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RESEARCH ARTICLE

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In-hospital outcomes of angiography versus intravascular ultrasound-guided percutaneous coronary intervention in ST-elevation myocardial infarction patients

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ABSTRACT

Background: We compared the in-hospital complications, outcomes, cost, and length of stay (LOS) between angiography-guided percutaneous coronary intervention (PCI) and intravascular ultrasound (IVUS)-guided PCI in patients with ST-elevation myocardial infarction (STEMI) in the USA.
Methods: A nationwide inpatient database was queried to identify patients >18 years with STEMI who underwent angiography-guided and IVUS-guided PCI from January 2016 to December 2016. We compared the in-hospital mortality, complications, cost, and LOS between the two groups.
Results: We identified 100,485 patients who underwent angiography-guided PCI and 5,460 patients who underwent IVUS-guided PCI. In-hospital mortality was not statistically different (odds ratio [OR] 0.76, 95% CI 0.46 – 1.22, P = 0.24). Patients who underwent PCI with IVUS were more likely to have coronary artery dissection (OR 4.26, 95% CI 2.34 – 7.7, p = <0.01), and both groups had a similar incidence of acute kidney injury requiring hemodialysis. The mean LOS was similar, but the mean total cost was higher in the group that underwent PCI under IVUS guidance.
Conclusions: The in-hospital mortality, hemodialysis, and the use of support devices did not reach a statistical difference between the two groups. However, we observed higher rates of coronary dissection with the use of IVUS in STEMI management.

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KEYWORDS
IVUS; STEMI; angiography; coronary dissection; mortality

1. Introduction

ST-elevation myocardial infarction (STEMI) is a life-threatening emergency requiring emergent revascularization. Hospitals utilize standard angiography-guided percutaneous coronary intervention (PCI) in the management of STEMI. Intravascular ultrasound (IVUS) has been developed to facilitate the visualization of blood vessels in a 3-dimensional image, which provides a more detailed image compared to the 2-dimensional view provided by fluoroscopy. IVUS utilizes a percutaneous transducer catheter that transmits data to a console that reconstructs the images. It provides real-time measurement of the vessel lumen and helps assess the plaque nature and burden. There have been limited studies evaluating the outcomes of IVUS-guided PCI, especially in high-risk lesions [1]. The use of IVUS has been well established in predicting stent thrombosis [2]. IVUS-guided PCI has been demonstrated to improve the event-free survival in patients with type 2 diabetes mellitus [3]. Recent data from East Asian countries suggest long-term benefit with IVUS guidance, including the reduced incidence of myocardial infarction and death [4–6]. In the USA, the use of IVUS is limited due to particular concerns about the increased stent use; particularly, longer stenting duration that has been reported previously [7]. Some studies reported less contrast use when IVUS was utilized [8]. A recent study in Japan examined angiography-guided PCI versus IVUS-guided PCI in patients with acute myocardial infarction and concluded that the use of IVUS was associated with better in-hospital mortality [9]. In this study, we sought to evaluate the in-hospital complications, outcomes, cost, and length of stay (LOS) in angiography-guided versus IVUS-guided PCI among patients with STEMI in the USA using a large-scale database.

2. Methods

2.1. Study population

We utilized the National Inpatient Database Sample (NIS) of the Health Care Utilization project. The description and design of this database are available

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The supplemental data for this article can be accessed here.

at http://hcup-us.ahrq.gov. The NIS represents a 20% stratified sample of the all-payer inpatient discharges from US community hospitals, excluding rehabilitation facilities. It contains information from more than 1,200 hospitals located all across the US. These data can be generalized to represent 96% of the US population. Due to the blinded nature of the data and retrospective design of the study, consent and IRB approval were not needed.

Data from January 2016 to December 2016 were utilized for this analysis. We identified adult patients (aged ≥18 years) from the NIS database. We used the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) coding system to include patients with STEMI and those who underwent PCI [10,11]. We excluded patients who required coronary artery bypass grafting (CABG) in the same admission as they represent a patient group with a more complex disease that might confound the data (Supplementary Table 1 contains the ICD codes utilized in this analysis and Figure 1 illustrates the selection process).

2.2. Baseline characteristics and outcome variables

The primary outcomes were the impact of IVUS on inpatient mortality in STEMI management. The secondary outcomes consisted of the impact of IVUS on inpatient complications such as acute kidney injury (AKI), the requirement for hemodialysis, coronary artery dissection, AKI requiring hemodialysis, ventricular tachycardia, cardiac arrest, the need for respiratory or circulatory support, length of stay, and total cost.

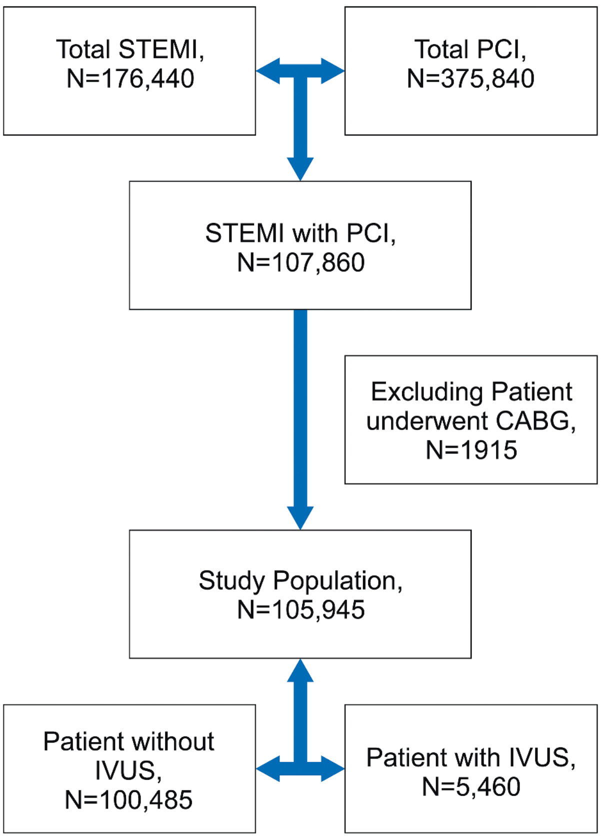

Figure 1. Patient selection and exclusion.

2.3. Statistical analysis

We utilized STATA version 16.0 (StataCorp, College Station, Texas, USA) in our analysis. This software enabled us to generate unbiased results and P values while producing representative data that can be generalized on a national level. We estimated the entire US population of hospitalized patients with STEMI using weighting of patient-level observations and clustering, which was provided by this database. We utilized the multiple imputation method to impute missing observations of the vital variable for the accuracy of the result. We employed propensity score matching and multivariate regression analysis to adjust for confounders. Propensity scores were used to match patients with STEMI who had undergone PCI excluding CABG to those who did not. A non-parsimonious multivariate logistic regression model was developed to estimate the propensity score for the following variables: prior stroke, prior myocardial infarction, prior history of PCI, prior history of CABG, prior congestive heart failure (CHF), pulmonary hypertension, hypertension, obesity, dyslipidemia, peripheral vascular disease, chronic lung disease, anemia, chronic kidney disease, metabolic syndrome, and hypothyroidism. The baseline characteristics pertaining to patients (including age, race, residential location, etc.) and hospitals (location, size, teaching status, etc.) were also included. We matched the two groups using generalized linear models after generating treatment weights and determined the inverse probability of treatment weighting using a double robust method [12]. We adjusted for potential confounders using multivariable regression models including all confounders that were significantly associated with the outcome on univariable analysis with a cutoff P value of 0.2. The model accounted for variables that were deemed essential determinants of the outcomes based on literature review. Logistic regression was used for binary outcomes (in-hospital all-cause mortality, shock, hypertension, and anemia, etc.), whereas linear regression was used for continuous outcomes (LOS, total hospitalization charges, and costs). Proportions were compared using the Fisher's exact test, and continuous variables were compared using the Student t-test. All P values were two-sided, with 0.05 as the threshold for statistical significance.

3. Results

We identified 105,945 patients who met the study criteria; among these patients, 100,485 underwent PCI under angiography guidance alone, and 5,460 patients underwent PCI under IVUS guidance. Subjects in both the groups had a similar age, sex, and ethnic distribution. Patients who underwent IVUS were more likely to have a prior myocardial infarction, pulmonary hypertension, and dyslipidemia than patients who underwent PCI without IVUS. The use of IVUS was notably increased in the southern and western region of the USA (33% and 31%, respectively). Both groups were equally likely to have atrial fibrillation, prior stroke, prior PCI, prior CABG, history of CHF, peripheral vascular disease, diabetes, chronic kidney disease, anemia, metabolic syndrome, smoking, and alcohol consumption. The baseline characteristics of the two groups are depicted in Table 1, and multiple imputation utilization is shown in Table 2.

There was no statistical difference in terms of in-hospital mortality after adjusting for patient-level and hospital-level factors (odds ratio [OR] 0.76, 95% confidence interval (CI) 0.46 − 1.22, P = 0.24); the remaining variables affecting the mortality in STEMI are shown in Table 3. Patients who underwent PCI with IVUS were more likely to have coronary artery dissection (OR 4.26, 95% CI 2.34 − 7.7 p < 0.01), and both groups had a similar incidence of AKI requiring hemodialysis (the complete list of secondary outcomes is provided in Table 4). The mean LOS was similar between both groups (overall mean LOS was 3.51 ± 4.71 days), but the mean total cost was higher in the group that underwent PCI under IVUS guidance (24,541 versus 30,265 US dollars, p < 0.001) as shown in Table 5. Figure 2 summarizes the findings above.

4. Discussion

We evaluated the in-hospital mortality and outcomes in patients with STEMI who underwent angiography-guided versus IVUS-guided PCI using the US national inpatient database. In our study, IVUS was utilized in 5% of the cases. Our main findings were as follows: (1) In-hospital mortality, AKI requiring dialysis, acute stroke, and cardiac arrest were similar in the two groups. (2) Coronary artery dissection was significantly higher in patients who had IVUS-guided PCI. IVUS is a useful ancillary device that is often employed by interventional cardiologists during PCI. It is used to size the stent prior to its implantation and to adjust the stent apposition and expansion post deployment. It also helps to identify complications post stent placement [13,14]. Currently, IVUS holds a class IIa recommendation from the American College of Cardiology/American Heart Association for the evaluation of indeterminate left main lesions and a class IIb recommendation for indeterminate non-left main lesions [15]. Since its introduction in the late 1980s, IVUS has enhanced our understanding of plaque pathology in patients with acute coronary syndromes [16–18]. Studies have shown that IVUS-guided PCI was associated with better cardiovascular outcomes than those of traditional angiography-guided PCI [3–5]. However, there is a lack of evidence and limited studies comparing inpatient outcomes between IVUS-guided PCI and conventional PCI in STEMI patients. A studey suggested an increased incidence of myocardial infarction when IVUS was used [7]. A recent Japanese trial reported results of 6 years' experience of 11,570 consecutive patients who underwent PCI. Similar rates of coronary dissection were observed between the traditional angiography group and the IVUS-assisted PCI group, including similar myocardial infarction rates [19]. Our study did not yield a statistical difference between the two study groups in terms of mortality during hospitalization. A previous study examined the amount of contrast agents used during PCI and suggested the possibility of controlling the amount of contrast media when IVUS was utilized [8]. We examined the rates of AKI and did not observe a statistical difference between the two groups, even after applying propensity matching.

Our analysis showed a statistically significant difference in the rate of coronary dissection in patients undergoing IVUS with a fourfold increase in the OR. This increase might be due to factors related to the culprit lesion. As angiography is an invasive procedure; therefore, it is considered operator dependent, and the complications can be attributed to the different techniques used during the procedure. IVUS has been widely used to assist in the diagnosis of spontaneous coronary artery dissection due to better visualization of the flap or intramural hematoma [20]. The high number of coronary artery dissection cases observed in the IVUS group may be due to a primary spontaneous coronary artery dissection (SCAD) presenting as a STEMI, rather than an iatrogenic dissection caused by the procedure. Available literature reported a general complication rate of 0.5% to 4% when IVUS is used. The reported complications included coronary spasms, coronary dissection, femoral artery aneurysms, and rarely coronary rupture [1]. SIPS trial reported similar coronary dissection in 3% of the cases where IVUS was utilized and 3.2% in angiography arm [21].

Table 1. Patient demographics and baseline characteristics.

	Total population	STEMI without IVUS	STEMI with IVUS	P value
Total population (N)	105,945	100,485	5,460	
Age in years ± SD	62 ± 12.47	62 ± 12.50	61 ± 11.83	
Female	30,682 (28.96)	29,171 (29.03)	1,515 (27.75)	0.398
Race (%)				0.563
White	82,023 (77.42)	77,785 (77.41)	4,246 (77.76)	
Black	8,370 (07.90)	7,979 (07.94)	390 (07.15)	
Hispanic	8,338 (07.87)	7,938 (07.90)	401 (07.35)	
Asian	2,978 (02.81)	2,804 (02.79)	174 (03.18)	
Native American	530 (00.50)	482 (00.48)	49 (00.89)	
Others	3,697 (03.49)	3,507 (03.49)	200 (03.67)	
Insurance				0.021
Medicare (%)	44,476 (41.98)	42,415 (42.21)	2,073 (37.97)	
Medicaid (%)	11,569 (10.92)	11,003 (10.95)	559 (10.24)	
Private (%)	42,823 (40.42)	40,355 (40.16)	2,469 (45.21)	
Self-pay (%)	7,077 (06.68)	6,712 (06.68)	359 (06.58)	
Urban location (%)	99,860 (94.26)	94,745 (94.29)	5,115 (93.68)	0.718
Teaching hospitals (%)	70,285 (66.34)	66,685 (66.36)	3,600 (65.93)	0.882
Hospital bed size (%)				0.346
Small	13,970 (13.19)	13,245 (13.18)	725 (13.28)	
Medium	30,795 (29.07)	29,400 (29.26)	1,395 (25.55)	
Large	61,180 (57.75)	57,840 (57.56)	3,340 (61.17)	
Hospital region (%)				<0.001
Northeast	17,185 (16.22)	16,500 (16.42)	685 (12.55)	
Midwest	25,390 (23.97)	24,135 (24.02)	1,255 (22.99)	
South	42,700 (40.30)	40,880 (40.68)	1,820 (33.33)	
West	20,670 (19.51)	18,970 (18.88)	1,700 (31.14)	
Median household income in US dollars (%)				0.256
$1 – $38,999	28,965 (27.34)	27,613 (27.48)	1,351 (24.74)	
$39,000 – $47,999	28,616 (27.01)	27,191 (27.06)	1,417 (25.96)	
$48,000 – $62,999	26,486 (25.00)	25,001 (24.88)	1,484 (27.18)	
$63,000 or more	21,888 (20.66)	20,680 (20.58)	1,208 (22.12)	
Disposition (%)				0.178
Routine	87,210 (82.41)	82,570 (82.27)	4,640 (84.98)	
Transfer to short-term hospital	2,490 (02.35)	2,375 (02.37)	115 (02.11)	
Skilled nursing facility	4,990 (04.72)	4,770 (04.75)	220 (04.03)	
Home health care	5,595 (05.29)	5,300 (05.28)	295 (05.40)	
Against Medical Advice	710 (00.67)	680 (00.68)	30 (00.55)	
Deceased	4,820 (04.55)	4,660 (04.64)	160 (02.93)	
Unknown	10 (00.01)	10 (00.01)	0 (00.00)	
Carlson CAT score (%)				0.985
1	40,315 (38.05)	38,250 (38.07)	2,065 (37.82)	
2	34,505 (32.57)	32,725 (32.57)	1,780 (32.60)	
3 or more	31,125 (29.38)	29,510 (29.37)	1,615 (29.58)	
Chronic comorbidities (%)				
Atrial fibrillation	10,970 (10.35)	10,405 (10.35)	564 (10.35)	0.994
Prior stroke	4,665 (04.40)	4,375 (04.35)	290 (05.31)	0.122
Prior myocardial infarction	11,510 (10.86)	10,765 (10.71)	745 (13.64)	0.003
Prior PCI	13,055 (12.32)	12,345 (12.29)	710 (13.00)	0.491
Prior CABG	3,625 (03.42)	3,445 (03.43)	180 (03.30)	0.821
Chronic heart failure	2,535 (02.39)	2,395 (02.38)	140 (02.56)	0.731
Pulmonary HTN	1,910 (01.80)	1,750 (01.74)	160 (02.93)	0.004
Hypertension	61,525 (58.07)	58,240 (57.96)	3,285 (60.16)	0.137
Obesity	17,525 (16.54)	16,515 (16.44)	1,010 (18.50)	0.096
Dyslipidemia	69,870 (65.95)	66,055 (65.74)	3,815 (69.87)	0.008
Peripheral vascular disease	4,120 (03.89)	3,910 (03.89)	210 (03.85)	0.940
Chronic lung disease	5,915 (05.58)	5,550 (05.52)	365 (06.68)	0.110
Diabetes mellitus	31,770 (29.99)	30,145 (30.00)	1,625 (29.76)	0.868
Chronic kidney disease	9,445 (08.92)	8,935 (08.89)	510 (09.34)	0.614
Anemia	1,445 (01.36)	1,360 (01.35)	85 (01.56)	0.567
Coronary artery disease equivalent	90,735 (85.64)	85.990 (85.57)	4,745 (86.90)	0.257
Metabolic syndrome	440 (00.42)	410 (00.41)	30 (00.55)	0.467
Hypothyroidism	8,685 (08.20)	8,170 (08.13)	515 (09.43)	0.112
Smoking	21,620 (20.41)	20,480 (20.38)	1,140 (20.88)	0.712
Cocaine	775 (00.73)	725 (00.72)	50 (00.92)	0.449
Alcohol	845 (00.80)	815 (00.81)	30 (00.55)	0.339

STEMI: ST-elevation myocardial infarction; IVUS: intravascular ultrasound; HTN: Hypertention.

5. Study limitations

We identified a few limitations to our study that deserve to be highlighted. First, we identified data from the NIS with variables that are subject to coding system errors. Nevertheless, the NIS has been heavily utilized for research in various medical subspecialties and is considered a validated tool. Second, the retrospective observational nature of the study design, despite the propensity matching, may result in residual selection bias and confound the results. Third, the data we analyzed lacked information on the types of stents used, the culprit vessel, TIMI flow, stent

Table 2. Missing observation generated with multiple imputation.

Missing values generated with multiple imputation	
Variable	Number of missing values generated
Median household income (ZIPINC_QRTL)	427
Age	1
Deceased	25
Female	10
Insurance (PAY1)	34
Race	1185

ZIPINC_QRTL.

sizing, and the number of vessels revascularized. Therefore, the beneficial effect of IVUS may be underestimated in this retrospective analysis given that the IVUS group consisted of only 5% of the total population studied.

Fourth, no information was present on whether the coronary dissection was the primary cause of the STEMI or was a complication of the procedure. Fifth, the database does not provide information on outcomes post discharge and long-term sequelae

Table 3. Multivariate non-propensity- and propensity-matched analysis showing the effect of IVUS on mortality in patients with STEMI undergoing PCI with stenting, excluding CABG.

	Non-propensity matched			Propensity matched		
Variable	Odds ratio	P > t	95% CI	Odds ratio	P > t	95% CI
IVUS	0.671	0.035	0.46–0.97	0.746	0.247	0.46–1.22
AGE	1.046	0.000	1.04–1.05	1.045	0.000	1.03–1.06
Insurance						
Medicaid	1.157	0.294	0.88–1.52	1.040	0.844	0.70–1.54
Private	0.730	0.003	0.59–0.90	0.616	0.000	0.47–0.80
Self-pay	1.187	0.321	0.85–1.67	0.795	0.310	0.51–1.24
Hospital region						
Midwest	1.272	0.049	1.00–1.62	1.275	0.185	0.89–1.83
South	1.349	0.006	1.09–1.67	1.265	0.158	0.91–1.75
West	1.504	0.001	1.19–1.89	1.091	0.614	0.78–1.53
Urban location	1.445	0.026	1.04–2.00	2.254	0.001	1.40–3.63
Atrial fibrillation	1.915	0.000	1.60–2.29	2.210	0.000	1.75–2.78
Prior stroke	0.933	0.654	0.69–1.26	1.220	0.338	0.81–1.83
Prior myocardial infarction	0.791	0.070	0.61–1.02	0.808	0.230	0.57–1.14
Prior CABG	1.093	0.603	0.78–1.53	1.503	0.124	0.89–2.53
Pulmonary hypertension	1.129	0.567	0.74–1.71	2.135	0.018	1.14–4.01
Obesity	1.018	0.864	0.83–1.25	1.067	0.672	0.79–1.44
Dyslipidemia	0.362	0.000	0.31–0.42	0.275	0.000	0.22–0.34
Peripheral vascular disease	2.064	0.000	1.60–2.66	2.211	0.000	1.59–3.07
Diabetes mellitus	1.707	0.000	1.47–1.98	1.858	0.000	1.50–2.30
Chronic heart failure	0.970	0.884	0.65–1.46	0.641	0.118	0.37–1.12
Chronic kidney disease	1.338	0.003	1.11–1.62	1.660	0.000	1.28–2.16
Coronary artery disease equivalent	0.640	0.000	0.54–0.76	0.590	0.000	0.45–0.77
Metabolic syndrome	0.283	0.189	0.04–1.86	0.024	0.000	0.00–0.18
Hypothyroidism	0.850	0.182	0.67–1.08	0.941	0.701	0.69–1.29
Cocaine	0.613	0.418	0.19–2.00	0.598	0.395	0.18–1.96

IVUS: intravascular ultrasound; CABG: coronary artery bypass grafting.

Table 4. Secondary outcome percentage with odds ratio.

Variable	Total population	STEMI & PCI without IVUS	STEMI & PCI with IVUS	P value	OR(CI) P value: non-propensity matched	OR(CI) P value: propensity matched
Mechanical ventilation	8,840 (08.34)	8,464 (08.65)	375 (06.87)	0.086	0.79 (0.60–1.03) 0.08	0.87 (0.64–1.17) 0.35
Pressure support requirement	1,410 (01.33)	1,320 (01.31)	90 (01.65)	0.357	1.16 (0.70–1.92) 0.57	1.16 (0.63–2.10) 0.64
Complete heart block	2,965 (02.80)	2,785 (02.77)	180 (03.30)	0.274	1.20 (0.87–1.67) 0.27	1.26 (0.86–1.83) 0.23
Hemorrhage	620 (00.59)	575 (00.57)	45 (00.82)	0.286	1.38 (0.67–2.85) 0.39	-
Blood transfusion	1,590 (01.50)	1,510 (01.50)	80 (01.47)	0.918	1.03 (0.62–1.69) 0.91	0.66 (0.36–1.22) 0.19
Hemorrhage requiring BT	70 (00.07)	65 (00.06)	5 (00.09)	0.737	1.61 (0.22–11.69) 0.64	-
Coronary artery dissection	985 (00.93)	835 (00.83)	150 (02.75)	<0.001	3.44 (2.30–5.16) <0.01	4.26 (2.34–7.77) <0.01
Left ventricular assist devices	8,145 (07.69)	7,710 (07.67)	435 (07.97)	0.726	1.02 (0.81–1.29) 0.85	1.02 (0.80–1.31) 0.88
Extracorporeal membrane oxygenation	265 (00.25)	255 (00.25)	10 (00.18)	0.650	0.75 (0.17–3.25) 0.70	-
Acute kidney injury	10,375 (09.79)	9,830 (09.78)	545 (09.98)	0.837	1.02 (0.81–1.28) 0.89	1.15 (0.89–1.47) 0.28
Hemodialysis	1,270 (01.20)	1,205 (01.20)	65 (01.10)	0.982	0.96 (0.51–1.81) 0.90	-
AKI requiring hemodialysis	290 (00.27)	270 (00.27)	20 (00.37)	0.549	1.43 (0.52–3.94) 0.49	-
Acute stroke	215 (00.20)	205 (00.20)	10 (00.18)	0.882	0.96 (0.24–3.77) 0.95	-
Respiratory failure	3,950 (03.73)	3,795 (03.78)	155 (02.84)	0.137	0.75 (0.50–1.12) 0.16	0.76 (0.48–1.19) 0.23
Ventricular tachycardia	18,120 (17.10)	17,165 (17.08)	955 (17.49)	0.731	0.98 (0.83–1.16) 0.78	0.96 (0.83–1.11) 0.59
Cardiac arrest	5,770 (05.45)	5,495 (05.47)	275 (05.04)	0.548	0.90 (0.67–1.20) 0.46	0.82 (0.61–1.12) 0.21

STEMI: ST-elevation myocardial infarction; IVUS: intravascular ultrasound; percutaneous coronary intervention; BT: Blood Transfusion.

Table 5. Mean hospital stay and total hospitalization cost in US dollars.

Variable	Overall STEMI & PCI	STEMI + PCI without IVUS	STEMI + PCI with IVUS	Non-propensity-matched P value	Propensity-matched P value
Median LOS (Days)	3.51 ± 4.71	3.51 ± 4.76	3.61 ± 3.61	0.175	0.174
Mean total cost (US $)	24,836	24,541	30,265	<0.001	<0.001

STEMI: ST-elevation myocardial infarction; IVUS: intravascular ultrasound; percutaneous coronary intervention; LOS: length of stay.

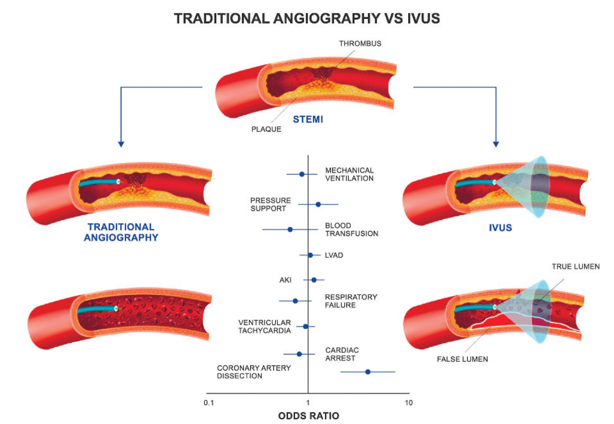

Figure 2. Summary of the findings.

such as stent thrombosis. Lastly, our cost analysis did not include the expenses of short- and long-term rehabilitation facilities (if any), which may have led to an underestimation of the total medical expenditure.

6. Conclusions

This is the first study evaluating the in-hospital outcomes of standard PCI versus IVUS-guided PCI in patients with STEMI. We did not observe any statistical difference in the in-hospital mortality, hemodialysis, or use of support devices, even when IVUS was employed. In contrast, a higher number of coronary dissection cases were observed in the group with IVUS utilization in STEMI management. Despite the findings in our study, IVUS has been shown to provide valuable diagnostic information. Given the high cost of hospitalization associated with the use of IVUS, a large prospective randomized trial further examining the differences between the two groups is required in the future.

Disclosure statement

No potential conflict of interest was reported by the authors.

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