Comparison of Outcomes After Percutaneous Coronary Interventions in Patients of Eighty Years and Above Compared With Those Less Than 80 Years

Yasser Al-khadra, MD[a,#], Marvin Kajy, MD[b,#], Amr Idris, MD[c], Fahed Darmoch, MD[d],
Homam Moussa Pacha, MD[e], Amjad Kabach, MD[f], Santiago Garcia, MD[g], Rodrigo Bagur, MD, PhD[h,i],
Chun Shing Kwok, MD[i,j], Amir Kaki, MD[k], James J. Glazier, MD[b], Samir Kapadia, MD[a],
Mamas Mamas, MD[j,k], and M Chadi Alraies, MD[b,*]

Life expectancy in the United States has increased due to advances in health care. Despite increased utilization of percutaneous coronary intervention (PCI), octogenarian patients are less likely to be referred to the catheterization laboratory for coronary interventions. This is in part due to multiple patient co-morbidities and lack of established guidelines. We examined in-hospital clinical outcomes of octogenarian and nonoctogenarian patients who underwent PCI in the United States. Using the National Inpatient Sampling database, we identified all adult patients who are older than 18 years and underwent PCI. Patient were stratified by age into 2 groups, ≥80 years old and <80 years old and in-hospital adverse outcome rates were determined. A total of 11,056,559 patients underwent PCI between the years of 2002 and 2014 and 1,544,563 patients were ≥80 years old (14%). After multivariable adjustment, patients who are ≥80 years old had higher in-hospital mortality (3.3% vs 1.3%, adjusted Odds Ratio, 1.624; 95% confidence interval, 1.602 to 1.647, p <0.0001) and longer length of stay (median length of stay days 3, range 2 to 8 days vs median 2 days, range 1 to 4 days) (p <0.0001). Patients ≥80 years old had a higher rate of cardiopulmonary complications, postprocedural stroke, acute kidney injury, postprocedural thromboembolic complications, and hemorrhage requiring transfusion. There was no difference in vascular complications between the 2 groups. In conclusion, octogenarians who underwent PCI were at increased risk for in-hospital mortality and morbidity compared with nonoctogenarians. The decision to proceed with PCI in this patient population should be individualized, taking into consideration known risk factors and patient's wishes.   © 2019 Published by Elsevier Inc. (Am J Cardiol 2019;124:1372−1379)

The use percutaneous coronary interventions (PCI) has become more widespread and there are a growing number of operators who are willing to perform PCI on elderly (≥80 years) patients for both stable coronary disease and acute coronary syndromes (ACS). The octogenarian population is rapidly growing, and these patients are often at the highest risk of procedural complications during PCI which is often attributed to greater prevalence of associated co-morbidities, frailty, complex coronary disease, high bleeding risk, depressed cardiac function, and less tolerance to of dual antiplatelet drugs compared with younger patients.[1,2]

The current guidelines lack clear recommendations regarding coronary interventions for octogenarian patients.[3−5] This is mainly due to insufficient data on PCI outcomes in octogenarian population as many trials exclude these patients, and the available data for long-term outcomes with coronary interventions are limited by small sample sizes.[6] Similarly, a randomized trial looked into the outcomes of patients older than 75 with chronic stable angina showed that revascularization is superior to medical therapy and more cost effective.[7,8] Furthermore, randomized trial and meta-analysis have demonstrated the merit of an early invasive strategy in patients with ACS in this population.[9,10] However, the national trends and outcome in this population not been studied before. Therefore, we sought to study the clinical outcomes, trends, and predictors of mortality in octogenarian patients (≥80 years) who underwent PCI regardless of indication, compared with nonoctogenarian patients (age <80 years).

Method

The National Inpatient Sampling (NIS) database is a publicly available database of hospital discharges in the United States. It contains data from approximately 8 million unweighted hospital stays, representing roughly 20% of

[a]Cleveland Clinic Foundation, Cleveland, Ohio; [b]Wayne State University, Detroit Medical Center, Detroit, Michigan; [c]University of Central Florida, Gainesville, Florida; [d]Beth Israel Harvard University, Boston, Massachusetts; [e]MedStar Washington Hospital Center, Washington, District of Columbia; [f]Creighton University, Omaha, Nebraska; [g]Minneapolis Heart Institute at Abbott Northwestern Hospital, Minneapolis, Minnesota; [h]London Health Sciences Centre, London, Ontario, Canada; [i]Keele Cardiovascular Research Group, Keele University, Stoke-on-Trent, United Kingdom; [j]Royal Stoke University Hospital, Stoke-on-Trent, United Kingdom; and [k]Ascension St John Hospital, Detroit, Michigan. Manuscript received June 12, 2019; revised manuscript received and accepted July 17, 2019.

[#]First and second authors contributed equally.

[*]Corresponding author: Tel: (216) 255-0008.

E-mail address: alraies@hotmail.com (M.C. Alraies).

hospital admissions in the United States.[11] Data from this database have been analyzed and used in different studies reporting trends and inpatient outcomes of disease. This study was exempt from institutional review board evaluation, as the data used are deidentified and publicly available. We queried the NIS database from 2002 to 2014 to identify all adult patients older than 18 years who underwent PCI using the International Classification of Disease, Ninth Edition, Clinical Modification (ICD-9-CM) codes (36.06, 36.07, 00.66). Patients were stratified based on age into 2 groups, ≥80 years old and <80 years old. The patient factors included in the present analysis were age, gender, race, median household income, Elixhauser co-morbidities, and other relevant co-morbidities which include coronary artery disease (CAD), carotid artery disease, previous transient ischemic attack/stroke and smoking. The clinical factors included acuity of the operation (i.e., elective vs urgent/emergent). The system factors included payment status (i.e., Medicare, Medicaid, self-pay or privately insured, or another form of payment), teaching status of the hospital, geographic location of the hospital, and hospital volume. Using the Clinical Classification Software codes provided by the Healthcare Cost and Utilization Project and the Elixhauser Comorbidity Index, co-morbidities were appointed through ICD-9 codes. Supplemental table 1 defines the co-morbidities from the Elixhauser co-morbidity index used in the analysis.

The primary outcome of the study was in-hospital mortality. The secondary outcomes were length of stay (LOS), bleeding requiring blood transfusion, cardiac complications (iatrogenic cardiac complications, complete heart block, and pericardial complications), postoperative stroke, vascular complications (injury to blood vessels accidental puncture, injury to retroperitoneum, other vascular complications, and vascular complications requiring surgery), respiratory complications (pneumothorax, other iatrogenic respiratory complications, and postprocedural aspiration pneumonia), acute kidney injury (AKI), and postprocedural thromboembolic complications.

Statistical analyses were performed on SPSS version 25 software (IBM Corp, Armonk, New York). Continuous variables were expressed as weighted mean values ± standard deviation if normally distributed (median [interquartile range] for skewed data) and frequencies were expressed as percentages. Independent t tests were used for the comparison of continuous variable measurements while chi-square test was utilized for categorical variables. Weighted values of patient-level observations were generated to produce a nationally representative estimate of the entire US population of hospitalized patients. Univariable and multivariable logistic regression analyses were performed to determine the primary and secondary outcomes between octogenarian patients (≥80 years old) and patients less than 80 years old undergoing PCI. The regression model was adjusted for demographics (age, race, and gender), urgency of procedure (elective vs emergent), Elixhauser co-morbidities, other relevant co-morbidities which include CAD, carotid artery disease, previous transient ischemic attack/stroke and smoking, patient insurance, socioeconomic status, and hospital characteristics. Linear regression models were used to assess the LOS. Log transformation of LOS was done to adjust for

positively skewed data. For the trend analysis, the Cochrane-Armitage test was used to assess the presence of a linear trend in the utilization of PCI, mortality, vascular complications, and cardiac complications in octogenarian patients. To further explore our findings, we used multivariable logistic regression to identify predictors of mortality in octogenarian patients. We also performed a subgroup analysis to explore the outcome of octogenarian patients who were diagnosed with ACS and underwent PCI compared with octogenarian patients who were not diagnosed with ACS and underwent PCI. p Value of less than 0.05 was considered statistically significant.

Results

A total of 11,056,559 patients underwent PCI over 12-year time period (between 2002 to 2014); out of which, 9,511,996 (86%) were <80 years old (mean age 62.2 ± 11.0 years, 34% women, 77.3% Caucasian) and 1,544,563 (14%) patients were ≥80 years old (mean age 83.9 ± 3.2 years) majority of which were women (50.1% women) and Caucasians (84.5%). Baseline characteristics are outlined in Table 1.

Octogenarian patients had higher rates of preprocedural stroke, heart failure, chronic lung disease, hypertension, anemia, rheumatoid arthritis, metastatic cancer, and lymphoma (p <0.001 for all). Whereas, patients who were <80 years had high rate of atrial fibrillation, myocardial infarction, coronary artery disease, hyperlipidemia, smoking, alcohol use, drug use, acquired immune deficiency syndrome, depression, diabetes mellitus, and liver disease (p <0.001 for all). Octogenarian patients were more likely to have an elective admission (37.7% vs 35.7%), more likely to have Medicare as a primary expected payer (55.6% vs 49.4%) and less likely to have a median household income in the lowest percentile (26.2% vs 23.5%; p <0.001 for all).

Octogenarians had higher incidence of cardiac complications (3.4% vs 2.4% adjusted Odds Ratio [aOR] 1.07; 95% confidence interval [CI] 1.06 to 1.087, p <0.001), permanent pacemaker implantation (1.4% vs 0.4% aOR 1.94; 95% CI 1.94 to 1.98, p <0.001), respiratory complications (2.8% vs 2.1% aOR 0.92; 95% CI 0.91 to 0.93, p <0.001), postprocedural stroke (6.3% vs 3.8% aOR 1.32; 95% CI 1.32 to 1.33, p <0.001), AKI (8.9% vs 4.6% aOR 1.52; 95% CI 1.50 to 1.53, p <0.001), postprocedural thromboembolic complication (16.7% vs 10.8% aOR 1.24; 95% CI 1.23 to 1.24, p <0.001), and bleeding requiring transfusion (2.1% vs 1.0% aOR 1.30; 95% CI 1.28 to 1.28, p <0.001) compared with patients <80 years old (Table 2). There was no difference in vascular complications between the 2 groups (2.0% vs 1.5% aOR 1.00; 95% CI 0.99 to 1.02, p = 1.021; Figure 2).

After adjusting for demographics, procedure urgency, included co-morbidities, patients' insurance and socioeconomic status, in-hospital mortality was higher in octogenarian group compared with patients who are <80 years old (3.3% vs 1.3% aOR, 1.62; 95% CI 1.60 to 1.64, p <0.001) (Table 2, Figure 1). Risk-adjusted linear regression for LOS showed longer hospital stay in octogenarian patients (median LOS days 3, range 1 to 6 days) when compared

Table 1
Baseline characteristics

Variable	Age (years)		p Value
	≥80 years N = (1,544,563)	<80 years N = (9,511,996)	
Age (Years)	62.2 ± 11.0	83.9 ± 3.2	<0.001
Women	34.0%	50.1%	<0.001
Atrial fibrillation	8.0%	3.0%	<0.001
Smoker	1.5%	2.0%	<0.001
Acute myocardial infarction	34.4%	30.9%	<0.001
Hyperlipidemia	60.1%	52.0%	<0.001
Smoking	22.8%	3.7%	<0.001
Acquired immune deficiency syndrome	0.1%	0.0%	<0.001
Alcohol abuse	2.2%	0.4%	<0.001
Deficiency anemia	9.0%	15.8%	<0.001
Rheumatoid arthritis/collagen vascular disease	1.8%	2.2%	<0.001
Chronic blood loss anemia	0.5%	0.6%	<0.001
Congestive heart failure	2.7%	5.1%	<0.001
Chronic lung disease	16.7%	17.5%	<0.001
Coagulopathy	2.4%	3.4%	<0.001
Depression	5.6%	4.5%	<0.001
Diabetes mellitus, uncomplicated	24.7%	23.9%	<0.001
Diabetes mellitus, complicated	5.5%	0.6%	<0.001
Drug abuse	1.3%	0.1%	<0.001
Hypertension	68.9%	74.3%	<0.001
Hypothyroidism	7.1%	14.1%	<0.001
Liver disease	1.1%	0.3%	<0.001
Metastatic cancer	0.4%	0.5%	<0.001
Fluid and electrolyte disorders	9.5%	13.5%	<0.001
Lymphoma	0.3%	0.5%	<0.001
Obesity	11.8%	3.8%	<0.001
Paralysis	1.0%	1.3%	<0.001
Other neurological disorders	2.7%	4.4%	<0.001
Peripheral vascular disorders	15.7%	22.6%	<0.001
Renal failure	11.0%	18.5%	<0.001
Solid tumor without metastasis	1.1%	1.9%	<0.001
Pulmonary circulation disorders	0.4%	0.8%	<0.001
Psychosis	1.4%	0.9%	<0.001
Peptic ulcer disease	0.1%	0.1%	<0.001
Valvular disease	1.0%	2.7%	<0.001
Weight loss	1.2%	2.1%	<0.001
			<0.001
White	77.3%	84.5%	
Black	9.5%	5.5%	
Hispanic	7.2%	5.4%	
Asian or Pacific Islander	2.0%	1.7%	
Native American	0.6%	0.4%	
Other	3.4%	2.5%	
Elective hospitalization	35.7%	37.7%	<0.001
Primary expected payer			<0.001
Medicare	49.4%	55.6%	
Medicaid	6.5%	5.7%	
Private insurance	36.2%	31.8%	
Self-pay	4.6%	4.0%	
No charge	0.5%	0.4%	
Other	2.8%	2.5%	
Median household income, percentile			<0.001
0 to 25	26.2%	23.5%	
26 to 50	26.5%	26.4%	
51 to 75	24.5%	25.1%	
76 to 100	22.8%	25.0%	
Bed size			<0.001
Small	7.7%	9.0%	
Medium	21.0%	21.2%	
Large	71.3%	69.8%	

(continued)

Table 1 (***Continued***)

| Variable	Age (years)		p Value
	≥80 years N = (1,544,563)	<80 years N = (9,511,996)	
Location/teaching status			<0.001
Rural	5.6%	5.7%	
Urban nonteaching	38.9%	41.5%	
Urban teaching	55.5%	52.8%	
Hospital region			<0.001
Northeast	18.2%	19.5%	
Midwest	24.9%	26.6%	
South	40.5%	35.6%	
West	16.4%	18.3%	

PCI = percutaneous coronary intervention. Hyperlipidemia, coagulopathy, deficiency anemia and obesity were identified using the Elixhauser comorbidities.

Table 2

Outcome of octogenarian patient (≥80 years) undergoing PCI compared with patients who are <80 years old

Outcome	<80 Years	≥80 Years	aOR (95% CI)	Adjusted p Value
Overall (n)	9,511,996	1,544,563		
In-hospital mortality	1.3%	3.3%	1.62 (1.60-1.64)	<0.001
Length of stay, days (median, IQR)	2 (1-4)	3 (1-6)		<0.001
Hemorrhage transfusion	1.0%	2.1%	1.30 (1.28-1.32)	<0.001
Vascular complications	1.5%	2.0%	1.00 (0.99-1.02)	0.486
Cardiac complications	2.4%	3.4%	1.07 (1.06-1.08)	<0.001
Permanent pacemaker implantation	0.4%	1.4%	1.94 (1.90-1.98)	<0.001
Respiratory complications	2.1%	2.8%	0.92 (0.91-0.93)	<0.001
Post-procedural stroke	3.8%	6.3%	1.32 (1.31-1.33)	<0.001
Post-procedural thromboembolic complication	10.8%	16.7%	1.24 (1.23-1.24)	<0.001
Acute kidney injury	4.6%	8.9%	1.52 (1.50-1.53)	<0.001

PCI = percutaneous coronary intervention, Aor = adjusted odds ratio, CI = confidence interval, IQR = interquartile range.
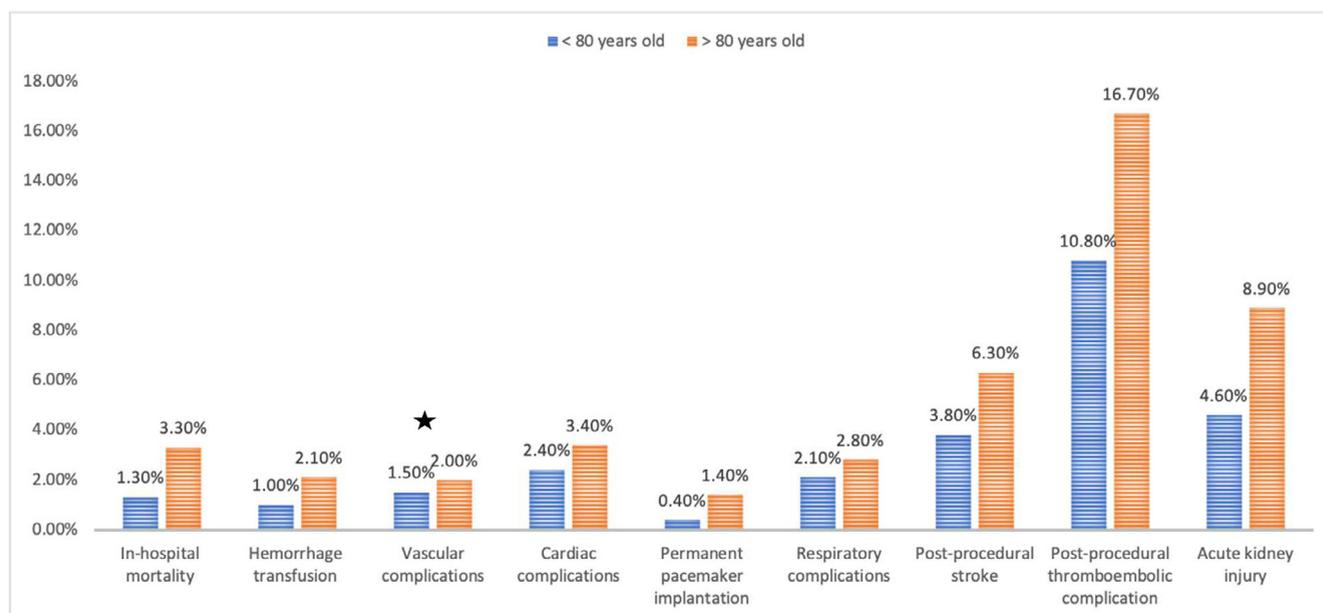
★ P ≥ 0.05

Figure 1. Outcomes rates of percutaneous coronary artery intervention in patients ≥80 years old compared with patients <80 years old.
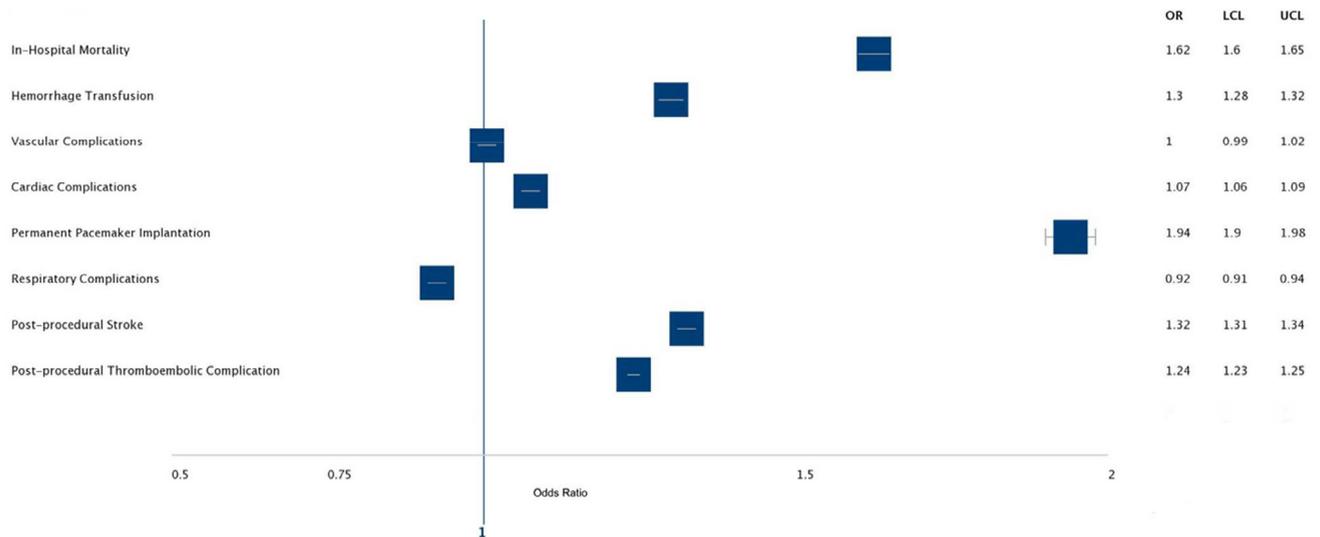
Figure 2. Multivariable logistic regression of the outcomes of percutaneous coronary artery intervention in patients ≥80 years old compared with patients <80 years old.

with <80 years old group (median 2 days, range 1 to 4 days; p <0.001).

Using the Cochrane-Armitage test, we found the utilization of PCI in octogenarian patients had a statistically significant upward trend from 69,597 cases to 109,650 cases between the years 2002 and 2014 (p trend <0.001) (Figure 3). Interestingly, we observed a linear increase in mortality of octogenarian patients undergoing PCI from 3.4% to 4.3% over the studied years. In contrast, vascular complications had a significant downward trend in octogenarian patients who underwent PCI from 1.9% to 1.8% during the study period (p trend <0.001 for all), whereas cardiac complications had no statistically significant trend (p trend = 0.060; Figure 4).

After applying multivariable logistic regression, we found female gender, Asian race, having private insurance or self-pay patients, medium or large hospitals, and weight loss as predictors of increased mortality in octogenarian patients undergoing PCI (Table 3A). Octogenarian patients who were diagnosed with ACS and undergone PCI had higher in-hospital mortality, vascular complications, cardiac complications, bleeding requiring transfusion, permanent pacemaker implantation, respiratory complications, and AKI compared with those who were not diagnosed with ACS (Table 3B).

Discussion

In this study, we demonstrated that there is increase of PCI utilization in octogenarian patients over the course of study period (2002 to 2014). Similarly, the co-morbidities of these patients have been increasing when compared with
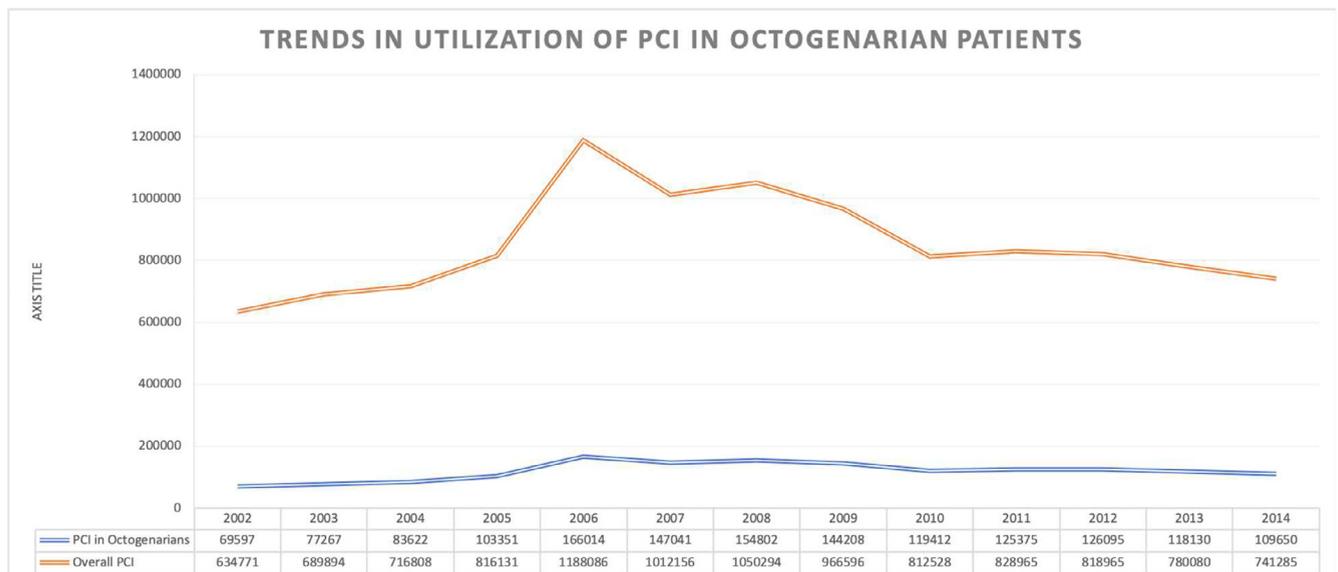

Figure 3. Trends in the utilization of percutaneous coronary interventions in octogenarian (≥80 years) patients.
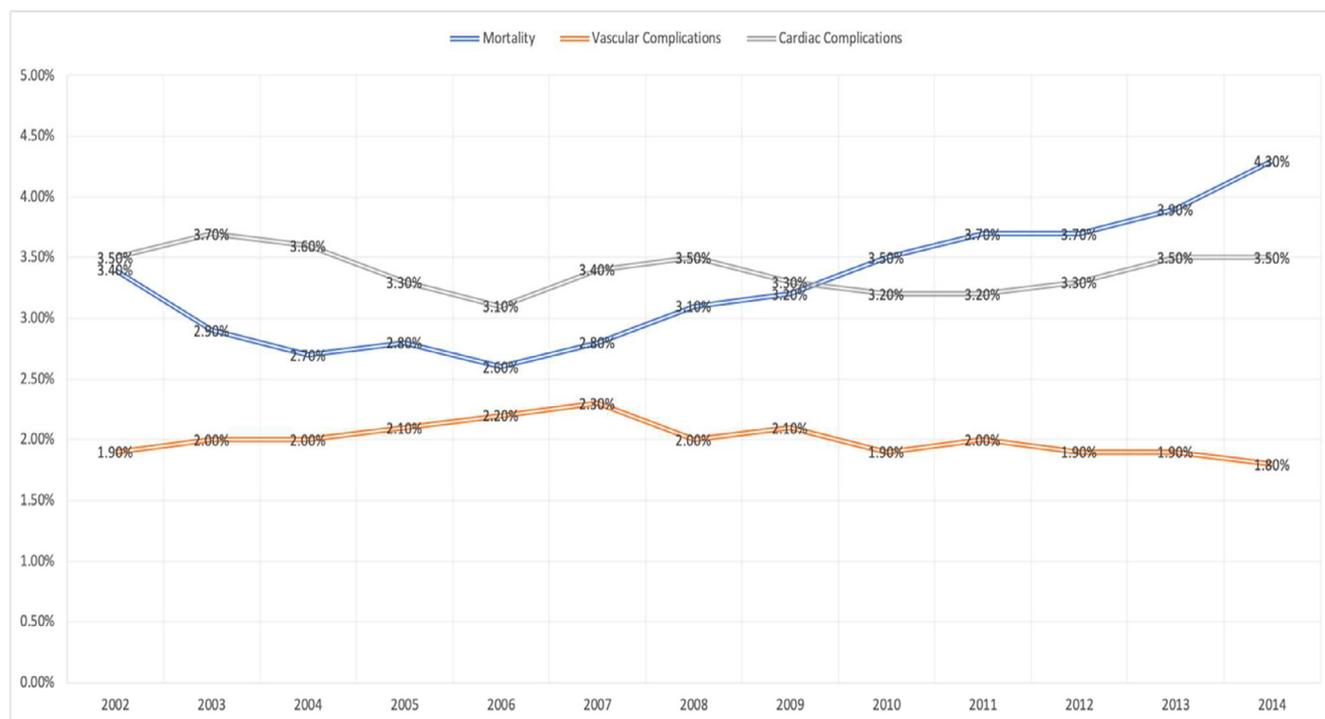
Figure 4. Trends of the outcomes of percutaneous coronary interventions in octogenarian patients.

Table 3
A. Predictors of mortality in patient's ≥80 years undergoing PCI

Outcome	OR	Lower CI	Upper CI	Adjusted p Value
Female	1.20	1.17	1.23	<0.001
Asian race	1.09	1.02	1.17	0.017
Private insurance	1.07	1.02	1.12	0.005
Self-pay	1.25	1.07	1.46	0.004
Medium hospitals	1.15	1.10	1.20	<0.001
Large hospitals	1.13	1.09	1.18	<0.001
Fluid and Electrolyte disorders	3.03	2.97	3.10	<0.001
Weight loss	1.53	1.47	1.60	<0.001

B. Outcome of octogenarian patient (≥80 years) diagnosed with acute coronary syndrome undergoing PCI compared with patients who were not diagnosed with acute coronary syndrome

Outcome	ACS	Non-ACS	aOR (95% CI)	Adjusted p-value
Overall (n)	476,659	1,067,214		
In-hospital mortality	7.3%	1.5%	4.74 (4.62-4.85)	<0.001
Hemorrhage transfusion	2.7%	1.8%	1.41(1.37-1,45)	<0.001
Vascular complications	2.2%	1.9%	1.27(1.23-1.31)	<0.001
Cardiac complications	6.8%	1.9%	4.25(4.15-4.35)	<0.001
Permanent pacemaker implantation	1.8%	1.2%	1.12(1.08-1.16)	<0.001
Respiratory complications	4.5%	2.0%	2.32(2.26-2.38)	<0.001
Acute kidney injury	15.1%	6.1%	2.51(2.47-2.55)	<0.001

ACS = acute coronary syndrome; PCI = percutaneous coronary intervention; Aor = adjusted odds ratio; CI = confidence interval.

patient who are <80 years old. This increase in PCI was associated with higher in-hospital mortality compared with patients who are <80 years old. Due to multiple co-morbidities, octogenarian patients had higher LOS, postprocedural cardiac complications, postprocedural stroke, bleeding requiring transfusion, permanent pacemaker implantation, postprocedural thromboembolic complications, and AKI.

Despite advances in PCI practices, age remains a significant predictor of increased postprocedural complications, in-hospital adverse cardiac events, and all-cause mortality.[12–14] Even though many elderly patients are in good health with minimal co-morbidities, age cannot be ignored when decisions are made about coronary revascularization therapies for stable ischemic and ACS patients. Even though elderly patients usually have a greater ischemic

burden with more complex lesions, there has been some level of physician reluctance in referring them for PCI. Possible reasons for this reluctance include atypical or "silent" presentation, increased prevalence of left bundle-branch block or residual ST-segment elevation from old infarcts, reduced reporting of chest pain, and increased incidence of heart failure on presentation.[15,16] Additional hesitation may stem from utilization of contrast and subsequent, potential contrast-induced nephropathy (CIN). A retrospective analysis of 152,373 patients outlined the incidence of CIN in patients who are 80 to 89 years old to be as high as 4.8%. In contrast, the incidence of CIN in those <80 was <3%.[17] As a secondary end point, this was also demonstrated in our study with elderly patients having 1.5 times the risk of developing AKI after PCI compared with nonelderly patients. The mechanism of increased CIN in octogenarian is due to higher prevalence of more complex coronary lesions that mandate increased contrast volume and worse baseline renal function.[18,19] Furthermore, elderly patients are often frail and thus be more susceptible to stress of procedures because of less physiological reserve such as those patients that are immobile or underweight.

Our results are comparable to previous assessments of revascularization in this age group showing increased in-hospital and long-term mortality in elderly undergoing PCI compared with nonelderly.[5,14,20−22] In our study, in-hospital mortality in elderly was almost twofolds increased compared with nonelderly with longer LOS. Furthermore, multiple studies have shown increased access-related complications in the elderly which drive bleeding rates and blood transfusion. In our study, we found comparable outcomes regarding vascular complications between the 2 groups. Previous studies have shown that age is an independent predictor of bleeding after PCI which is consistent and comparable with our findings using more contemporary data.[23−26]

The consistency in worse outcome in octogenarian patients over the course of many years despite advances in imaging and interventional techniques emphasizes the point that the elderly patients should be approached differently compared with younger population. Radial access to minimize bleeding risk, culprit-only intervention, less use of thrombolytics and glycoprotein IIb/IIIa inhibitors, less contrast volume, proper pre- and post-PCI hydration, discussing goals of care with the patients and their families, and careful patient selection for high risk and long interventions are all important points to keep in mind when referring elderly patients for PCI.

Our study has several limitations. First, this is a retrospective, observational study, and inference regarding causation should be made with caution. Second, using this database, the influence of unmeasured confounders (such as frailty, vascular access site) should be considered when analyzing the outcomes. However, we have included an extensive list of variables that we adjusted for. Third, NIS does not provide data regarding medications which can be important when comparing PCI data. Fourth, we had only in-hospital outcome data with lack of long-term follow-up. Fifth, comparing the outcome of octogenarian patients with CAD treated with medical therapy alone to those who underwent PCI is necessary, however, we could not perform this analysis given the limitation of

NIS data. Finally, NIS is an administrative database which could be subject to inaccurate coding and underreporting of co-morbid diagnoses. However, NIS and the codes used in this study have been applied in multiple clinical studies and can be considered a highly reliable database and giving the large cohort analyzed this minimize the study limitation.

Our study provides a national analysis which builds on the existing data suggesting that octogenarians have worse in-hospital outcomes compared with younger patients. Our study suggests that the number/proportion of patients who are octogenarians who are undergoing PCI has been growing over time and patient outcomes have improved over time. Furthermore, while octogenarians have a greater proportion of patients who have co-morbidities, frailty, and complex coronary disease, we show that there is a subgroup of patients which clearly benefits from undergoing PCI procedures. These findings suggest that decisions to proceed with PCI in octogenarians should be individualized, taking into consideration known risk factors and patient's wishes and patients should not be excluded from PCI solely based on age.

In conclusion, patients of 80 years or more who underwent PCI were at increased risk for in-hospital mortality and morbidity compared with nonelderly. The decision to proceed with PCI in this patient population should be individualized, taking into consideration known risk factors and patient's wishes.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.07.055.

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