing limb revascularization

	Surgical group n = 92,095	Endovascular group n = 121,836	p-value
In-hospital mortality			
%	4.0%	3.1%	
Unadjusted OR (95% CI)	Ref.	0.76 (0.72-0.79)	< 0.001
Adjusted OR (95% CI)	Ref.	0.71 (0.67-0.75)	< 0.001
Myocardial infarction			
%	4.0%	2.7%	
Unadjusted OR (95% CI)	Ref.	0.67 (0.64-0.70)	< 0.001
Adjusted OR (95% CI)	Ref.	0.68 (0.65-0.72)	< 0.001
Stroke			
%	8.4%	7.6%	
Unadjusted OR (95% CI)	Ref.	0.90 (0.82-0.96)	< 0.001
Adjusted OR (95% CI)	Ref.	0.92 (0.86-0.98)	0.01
Vascular complications			
%	1.3%	2.7%	
Unadjusted OR (95% CI)	Ref.	2.21 (1.98-2.53)	< 0.001
Adjusted OR (95% CI)	Ref.	2.11 (1.95-2.27)	< 0.001
Major bleeding			
%	7.3%	9.0%	
Unadjusted OR (95% CI)	Ref.	1.25 (1.21-1.29)	< 0.001
Adjusted OR (95% CI)	Ref.	1.30 (1.25-1.34)	< 0.001
Acute kidney injury			
%	10.4%	12.7%	
Unadjusted OR (95% CI)	Ref.	1.25 (1.22-1.29)	< 0.001
Adjusted OR (95% CI)	Ref.	0.96 (0.93-0.995)	0.02
Major amputation			
%	5.5%	5.3%	
Unadjusted OR (95% CI)	Ref.	0.96 (0.93-0.99)	0.04
Adjusted OR (95% CI)	Ref.	0.85 (0.82-0.89)	< 0.001

Adjusted for demographics (age, gender, race), hospital characteristics (region, bed size, teaching status), and all co-morbidities listed in Table 1.
OR - odds ratio

interventions are all important points to keep in mind when referring elderly patients for EVI.

NIS is large, nationally representative database that has been validated multiple times for accuracy. Nevertheless, as with all studies that use routinely collected electronic healthcare data, there are several limitations to our study. Given the retrospective design, the possibility of unmeasured confounding is present due to lack of randomization. This analysis relied on ICD-9-CM codes and there was no information on key variables related to limb revascularization such as indication, complexity, target lesion localization (below vs above knee), duration, and success rate of the procedure. The NIS does not capture information related to the indication of limb amputation and the severity of comorbid conditions that may determine type of intervention. Furthermore, medications are not available in this dataset and the analysis was limited to in-hospital outcomes as follow up after discharge was not available.

Conclusion

Among octogenarian patients with PAD, EVI is associated with lower in-hospital mortality, lower rates of adverse cardiovascular and limb outcomes, higher rates of major bleeding and vascular complications, and shorter length of hospital stay compared with surgical revascularization.

Credit Author Statement

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Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2020.12.091.

1. Fowkes FG, Rudan D, Rudan I, Aboyans V, Denenberg JO, McDermott MM, Norman PE, Sampson UK, Williams LJ, Mensah GA, Criqui MH. Comparison of global estimates of prevalence and risk factors for peripheral artery disease in 2000 and 2010: a systematic review and analysis. *Lancet* 2013;382:1329–1340.
2. Kalbaugh CA, Kucharska-Newton A, Wruck L, Lund JL, Selvin E, Matsushita K, Bengtson LGS, Heiss G, Loehr L. Peripheral artery disease prevalence and incidence estimated from both outpatient and inpatient settings among medicare fee-for-service beneficiaries in the Atherosclerosis Risk in Communities (ARIC) study. *J Am Heart Assoc* 2017;6:e003796.
3. Aboyans V, Ricco JB, Bartelink MEL, Bjorck M, Brodmann M, Cohnert T, Collet JP, Czerny M, De Carlo M, Debus S, Espinola-Klein C, Kahan T, Kownator S, Mazzolai L, Naylor AR, Roffi M, Rother J, Sprynger M, Tendera M, Tepe G, Venermo M, Vlachopoulos C, Desormais I, Group ESCSD. 2017 ESC Guidelines on the Diagnosis and Treatment of Peripheral Arterial Diseases, in collaboration with the European Society for Vascular Surgery (ESVS): Document covering atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, upper and lower extremity arteriesEndorsed by: the European Stroke Organization (ESO)The Task Force for the Diagnosis and Treatment of Peripheral Arterial Diseases of the European Society of Cardiology (ESC) and of the European Society for Vascular Surgery (ESVS). *Eur Heart J* 2018;39:763–816.
4. Overview of the National (Nationwide) Inpatient Sample (NIS). Agency for Healthcare Research and Quality (AHRQ). Available at: https://www.hcup-us.ahrq.gov/nisoverview.jsp.
5. Kullo IJ, Rooke TW. Clinical practice. Peripheral artery disease. *N Engl J Med* 2016;374:861–871.
6. Agarwal S, Sud K, Shishehbor MH. Nationwide trends of hospital admission and outcomes among critical limb ischemia patients: from 2003-2011. *J Am Coll Cardiol* 2016;67:1901–1913.
7. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* 1998;36:8–27.
8. Sullivan TM, Taylor SM, Blackhurst DW, Langan EM 3rd, Cull DL, Carsten CG 3rd, Gray BH, Snyder BA, Youkey JR. Has endovascular surgery reduced the number of open vascular operations performed by an established surgical practice? *J Vasc Surg* 2002;36:514–519.
9. Malyar N, Furstenberg T, Wellmann J, Meyborg M, Luders F, Gebauer K, Bunzemeier H, Roeder N, Reinecke H. Recent trends in morbidity and in-hospital outcomes of in-patients with peripheral arterial disease: a nationwide population-based analysis. *Eur Heart J* 2013;34:2706–2714.
10. Brosi P, Dick F, Do DD, Schmidli J, Baumgartner I, Diehm N. Revascularization for chronic critical lower limb ischemia in octogenarians is worthwhile. *J Vasc Surg* 2007;46:1198–1207.
11. Chang JB, Stein TA. Infrainguinal revascularizations in octogenarians and septuagenarians. *J Vasc Surg* 2001;34:133–138.
12. O'Mara CS, Kilgore TL Jr., McMullan MH, Maples MD, Hollingsworth JF, Tyler HB. Distal bypass for limb salvage in very elderly patients. *Am Surg* 1987;53:66–70.
13. Pomposelli FB Jr., Arora S, Gibbons GW, Frykberg R, Smakowski P, Campbell DR, Freeman DV, LoGerfo FW. Lower extremity arterial reconstruction in the very elderly: successful outcome preserves not only the limb but also residential status and ambulatory function. *J Vasc Surg* 1998;28:215–225.
14. Balmer H, Mahler F, Do DD, Triller J, Baumgartner I. Balloon angioplasty in chronic critical limb ischemia: factors affecting clinical and angiographic outcome. *J Endovasc Ther* 2002;9:403–410.
15. Nasr MK, McCarthy RJ, Hardman J, Chalmers A, Horrocks M. The increasing role of percutaneous transluminal angioplasty in the primary management of critical limb ischaemia. *Eur J Vasc Endovasc Surg* 2002;23:398–403.
16. Diehm C, Schuster A, Allenberg JR, Darius H, Haberl R, Lange S, Pittrow D, von Stritzky B, Tepohl G, Trampisch HJ. High prevalence of peripheral arterial disease and co-morbidity in 6880 primary care patients: cross-sectional study. *Atherosclerosis* 2004;172:95–105.
17. Dick P, Barth B, Mlekusch W, Sabeti S, Amighi J, Schlager O, Koppensteiner R, Minar E, Schillinger M. Complications after peripheral vascular interventions in octogenarians. *J Endovasc Ther* 2008;15:383–389.
18. Johnson RC, Leopold JA, Loscalzo J. Vascular calcification: pathobiological mechanisms and clinical implications. *Circ Res* 2006;99:1044–1059.