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Original Article

Comparison of prognosis between intravascular ultrasound-guided and angiography-guided percutaneous coronary intervention in patients with acute coronary syndrome

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Abstract: Objective: To compare the prognosis of intravascular ultrasound (IVUS)-guided versus angiography-guided percutaneous coronary intervention (PCI) in patients with acute coronary syndrome (ACS). Methods: This retrospective cohort study included 190 ACS patients who underwent PCI between January 2019 and January 2024. Patients were equally divided into two groups: IVUS-guided (n=95) and angiography-guided PCI (n=95). Baseline characteristics, procedural details, and clinical outcomes were analyzed. Follow-up duration was one year. Primary endpoints included cardiac function parameters, target vessel-related events, major adverse cardiovascular and cerebrovascular events , and quality of life (QoL) measures. Results: The IVUS-guided group demonstrated better procedural outcomes, with significantly lower stent volume (P=0.002) and reduced neointima volume at 9 months (P=0.002). Improvements in cardiac function were more notable in the IVUS group, reflected in lower post-treatment left ventricular end-diastolic volume index (P=0.004) and end-systolic volume index (P=0.003). QoL scores were significantly higher in physical function (P=0.001) and social function (.002). However, IVUS-guided procedures required longer procedural time and greater contrast media use. Conclusion: IVUS-guided PCI yields superior procedural precision, improved cardiac function, and better quality of life compared to angiography-guided PCI in ACS patients, with acceptable trade-offs in procedural complexity.

Keywords: Intravascular ultrasound, percutaneous coronary intervention, acute coronary syndrome, angiography-guided, cardiac function, quality of life

Introduction

Acute coronary syndrome (ACS) remains a leading cause of global morbidity and mortality, encompassing a spectrum of conditions characterized by sudden reductions in myocardial blood flow, ranging from unstable angina to acute myocardial infarction (AMI). Despite advances in prevention, diagnosis, and treatment, ACS continues to present a significant clinical challenge due to its complex pathophysiology and acute life-threatening potential [1-3].

Timely medical intervention is critical in ACS management, with percutaneous coronary intervention (PCI) serving as a cornerstone of reperfusion therapy. PCI, which mechanically restores blood flow in occluded coronary arteries, is widely favored for its effectiveness in improving patient outcomes. Traditionally, angiography-guided PCI has been the standard approach [4-6]. However, intravascular ultrasound (IVUS)-guided PCI has emerged as a promising alternative, particularly for complex lesions often seen in ACS.

Coronary angiography provides a two-dimensional view of the coronary anatomy through contrast dye injection and X-ray imaging, but its resolution is limited in assessing detailed lesion morphology. In contrast, IVUS employs high-frequency sound waves to produce detailed cross-sectional images of the vessel lumen and wall, enabling precise evaluation of plaque burden, stent expansion, and apposition. This enhanced visualization has been associated with optimized stent deployment and improved detection of post-procedural complications [7, 8].

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Several studies report that IVUS-guided PCI may reduce restenosis rates and major adverse cardiovascular and cerebrovascular events (MACCE) compared to angiography-guided PCI [9-11], primarily due to more accurate lesion assessment and stent placement.

Despite these advantages, IVUS is not yet widely adopted in routine practice due to factors such as higher procedural cost, longer operation time, and the need for specialized expertise [12, 13]. Clinical guidelines increasingly recognize the utility of IVUS-guided PCI in complex scenarios, including left main disease, chronic total occlusions, and multivessel involvement - features frequently encountered in ACS [14, 15]. However, evidence remains limited regarding direct prognostic comparisons between IVUS-guided and angiography-guided PCI specifically in ACS populations. This retrospective cohort study aims to address this gap by evaluating and comparing the prognosis of IVUS-guided versus angiography-guided PCI in patients with ACS.

Materials and methods

Ethics statement

This study was reviewed and approved by the Institutional Review Board and Ethics Committee of Hankou Hospital of Wuhan. Only de-identified patient data were used, posing no risk to patient care.

Clinical setting

This retrospective analysis included 190 patients who underwent PCI at Hankou Hospital of Wuhan between January 2019 and January 2024. All patients were followed for one year. Based on the type of procedural guidance, patients were divided into two groups: the IVUS-guided group (n=95) and the angiography-guided group (n=95). Data were collected from the hospital's electronic medical records.

Eligibility criteria

Inclusion criteria: Patients were eligible if they: (1) met the American College of Cardiology/American Heart Association (ACC/AHA) criteria for ACS and underwent PCI [16]; (2) were aged ≥18 years; (3) had clear consciousness and no communication impairments; (4) had normal cognitive function; and (5) had complete and adequate clinical data.

Exclusion criteria: Patients were excluded if they: (1) had severe organ dysfunction (e.g., hepatic or renal failure); (2) had uncontrolled hypertension(systolic blood pressure >180 mmHg or diastolic blood pressure >110 mmHg); (3) were in critical condition (e.g., acute heart failure, multi-organ failure, or shock); (4) had severe comorbidities such as malignancies or autoimmune disorders; (5) had known hypersensitivity or contraindications to contrast agents; (6) were pregnant or lactating; or (7) had incomplete clinical records.

Baseline characteristics and procedural details

Baseline characteristics, including age, sex, body mass index (BMI), diagnosis, prior medications, and other relevant variables, were obtained from medical records. Intraoperative details and perioperative complications were recorded and analyzed accordingly.

Optical Frequency Domain Imaging (OFDI) follow-up angiography

Postoperative and 9-month follow-up OFDI was performed using the Optis Coronary Imaging System (Terumo, Japan). Catheter selection was based on individual vascular anatomy. A standardized guiding catheter and automatic pullback system were used to capture high-resolution vessel images, which were stored for offline analysis. Three software packages were utilized: QAngio XA (Medis Medical Imaging), Lunawave (Terumo Corporation), and echoPlaque (INDEC Medical Systems). Analysts were blinded to clinical data, lesion characteristics, and treatment allocation. Evaluated parameters included stent edge dissection, hematoma, plaque protrusion, and thin-cap fibroatheroma. In-stent tissue protrusion was categorized as smooth, fractured fibrous tissue, or irregular.

Cardiac function assessment

Cardiac function was evaluated by color Doppler echocardiography (Vivid E95, GE Healthcare, USA) one day before and three months

after PCI. The modified Simpson's method was used to measure left ventricular end-diastolic volume index (LVEDVI), end-systolic volume index (LVESVI), left ventricular mass index (LVMI), and left ventricular ejection fraction (LVEF). For patients in sinus rhythm, measurements were averaged over three cardiac cycles; for those with atrial fibrillation, four cycles were used.

Target vessel-related and cardiocerebrovascular events

Data on target vessel-related complications - including target vessel failure, repeat revascularization, contrast-induced nephropathy, and definite stent thrombosis - were extracted from medical records. Additional adverse events such as myocardial infarction, stroke, heart failure, unstable angina, and significant arrhythmias were recorded. Follow-up data were collected during 12-month outpatient visits.

Quality of life assessment

At three months post-procedure, quality of life was assessed across four domains: physical function, social function, activities of daily living, and psychological well-being. Each domain was scored on a 0-100 scale, with higher scores indicating better outcomes. This comprehensive assessment aimed to evaluate the broader impacts of the interventions on patients' overall health and daily life.

Outcome measures

Primary outcome measures included cardiac function parameters - specifically LVEDVI and LVESVI - target vessel-related events (e.g., target vessel failure and repeat revascularization), and MACCE.

Secondary outcomes included quality of life assessments across physical, social, functional, and psychological domains.

Statistical analysis

All statistical analyses were performed using SPSS version 29.0 (SPSS Inc., Chicago, IL, USA). Graphs and figures were generated using GraphPad Prism version 9.0 (GraphPad Software, San Diego, CA, USA). Categorical variables were presented as counts and percentages [n (%)]. Fisher's exact test was applied when expected cell counts were <5; otherwise, Pearson's χ^2 test was used. Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed data were expressed as mean ± standard deviation (M ± SD) and analyzed using independent samples t-tests; non-normally distributed data were reported as median [interquartile range, IQR] and compared using the Mann-Whitney U test. A *p*-value <0.05 was considered statistically significant.

Results

Comparison of baseline characteristics

Baseline characteristics were well balanced between the groups (**Table 1**). No significant differences were found in demographic variables, cardiovascular risk factors, clinical presentation, family history, medical history, baseline cardiac function, or discharge medications (aspirin and P2Y12 inhibitors) (all P>0.05). This comparability minimizes potential confounding in subsequent outcome analyses.

Comparison of procedural and anatomical characteristics

Distribution of diseased vessels and lesion locations were similar between the groups (P= 0.985 and P=0.907, respectively; **Table 2**). The mean number of lesions treated per patient was also comparable (P=0.853). However, the IVUS-guided group required a significantly greater volume of contrast media (P=0.047) and had longer procedural times (P=0.031). A non-significant trend toward larger stent diameters was observed in the IVUS-guided group (P= 0.053).

Comparison of periprocedural complications

Periprocedural complication rates were similar between groups. No significant differences were noted in life-threatening arrhythmias, coronary dissection, coronary spasm, or side branch occlusion (all P>0.05) (**Table 3**). Although distal embolization occurred more frequently in the angiography-guided group, this did not reach statistical significance (P=0.151). Notably, no cases of acute coronary occlusion were reported in either group (P=1.000), indicating a favorable safety profile for both guidance methods.

Table 1. Comparison of baseline characteristics

Indicator	IVUS-guided group (n=95)	Angiography-guided group (n=95)	t/χ^2	P
Age	64.57±9.53	65.35±9.16	0.580	0.562
Sex			0.035	0.852
Female	17 (17.89%)	18 (18.95%)		
Male	78 (82.11%)	77 (81.05%)		
BMI	22.74±3.32	22.95±3.41	0.442	0.659
Current smoker	29 (30.53%)	27 (28.42%)	0.101	0.750
Current drinker	31 (32.63%)	32 (33.68%)	0.024	0.878
Clinical presentation			0.142	0.932
ST-segment elevation myocardial infarction	54 (56.84%)	53 (55.79%)		
Non-ST-segment elevation myocardial infarction	24 (25.26%)	23 (24.21%)		
Unstable angina	17 (17.89%)	19 (20.00%)		
Family history of CAD	9 (9.47%)	10 (10.53%)	0.058	0.809
Medical history				
Diabetes mellitus	35 (36.84%)	37 (38.95%)	0.089	0.765
Hypertension	47 (49.47%)	49 (51.58%)	0.084	0.772
Hyperlipidemia	43 (45.26%)	42 (44.21%)	0.021	0.884
Previous MI	5 (5.26%)	6 (6.32%)	0.096	0.756
Previous stroke	6 (6.32%)	5 (5.26%)	0.096	0.756
LVEF (%)	57.58±10.74	58.12±10.43	0.355	0.723
Creatinine, μmol/L	86.89±16.46	87.49±17.37	0.244	0.808
Initial diagnosis	83 (87.37%)	82 (86.32%)	0.046	0.830
Recurrence	12 (12.63%)	13 (13.68%)		
Medication at discharge				
Aspirin	92 (96.84%)	92 (96.84%)	0.172	0.678
P2Y12 inhibitor	90 (94.74%)	91 (95.79%)	0.117	0.732
Statin	87 (91.58%)	85 (89.47%)	0.245	0.620
Beta-blocker	36 (37.89%)	35 (36.84%)	0.022	0.881

Body mass index (kg/m^2); CAD: coronary artery disease; MI: myocardial infarction; LVEF: Left ventricular ejection fraction; IVUS: intravascular ultrasound.

Table 2. Comparison of procedural and anatomical features

Indicator	IVUS-guided group (n=95)	Angiography-guided group (n=95)	t/χ^2	P
Number of diseased vessels			0.030	0.985
Single-vessel disease	31 (32.63%)	30 (31.58%)		
Double-vessel disease	36 (37.89%)	37 (38.95%)		
Triple-vessel disease	28 (29.47%)	28 (29.47%)		
Location			0.196	0.907
Proximal	32 (33.68%)	34 (35.79%)		
Mid	53 (55.79%)	50 (52.63%)		
Distal	10 (10.53%)	11 (11.58%)		
Total no. of target lesions treated	1.58±0.74	1.60±0.77	0.186	0.853
Volume of contrast media used, ml	202.29±108.54	171.76±101.32	2.004	0.047
Procedural time, min	67.42±22.85	60.59±20.31	2.177	0.031
Stent diameter, mm	3.25±0.22	3.18±0.27	1.952	0.053

IVUS: intravascular ultrasound.

Table 3. Comparison of peri procedural complications

Indicator	IVUS-guided group (n=95)	Angiography-guided group (n=95)	t/χ^2	P
Life-threatening arrhythmia	3 (3.16%)	3 (3.16%)	0.172	0.678
Coronary dissection	1 (1.05%)	2 (2.11%)	0.339	0.560
Coronary spasm	1 (1.05%)	1 (1.05%)	0.503	0.477
Distal embolisation	4 (4.21%)	9 (9.47%)	2.064	0.151
Side branch occlusion	4 (4.21%)	3 (3.16%)	0.148	0.700
Acute coronary occlusion	0 (0%)	0 (0%)	None	1.000

IVUS: intravascular ultrasound.

Table 4. Comparison of stent deployment and tissue protrusion

Indicator	IVUS-guided group (n=95)	Angiography-guided group (n=95)	t/χ^2	P
In-stent segment (3D analysis)				
Stent volume, mm^3	193.49±46.75	215.13±48.56	3.129	0.002
Stent volume index, mm^3/mm	6.87±1.08	7.36±1.27	2.881	0.004
Lumen volume, mm^3	197.32±46.47	217.57±48.82	2.928	0.004
Lumen volume index, mm^3/mm	6.97±1.17	7.25±1.29	1.618	0.107
Tissue protrusion				
Quantitative tissue protrusion analysis				
Tissue protrusion volume, mm^3	7.64±1.92	8.37±1.87	2.637	0.009
Mean tissue protrusion area, mm^2	0.38±0.11	0.41±0.13	1.893	0.060
Classification of tissue protrusion				
Smooth protrusion	51 (53.68%)	42 (44.21%)	1.706	0.192
Disrupted protrusion	39 (41.05%)	19 (20.00%)	9.927	0.002
Irregular protrusion	85 (89.47%)	93 (97.89%)	5.693	0.017
Quantitative irregular protrusion analysis				
Number of irregular protrusions	1.81±0.62	2.15±0.87	3.125	0.002
Irregular protrusion volume, mm^3	2.93±1.21	3.52±1.59	2.863	0.005
Mean irregular protrusion area, mm^2	0.41±0.11	0.45±0.08	3.181	0.002
Max irregular protrusion length, mm	6.95±2.05	8.17±3.22	3.129	0.002
Max irregular protrusion area, mm^2	0.72±0.21	0.79±0.18	2.338	0.020
Max irregular protrusion thickness, mm	0.43±0.09	0.45±0.11	1.025	0.307
Stent edge dissection and haematoma				
Overall stent edge dissection	10 (10.53%)	21 (22.11%)	4.664	0.031
Proximal edge dissection	4 (4.21%)	17 (17.89%)	9.048	0.003
Distal edge dissection	7 (7.37%)	12 (12.63%)	1.462	0.227
Haematoma	2 (2.11%)	3 (3.16%)	0.205	0.650

IVUS: intravascular ultrasound.

Comparison of stent deployment and tissue protrusion

The IVUS-guided group had significantly lower stent volume (P=0.002), stent volume index (P=0.004), and lumen volume (P=0.004) compared to the angiography-guided group (**Table 4**). Although the lumen volume index difference was not statistically significant (P=0.107), the IVUS-guided group exhibited significantly less tissue protrusion volume (P=0.009). Disrupted protrusions were more frequent (P=0.002), while irregular protrusions were less common (P=0.017), with reduced frequency (P=0.002) and volume (P=0.005). Maximum area and length of irregular protrusions were also significantly smaller in the IVUS-guided group (both P<0.05). Furthermore, stent edge dissections, particularly at the proximal edge, occurred less frequently in the IVUS-guided group (proximal:

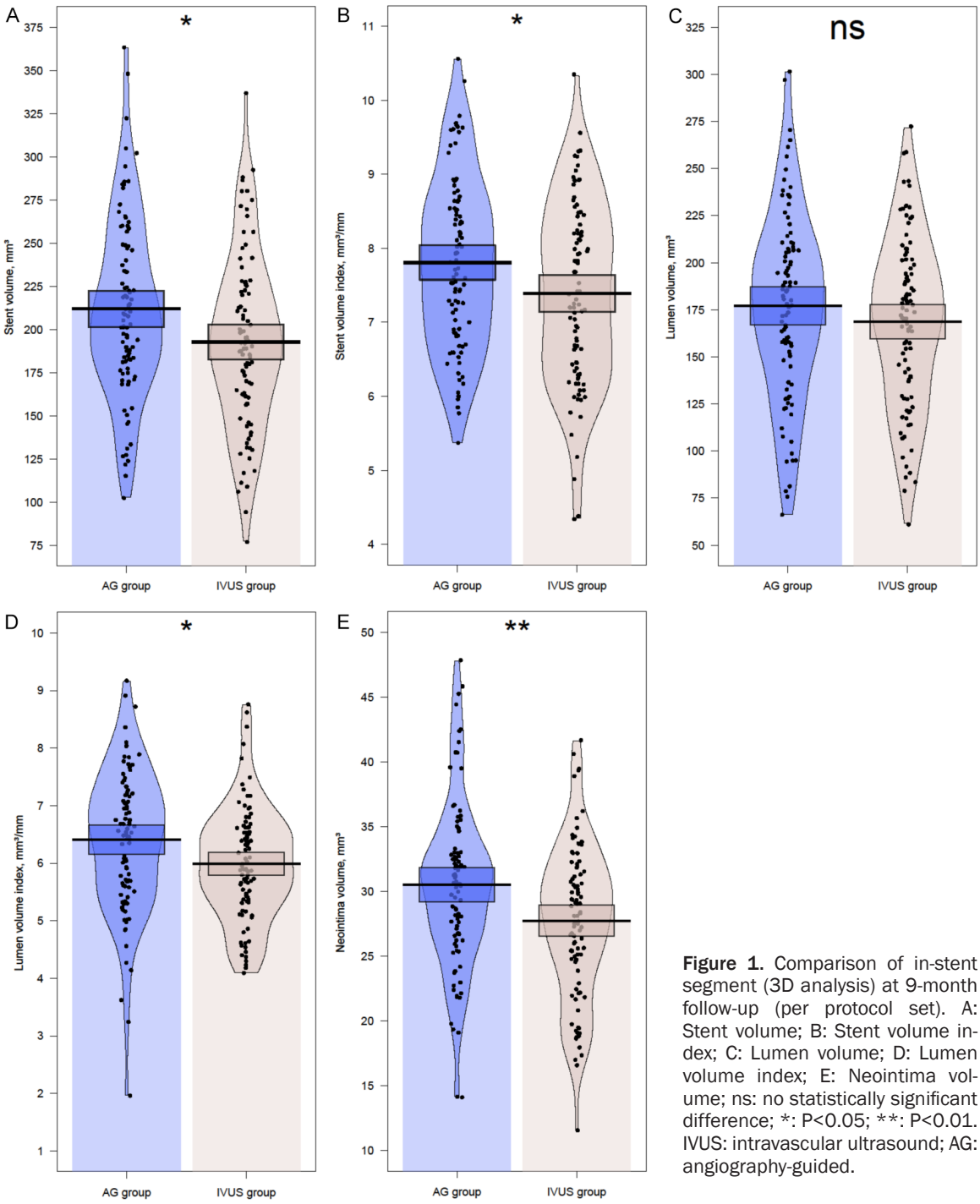

Figure 1. Comparison of in-stent segment (3D analysis) at 9-month follow-up (per protocol set). A: Stent volume; B: Stent volume index; C: Lumen volume; D: Lumen volume index; E: Neointima volume; ns: no statistically significant difference; *: P<0.05; **: P<0.01. IVUS: intravascular ultrasound; AG: angiography-guided.

P=0.003; overall: P=0.031). Distal edge dissections and intramural hematoma rates did not differ significantly (both P>0.05).

At the 9-month follow-up (**Figure 1**), the IVUS-guided group continued to show significantly smaller stent volume (P=0.010), stent volume index (P=0.016), and lumen volume index (P=0.011). Although the difference in absolute lumen volume was not statistically significant (P=0.223), neointima volume was significantly lower in the IVUS-guided group (P=0.002).

Comparison of cardiac function

At baseline, there were no significant differences in LVEDVI or LVESVI between the groups (both P>0.05) (**Figure 2**). However, post-inter-

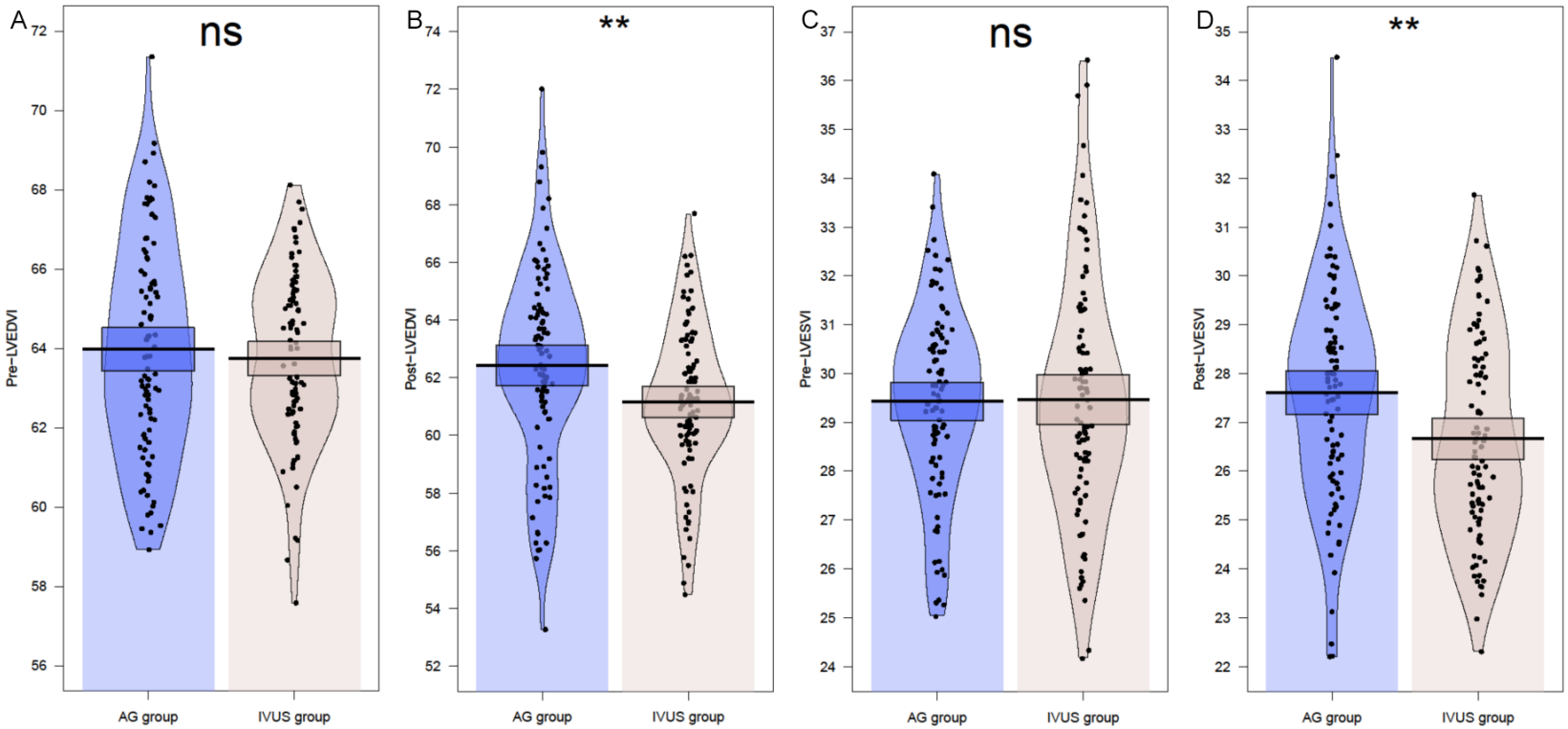

Figure 2. Comparison of cardiac function indicators. A: Pre-treatment LVEDVI; B: Post-treatment LVEDVI; C: Pre-treatment LVESVI; D: Post-treatment LVESVI. LVEDVI: left ventricular end-diastolic volume index; LVESVI: left ventricular end-systolic volume index; ns: no statistically significant difference; IVUS: intravascular ultrasound; AG: angiography-guided. **: P<0.01.

Table 5. Comparison of target-vessel related events and complications

Indicator	IVUS-guided group (n=95)	Angiography-guided group (n=95)	t/X^2	P
Target-vessel failure	7 (7.37%)	13 (13.68%)	2.012	0.156
Target-vessel failure without procedure-related myocardial infarction	5 (5.26%)	8 (8.42%)	0.743	0.389
Repeat revascularization	6 (6.32%)	7 (7.37%)	0.083	0.774
Target-vessel revascularization	3 (3.16%)	5 (5.26%)	0.130	0.718
Target-lesion revascularization	2 (2.11%)	4 (4.21%)	0.172	0.678
Contrast-induced nephropathy	2 (2.11%)	2 (2.11%)	0.255	0.613
Definite stent thrombosis	1 (1.05%)	1 (1.05%)	0.505	0.477

IVUS: intravascular ultrasound.

vention, the IVUS-guided group demonstrated significantly greater reductions in LVEDVI (P= 0.004) and LVESVI (P=0.003), suggesting superior improvement in left ventricular function following IVUS-guided PCI.

Comparison of MACCE

The incidence of target vessel failure was lower in the IVUS-guided group, although this did not reach statistical significance (P=0.156) (**Table 5**). No significant differences were observed in repeat revascularization (P=0.774), target-vessel revascularization (P=0.718), or target-lesion revascularization (P=0.678). Rates of contrast-induced nephropathy and definite stent thrombosis were also comparable (P=0.613 and P= 0.477, respectively).

The incidence of myocardial infarction, stroke, heart failure, unstable angina, and severe arrhythmias was similar between groups (all P>0.05) (**Figure 3**).

Comparison of quality of life

At the 3-month follow-up, quality of life scores across all evaluated domains were significantly higher in the IVUS-guided group (**Figure 4**). Specifically, physical function (P=0.001), social function (P=0.002), activities of daily living (P= 0.004), and psychological well-being (P=0.005) were all significantly improved in patients who underwent IVUS-guided PCI.

Discussion

This retrospective cohort study identified several important differences in outcomes between IVUS-guided and angiography-guided PCI in patients with ACS. A notable strength of this study is its comprehensive assessment of both procedural and mid-term clinical outcomes, utilizing advanced imaging to guide intervention.

IVUS offers high-resolution, cross-sectional imaging that enables detailed evaluation of coronary anatomy, including lesion morphology, vessel dimensions, and plaque characteristics - factors critical for optimal stent deployment [17]. In our study, the IVUS group demonstrated superior procedural outcomes, including significantly lower stent volume and reduced in-stent tissue protrusion. These benefits likely stem from IVUS's ability to more accurately assess vessel dimensions, facilitating better stent sizing and placement. This finding aligns with previous research indicating that IVUS can improve stent expansion and reduce complications such as malapposition and edge dissection [18, 19].

A key observation was the significantly lower neointima volume in the IVUS group at the 9-month follow-up, suggesting reduced neointimal proliferation. This may be attributed to IVUS-guided optimization of stent apposition, minimizing vessel injury and reducing stimuli for neointimal hyperplasia - a major contributor to in-stent restenosis. Proper stent expansion can help mitigate pathological processes like platelet activation, smooth muscle cell proliferation, and extracellular matrix deposition, which are exacerbated by suboptimal stenting and disturbed flow [20-22].

IVUS guidance also appeared to enhance cardiac function and quality of life post-PCI. Greater improvements in left ventricular volume indices in the IVUS group may reflect more complete revascularization and improved myocardial perfusion. IVUS is particularly beneficial for

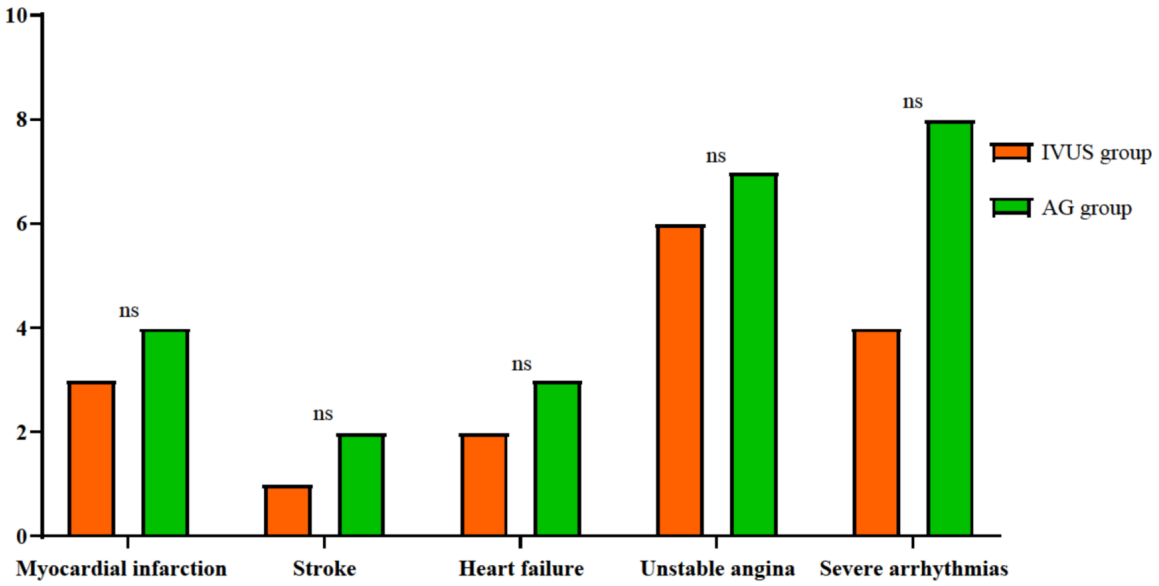

Figure 3. Comparison of major adverse cardiovascular and cerebrovascular events. ns: no significant; IVUS: intravascular ultrasound; AG: angiography-guided.

complex lesions - such as calcified plaques or bifurcations - that are difficult to evaluate using angiography alone. Improved precision in stent deployment ensures more uniform radial force distribution, reducing adverse remodeling and promoting myocardial recovery [23-25]. Furthermore, significantly better scores across physical, social, and psychological domains in the IVUS group indicate that the benefits extend beyond anatomical results to patient-perceived well-being. Enhanced quality of life may be due not only to improved health status but also to fewer complications, reduced need for repeat interventions, and greater confidence in the treatment [26, 27].

Nevertheless, IVUS guidance was associated with increased contrast media use and longer procedural times. These factors are clinically relevant, particularly in patients at risk for contrast-induced nephropathy or those susceptible to prolonged radiation exposure. Thus, careful patient selection remains essential. Despite the procedural advantages, the incidence of MACCE was similar between groups, suggesting that immediate safety is influenced more by baseline patient risk than by imaging modality [28, 29].

These findings support the integration of IVUS into routine PCI, especially for complex lesions or anatomically challenging cases. However, broader adoption must consider cost-effectiveness, training requirements, and resource availability. Implementing IVUS on a wider scale necessitates infrastructure investment and clinician expertise [27, 30, 31].

Several limitations in this study must be acknowledged. First, the retrospective design limits its causal inference and is subject to selection bias. Second, the single-center nature and relatively small sample size may restrict generalizability. Third, the one-year follow-up period may not capture long-term outcomes such as late stent thrombosis or very late restenosis. Fourth, reliance on de-identified medical records could introduce data omissions or inaccuracies. Lastly, although baseline characteristics were balanced, unmeasured confounders may have influenced the results. Future multicenter, prospective studies with larger cohorts and extended follow-up are warranted to validate these findings.

Conclusion

This study demonstrates that IVUS-guided PCI confers procedural and post-procedural advantages over angiography-guided PCI in patients with ACS. These benefits appear to be driven by IVUS's superior imaging capabilities, which en-

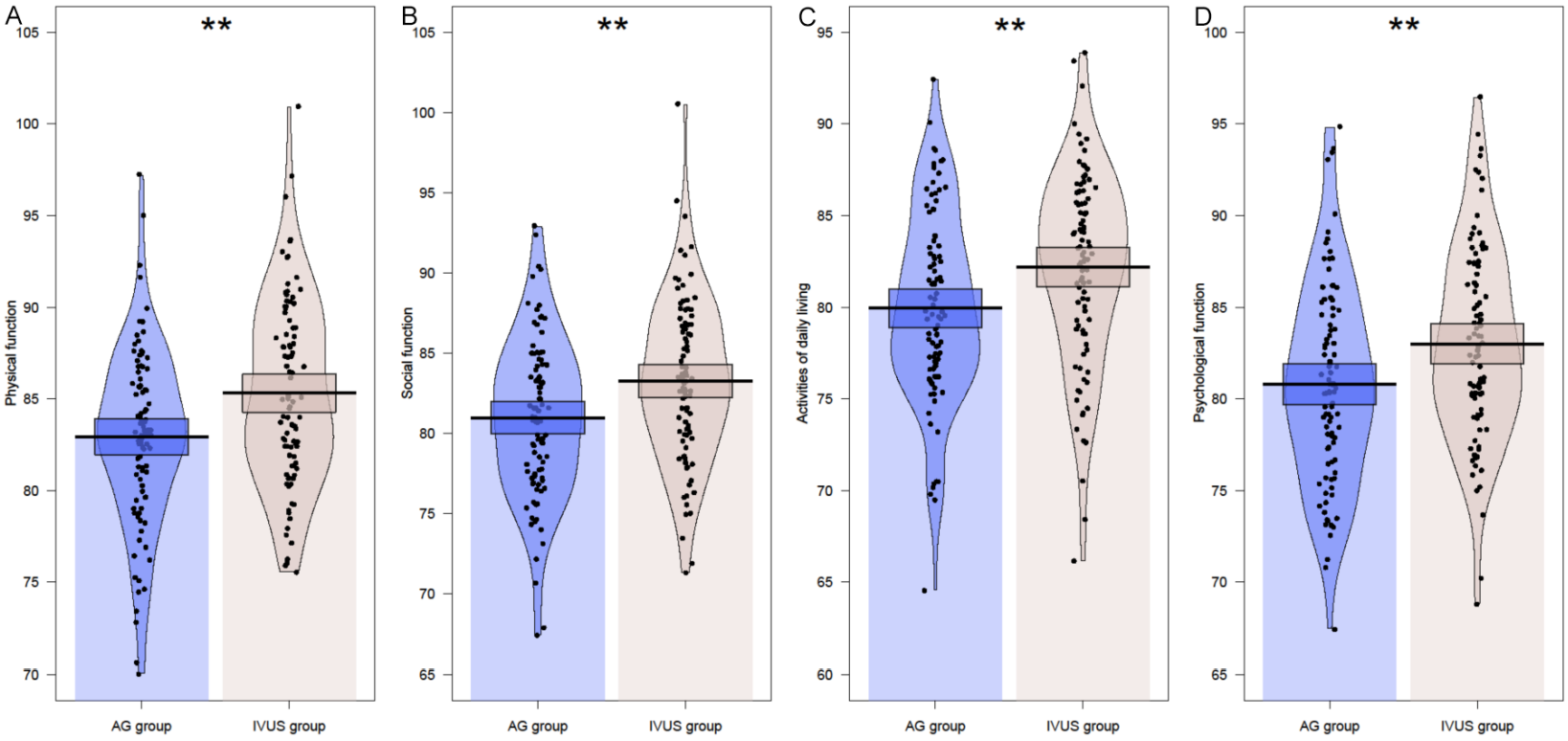

Figure 4. Comparison of quality of life scores across different domains post-PCI treatment. A: Physical function; B: Social function; C: Activities of daily living; D: Psychological function. **: P<0.01. IVUS: intravascular ultrasound; AG: angiography-guided.

able more precise and effective stent deployment. As a result, IVUS guidance may lead to improved cardiac function, reduced neointimal proliferation, and enhanced patient quality of life. Future prospective studies are needed to evaluate the long-term outcomes and cost-effectiveness of IVUS, with the aim of refining interventional strategies and improving care in coronary artery disease.

Disclosure of conflict of interest

None.

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