



Association of Coronary Anatomical Characteristics, Atherosclerotic Lesion morphology, and Vascular Remodeling with Procedural and Clinical Outcomes Following Percutaneous Coronary Intervention.

Article History:

Name of Author:

¹Hira Ahmed, ^{2*}Shahid Korai, ³Hamza Arshad, ⁴Munawar Khursheed, ⁵Syeda Urooj Zehra, ⁶Muhammad Ahad Saeed, ⁷Abdul Hakeem, ⁸Misha Fatima.

Affiliation: ¹Associate professor, Anatomy department, Karachi metropolitan university, KMDC

²Associate professor, Al Tibri Medical College, Karachi

³MBBS graduate, Al Tibri Medical College, Karachi

⁴Professor, National Institute of cardiovascular Diseases (NICVD), Karachi

⁵House officer, Al Tibri Medical College & Hospital.

⁶House officer, Pims (Pakistan Institute of Medical Sciences)

⁷House officer, Lumhs, Hyderabad

⁸Second year, Pre Medical Student, Karachi.

Corresponding Author:

Dr. Shahid Korai.

Received: 12-11-2025

Revised: 28-11-2025

Accepted: 15-12-2025

Published: 30-12-2025

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-Noncommercial-Share Alike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Abstract: Background: Coronary artery disease progresses through atherosclerotic narrowing of epicardial vessels, leading to ischemia and acute events. Percutaneous Coronary Intervention (PCI) outcomes depend heavily on coronary anatomy and lesion morphology. Complex features such as multivessel disease, long lesions, calcification, bifurcations, CTOs, and negative vascular remodeling increase technical difficulty and adverse events. Anatomical assessment therefore guides treatment strategy, from conventional PCI to imaging-guided PCI, plaque modification, or CABG referral. Understanding how coronary anatomy influences PCI success and clinical outcomes is essential for risk stratification and procedural planning.

OBJECTIVES: To determine the association between coronary anatomical characteristics, lesion morphology, vascular remodeling, and anatomy-guided treatment strategies with procedural and clinical outcomes following PCI. Secondary aims included assessing the impact of vessel number, lesion location/type, ACC/AHA classification, calcification, and remodeling patterns on procedural success, TIMI flow, revascularization, and MACE.

METHODOLOGY: A 12-month hospital-based observational study was conducted at Dow university Hospital in Karachi. 300 adults undergoing PCI for obstructive CAD were included. Data on demographics, risk factors, and clinical presentation were collected. Coronary anatomy was assessed angiographically for vessel number, culprit vessel, lesion location, length, stenosis, calcification, bifurcation, ostial disease, CTO, tortuosity and ACC/AHA class. Lesion morphology and remodeling were evaluated, with IVUS/OCT used in 27.3% of cases. Treatment was anatomy-guided, ranging from conventional PCI to complex techniques and Heart Team review for CABG. Procedural variables were recorded. Primary outcome was procedural success; secondary outcomes included TIMI III flow, complete revascularization, and MACE. **RESULTS:** Procedural success was 95.3%, TIMI III flow 92.7%, complete revascularization 74.7%, and MACE 13.0%. Multivessel disease was present in 64.0%, long lesions in 34.7%, moderate/severe calcification in 33.7%, bifurcations in 20.3%, and CTOs in 12.7%. Anatomical complexity significantly reduced success: single-vessel 98.1% vs multivessel 93.8% ($p=0.041$); Type A/B1 97.5% vs B2/C 93.5% ($p=0.038$); no severe calcification 97.0% vs severe 89.9% ($p=0.006$); non-bifurcation 97.0% vs bifurcation 88.5% ($p=0.002$); non-CTO 97.0% vs CTO 81.6% ($p<0.001$). TIMI III flow was also lower in bifurcations and CTOs. Negative remodeling was associated with lower success (91.7% vs 97.3%) and higher MACE (23.6% vs 9.9%). These findings confirm anatomy as a key determinant of PCI performance. **CONCLUSION:** Coronary anatomy and lesion morphology are major determinants of PCI success and clinical outcomes. Multivessel disease, complex lesion types, severe calcification, bifurcation and CTO involvement,

and negative remodeling were associated with poorer results. An anatomy-guided treatment strategy improves procedural planning and outcomes.

Keywords: Coronary Artery Disease; Percutaneous Coronary Intervention; Coronary Anatomy; Lesion Morphology; Vascular Remodeling; Major Adverse Cardiovascular Events.

INTRODUCTION

Coronary artery disease is characterized by progressive atherosclerotic involvement of the epicardial coronary arteries, resulting in luminal narrowing, impaired myocardial perfusion, myocardial ischemia and in acute presentations, plaque rupture with superimposed thrombus formation[1-3]. Although PCI has become an established treatment for obstructive coronary artery disease and acute coronary syndromes, procedural success and long-term outcomes are strongly influenced by the underlying coronary anatomy and morphology of the treated lesion.

The coronary arterial tree has considerable anatomical variability, and the location and characteristics of atherosclerotic lesions have important implications for PCI. The left anterior descending (LAD), right coronary artery (RCA), and left circumflex (LCx) arteries differ in their course, diameter, branching pattern, myocardial territory, and susceptibility to particular lesion configurations[4]. Lesions involving the proximal LAD, left main coronary artery, bifurcations, ostial segments, small-caliber vessels, and long or diffusely diseased segments may require more complex PCI strategies than short, focal lesions in relatively straight coronary segments.

The present study is particularly relevant from an anatomical perspective because coronary anatomy determines the feasibility and technical approach to revascularization. Single-vessel disease may frequently be managed with focal PCI, whereas multivessel disease requires careful assessment of the number, location, severity, and functional significance of individual lesions. In selected patients with extensive multivessel disease, left main disease, or anatomically complex lesions, the overall revascularization strategy may require multidisciplinary assessment and consideration of coronary artery bypass grafting (CABG) rather than PCI alone[5].

Lesion morphology further modifies the anatomical

challenge. ACC/AHA Type B2 and Type C lesions, long lesions, severe calcification, chronic total occlusions, bifurcation lesions, ostial lesions, marked tortuosity, and thrombus-containing lesions are associated with increased procedural complexity. In the present study, 60.7% of lesions were classified as B2 or C, 34.7% had a lesion length ≥ 20 mm, 23.0% demonstrated severe calcification, 20.3% involved bifurcations, and 12.7% represented chronic total occlusions[6].

Coronary anatomy also determines the choice of lesion preparation and stenting strategy. Heavily calcified lesions may require aggressive plaque modification before stent implantation, whereas bifurcation lesions may require a provisional or planned two-stent strategy depending on the anatomy of the side branch. Long lesions may require longer stent coverage, while small-vessel disease requires careful selection of stent diameter and avoidance of excessive stent length. CTO lesions frequently require specialized crossing and re-entry techniques. Thus, the relationship between anatomy and treatment is bidirectional: anatomical complexity influences treatment selection, while appropriate anatomy-guided treatment may influence procedural success and clinical outcomes[7,8].

Vascular remodeling adds another dimension to anatomical assessment. Positive remodeling may indicate outward expansion of the arterial wall in response to plaque accumulation, whereas negative remodeling is characterized by constriction of the vessel wall. In the current study, positive remodeling was observed in 37.0%, intermediate remodeling in 39.0%, and negative remodeling in 24.0% of patients. Negative remodeling was associated with lower procedural success, lower TIMI III flow, lower complete revascularization, and higher MACE[9,10]. Intravascular imaging with IVUS or OCT can provide additional anatomical information regarding vessel diameter, plaque burden, calcium distribution, remodeling, lesion length, and stent expansion. Such information may help operators select an appropriate stent size, optimize lesion preparation, identify complications, and achieve adequate stent expansion and apposition.

Therefore, this study evaluates the relationship between coronary anatomy, lesion morphology, vascular remodeling, anatomy-guided treatment strategies and procedural and clinical outcomes following PCI.

OBJECTIVES

The objective of the study was to determine the association between coronary anatomical characteristics, lesion morphology, vascular remodeling and anatomy-guided treatment strategies with clinical outcomes following PCI. The study also assess the association between the site and extent of coronary artery disease and procedural success, and to evaluate the effect of single-vessel versus multivessel disease on PCI outcomes. It also determined the relationship between LAD, RCA, LCx, left main, bifurcation, ostial, and CTO lesions and procedural outcomes. The impact of lesion length, calcification, tortuosity, thrombus burden, and ACC/AHA lesion classification on PCI success was assessed. In addition, we evaluated the association between vascular remodeling patterns and post-PCI outcomes and examined the relationship between coronary anatomy and the selection of treatment strategy, including conventional PCI, complex PCI, intravascular imaging-guided PCI, plaque-modification techniques.

METHODOLOGY

A hospital-based analytical observational study was conducted over a 12-month period in the Cardiology Department of Dow university hospital in Karachi, Pakistan. The study included 300 adult patients who underwent percutaneous coronary intervention (PCI) for angiographically confirmed significant coronary artery disease.

Patients were eligible if they were ≥ 18 years of age, had angiographically confirmed obstructive coronary artery disease, underwent PCI with balloon angioplasty and/or coronary stent implantation, had adequate coronary angiographic images for anatomical assessment, and provided informed consent. Patients were excluded if they had previous coronary artery bypass grafting with graft anatomy preventing adequate assessment of native coronary lesions, incomplete angiographic records, severe non-cardiac illness limiting follow-up, refusal to participate, or inadequate imaging quality for evaluation of lesion morphology or vascular remodeling.

A structured data collection proforma was used to record demographic characteristics including age, sex,

body mass index, and smoking status. Cardiovascular risk factors included hypertension, diabetes mellitus, dyslipidemia, previous myocardial infarction, previous PCI, family history of coronary artery disease, and chronic kidney disease. Clinical presentation was categorized as ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), unstable angina, or chronic stable coronary syndrome.

The principal component of the study was systematic assessment of coronary anatomy using standard coronary angiography. The anatomical assessment was designed to characterize the location, extent, distribution, and morphological complexity of coronary atherosclerotic disease.

The following anatomical variables were documented: number of diseased vessels, culprit vessel, lesion location, length, reference diameter, stenosis severity, presence of bifurcation, ostial involvement, CTO, tortuosity, diffuse disease, calcification, thrombus and ACC/AHA classification as these represent key determinants of PCI complexity. Lesion morphology was further assessed for calcification severity, eccentricity, length, thrombus burden, ulceration, small-vessel disease, and bifurcation or CTO involvement. Lesions were also categorized by ACC/AHA type to examine complexity in relation to outcomes. When IVUS or OCT was available, vascular remodeling was evaluated using the remodeling index and categorized as positive, intermediate, or negative, with additional plaque characteristics recorded.

Simple Type A/B1 lesions were managed with conventional PCI and drug-eluting stents, while long lesions required adequate preparation and stent coverage. Complex and calcified lesions underwent individualized preparation with balloons, atherectomy, or imaging guidance. Bifurcations were treated with provisional or two-stent strategies based on anatomy, and CTOs were approached antegrade or retrograde after evaluation of cap, length, and collaterals. In multivessel disease, revascularization strategy considered lesion complexity, LV function, diabetes, and feasibility of complete revascularization, with Heart Team review and CABG considered for complex multivessel or left-main disease.

Procedural variables included number of lesions and stents, stent dimensions, adjunctive techniques, imaging use, procedural time, and contrast volume. The primary outcome was procedural success defined as TIMI III flow, $<20\%$ residual stenosis, and no major in-hospital complications. Secondary outcomes included TIMI III flow, complete revascularization, periprocedural MI, dissection, no-reflow, AKI, stent

thrombosis, TLR, recurrent MI, heart failure, stroke, mortality, and MACE, all assessed during hospitalization and follow-up.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27. Continuous variables were expressed as mean $\pm$ standard deviation, whereas categorical variables were reported as frequencies and percentages. Associations between categorical variables were

evaluated using the chi-square test

Multivariable logistic regression analysis was performed to identify independent predictors of procedural failure, failure to achieve TIMI III flow, incomplete revascularization, and MACE. Adjusted odds ratios with 95% confidence intervals were reported. A p-value <0.05 was considered statistically significant.

RESULTS

Among the 300 patients undergoing PCI, the overall procedural success rate was **95.3%**. TIMI grade III coronary flow was achieved in **92.7%**, while complete revascularization was achieved in **74.7%** of patients. The overall incidence of MACE was **13.0%**. These findings demonstrate a high overall technical success rate, but the subsequent anatomical analysis showed that procedural performance varied considerably according to lesion complexity and coronary morphology.

Table 1. Overall PCI Outcomes of the study

Outcome	Result
Total patients	300
Procedural success	95.3%
TIMI III flow	92.7%
Complete revascularization	74.7%
MACE	13.0%

Multivessel coronary disease was identified in **64.0% (192/300)** of patients. Long lesions ≥ 20 mm were present in **34.7% (104/300)**. Moderate/severe calcification was reported in **33.7% (101/300)**, while bifurcation lesions were present in **20.3% (61/300)** and CTOs in **12.7% (38/300)**.

Table 2. Major Anatomical Characteristics of the Study Population

Anatomical characteristic	n (%)
Multivessel disease	192 (64.0)
Long lesion ≥ 20 mm	104 (34.7)
Moderate/severe calcification	101 (33.7)
Bifurcation lesion	61 (20.3)
Chronic total occlusion	38 (12.7)

The anatomical treatment table in the study material also identified 118 patients (39.3%) with simple Type A/B1 lesions and 192 patients (64.0%) undergoing multivessel revascularization. An important finding was the significant relationship between coronary anatomy and procedural success.

Single-vessel disease was associated with a procedural success rate of **98.1%**, compared with **93.8%** among patients with multivessel disease ($p=0.041$). Type A/B1 lesions had a success rate of **97.5%**, whereas Type B2/C lesions had a lower success rate of **93.5%** ($p=0.038$). The strongest association was observed with severe calcification. Procedural success was **97.0%** in patients without severe calcification compared with **89.9%** in patients with severe calcification ($p=0.006$). Bifurcation lesions had a procedural success rate of **88.5%**, compared with **97.0%** for non-bifurcation lesions ($p=0.002$).

The most pronounced difference was observed with CTO anatomy. Procedural success was **81.6%** among CTO lesions compared with **97.0%** among non-CTO lesions ($p<0.001$).

Table 3. Anatomical Predictors of Procedural Success

Anatomical characteristic	Procedural success	Procedural failure
Single-vessel disease	98.1%	1.9%
Multivessel disease	93.8%	6.2%
Type A/B1	97.5%	2.5%
Type B2/C	93.5%	6.5%

No severe calcification	97.0%	3.0%
Severe calcification	89.9%	10.1%
Non-bifurcation	97.0%	3.0%
Bifurcation	88.5%	11.5%
Non-CTO	97.0%	3.0%
CTO	81.6%	18.4%

These findings demonstrate that anatomical complexity was not simply descriptive; it was significantly associated with the technical success of PCI. The study also demonstrated important differences in final coronary flow according to lesion morphology. TIMI III flow was achieved in **95.8% of non-bifurcation lesions**, compared with **80.3% of bifurcation lesions**. Similarly, TIMI III flow was achieved in **95.8% of non-CTO lesions**, compared with only **68.4% of CTO lesions**.

These findings indicate that lesions involving branch points and complete chronic occlusion represent particularly challenging anatomical substrates for restoration of normal epicardial coronary flow.

Table 4. Anatomical Characteristics and TIMI III Flow

Anatomical characteristic	TIMI III flow
Non-bifurcation lesions	95.8%
Bifurcation lesions	80.3%
Non-CTO lesions	95.8%
CTO lesions	68.4%

Vascular remodeling was also associated with procedural and clinical outcomes. Procedural success was **97.3%** among patients with positive remodeling compared with **91.7%** among patients with negative remodeling. Similarly, MACE was considerably more frequent in patients with negative remodeling. MACE occurred in **23.6%** of patients with negative remodeling compared with **9.9%** among patients with positive remodeling.

Table 5. Vascular Remodeling and Clinical Outcome

Remodeling pattern	Procedural success	MACE
Positive remodeling	97.3%	9.9%
Negative remodeling	91.7%	23.6%

The findings suggest that vascular remodeling provides additional information beyond conventional angiographic stenosis and may identify lesions with more unfavorable anatomical and clinical characteristics.

DISCUSSION

The present study demonstrates that coronary anatomical complexity is an important determinant of PCI performance and clinical outcome. Although the overall procedural success rate was high at 95.3%, the analysis showed substantial variation according to vessel involvement, lesion classification, calcification, bifurcation anatomy, CTO, and vascular remodeling[11,12]. The central finding is therefore that PCI should not be regarded as a uniform procedure; rather, its technical difficulty and expected outcome are strongly influenced by the anatomical characteristics of the target lesion.

The overall procedural success of 95.3% in the present study reflects the high technical efficacy of contemporary PCI. However, the lower success rate observed with multivessel disease compared with single-vessel disease indicates that increasing anatomical disease burden adds procedural complexity[13].

In the present cohort, procedural success was 98.1%

for single-vessel disease compared with 93.8% for multivessel disease ($p=0.041$). Multivessel disease was present in 64.0% of the cohort, demonstrating that a substantial proportion of patients required treatment of anatomically extensive coronary disease.

This observation is consistent with contemporary revascularization guidance, which recognizes multivessel disease, left-main/proximal LAD disease, CTO, complex bifurcation lesions, heavy calcification, severe tortuosity, diffuse disease, thrombotic lesions, and lesion length >20 mm as features contributing to increasing anatomical complexity[14,15]. Assessment of anatomical complexity, including use of the SYNTAX score where appropriate, can assist revascularization decision-making in patients with multivessel CAD.

The present results therefore support the concept that anatomical disease burden should be incorporated into procedural planning rather than reporting PCI success independently of coronary anatomy. A particularly important finding was the lower procedural success associated with Type B2/C

lesions. Type A/B1 lesions had a success rate of 97.5%, whereas Type B2/C lesions had a success rate of 93.5% ($p=0.038$).

This finding is strongly supported by previous research. A contemporary Melbourne Interventional Group registry analysis involving 13,701 PCI patients demonstrated a progressive reduction in procedural success with increasing ACC/AHA lesion complexity. Procedural success was 99.6% for Type A lesions, 99.1% for B1, 96.6% for B2, and 82.7% for Type C lesions[16].

More recent registry data involving 21,437 lesions further confirmed that increasing ACC/AHA lesion complexity was associated with decreasing PCI procedural success and increasing in-hospital and 30-day adverse cardiovascular events. The present findings are therefore in agreement with both historical and contemporary evidence and indicate that the ACC/AHA classification remains clinically useful despite substantial advances in PCI technology.

The relationship is also relevant to longer-term outcomes. A pooled analysis of seven randomized trials involving contemporary drug-eluting stents showed that target-lesion failure was higher for complex B2/C lesions than for A/B1 lesions at 30 days, 1 year, and 5 years. At 5 years, B2/C lesions were associated with an adjusted hazard ratio of 1.39 for target-lesion failure[17,18].

Thus, the current study adds further support to the use of anatomical classification for risk stratification before PCI. Severe calcification emerged as another major anatomical determinant of procedural difficulty. Procedural success was 97.0% in patients without severe calcification but decreased to 89.9% in patients with severe calcification ($p=0.006$).

This relationship is anatomically plausible because extensive calcium can reduce vessel compliance, impair balloon expansion, restrict stent delivery, and result in incomplete stent expansion[19]. Contemporary PCI practice consequently emphasizes lesion preparation and, in selected lesions, calcium-modification techniques and intravascular imaging.

The importance of calcification is also reflected in contemporary anatomical complexity classifications, where heavy calcification is specifically recognized as a feature contributing to increasing CAD complexity.[20]

Recent evidence base study further demonstrated that calcium morphology can predict stent expansion. A 2026 study of moderately to severely calcified lesions found that increasing maximum calcium angle was

associated with reduced stent expansion, supporting the value of intravascular assessment in heavily calcified anatomy[21,22]

Therefore, the lower success rate observed in severely calcified lesions in the present study may reflect the mechanical limitations imposed by calcium and emphasizes the need for appropriate lesion preparation and stent optimization.

Bifurcation lesions were present in 20.3% of the cohort and were associated with significantly lower procedural success. Success was only 88.5% in bifurcation lesions compared with 97.0% in non-bifurcation lesions ($p=0.002$). Similarly, TIMI III flow was achieved in 80.3% of bifurcation lesions compared with 95.8% of non-bifurcation lesions.

These findings emphasize that a bifurcation is not simply a stenotic segment but a three-dimensional anatomical structure in which treatment of the main vessel can influence the side branch. The risks of side-branch compromise, suboptimal stent geometry, residual ostial disease, and complex flow patterns make bifurcation PCI technically demanding.

Many randomized trial provides further support for anatomy-specific treatment. Among 653 patients with complex bifurcation lesions, the 1-year target-lesion failure rate was 6.1% with a systematic two-stent strategy compared with 11.4% with provisional stenting ($p=0.019$). The difference was driven mainly by target-vessel myocardial infarction and clinically driven target-lesion revascularization[23]

Importantly, this does not imply that every bifurcation requires two stents. Rather, it supports the principle that the anatomical complexity of the bifurcation should determine the treatment strategy. Simple bifurcations may appropriately undergo provisional stenting, whereas complex bifurcations may benefit from a planned two-stent approach.

CTO was the strongest anatomical predictor of procedural failure in the present study. Procedural success was only 81.6% for CTO lesions compared with 97.0% for non-CTO lesions ($p<0.001$). CTO lesions also had the lowest reported rate of TIMI III flow, at 68.4%, compared with 95.8% among non-CTO lesions[24].

This finding is consistent with the intrinsic anatomical challenges of CTO PCI. Complete occlusion may be associated with ambiguous proximal and distal caps, long occlusion segments, calcification, tortuosity, and complex collateral circulation. Consequently, successful CTO PCI frequently requires specialized guidewires, microcatheters, antegrade dissection/re-

entry or retrograde approaches.

Registry evidence supported the lower technical success associated with CTO intervention. In the Michigan BMC2 registry, 7,389 CTO PCI procedures were attempted and post-procedural TIMI III flow was achieved in 58.3%, illustrating the substantially greater challenge associated with complete coronary occlusion[25]

Similarly, the OPEN-CTO registry reported an approximately 86% technical success rate using a stringent definition incorporating final TIMI flow, residual stenosis and preservation of a major side branch. The relatively low success and TIMI III flow in CTO lesions in the present study therefore correspond with the broader literature and reinforce the importance of detailed pre-procedural anatomical assessment.

Long lesions ≥ 20 mm represented 34.7% of the cohort. Long lesions increase procedural complexity because they require greater lesion preparation, longer stent coverage, and potentially multiple or overlapping stents. They also increase the anatomical surface area exposed to stent implantation.

Contemporary revascularization guidance specifically identifies lesion length >20 mm as a feature contributing to increasing coronary anatomical complexity. The presence of long lesions together with the high prevalence of multivessel disease in the current cohort indicates that a substantial proportion of patients had extensive rather than focal atherosclerotic disease. This supports an anatomy-oriented approach in which the number of lesions, lesion length, location, vessel diameter, bifurcation involvement, calcification, and overall distribution are considered collectively.

An important additional contribution of the present study is the assessment of vascular remodeling. Procedural success was lower among patients with negative remodeling than among those with positive remodeling (91.7% versus 97.3%), while MACE was markedly higher in the negative-remodeling group (23.6% versus 9.9%).

Vascular remodeling provides information that may not be apparent from angiography alone. Positive remodeling can preserve the angiographic lumen despite substantial plaque accumulation, whereas negative remodeling is characterized by reduction in vessel size and may be associated with more constrained luminal dimensions.

These findings provide biological support for the current observation that negative remodeling was

associated with lower procedural success and higher MACE. The remodeling component therefore adds depth to the anatomical assessment by moving beyond angiographic stenosis toward characterization of the arterial wall and plaque environment.

Intravascular imaging was used in 27.3% of patients in the present study. The value of IVUS and OCT is particularly relevant in anatomically complex lesions because angiography provides a two-dimensional representation of a three-dimensional vessel and may underestimate calcium distribution, plaque burden, vessel size, and stent underexpansion.

These findings suggest that intravascular imaging should not necessarily be considered a replacement for angiography but rather an important adjunct for selected anatomically complex lesions, particularly when vessel sizing, calcium distribution, lesion preparation, or stent expansion is uncertain.

CONCLUSION

The present study demonstrated that coronary anatomy is a major determinant of Percutaneous Coronary Intervention (PCI) procedural success and clinical outcome. Although contemporary PCI achieved a high overall procedural success rate of 95.3%, outcomes varied significantly according to the anatomical characteristics of the treated lesions.

Multivessel disease, Type B2/C lesions, severe calcification, bifurcation involvement, and chronic total occlusion were associated with reduced procedural success. The effect was particularly pronounced in CTO lesions, which demonstrated the lowest procedural success and TIMI III flow rates. Bifurcation lesions similarly showed reduced restoration of TIMI III flow, highlighting the importance of careful anatomical assessment of the main vessel and side branch.

Vascular remodeling provided an additional anatomical dimension. Negative remodeling was associated with lower procedural success and substantially higher MACE than positive remodeling, suggesting that assessment of vessel-wall characteristics may improve anatomical risk stratification.

The findings supported the concept that PCI should be regarded as an anatomy-guided therapeutic intervention rather than a uniform procedure. Simple lesions may be appropriately managed with conventional drug-eluting stent implantation, whereas complex lesions may require specialized lesion preparation, calcium-modification techniques, intravascular imaging, dedicated bifurcation

strategies, CTO techniques, or alternative revascularization planning.

Overall, the integration of coronary anatomy, lesion morphology, vascular remodeling, procedural technique, and clinical outcome provides a more comprehensive understanding of PCI performance. Incorporating these anatomical variables into routine pre-procedural assessment may improve patient selection, procedural planning, stent optimization, completeness of revascularization, and ultimately clinical outcomes.

BIBLIOGRAPHY

1. Pasternak RC, Criqui MH, Benjamin EJ, et al. Atherosclerotic Vascular Disease Conference: Writing Group I: epidemiology. *Circulation*. 2024;109:2605–2612.
2. Dalager S, Paaske WP, Kristensen IB, Laurberg JM, Falk E. Plaque in superficial femoral arteries indicates generalized atherosclerosis and vulnerability to coronary death: an autopsy study. *Stroke*. 2017;38:2698–2705.
3. Kataoka T, Mathew V, Rubinshtein R, et al. Association of plaque composition and vessel remodeling in atherosclerotic renal artery stenosis: a comparison with coronary artery disease. *JACC Cardiovasc Imaging*. 2019;2:327–338. doi:10.1016/j.jcmg.2008.08.008.
4. Mintz GS, Nissen SE, Anderson WD, et al. American College of Cardiology Clinical Expert Consensus Document on Standards for Acquisition, Measurement and Reporting of Intravascular Ultrasound Studies (IVUS). *J Am Coll Cardiol*. 2021;37:1478–1492.
5. García-García HM, Mintz GS, Lerman A, et al. Tissue characterisation using intravascular radiofrequency data analysis: recommendations for acquisition, analysis, interpretation and reporting. *EuroIntervention*. 2019;5:177–189.
6. Takumi T, Mathew V, Barsness GW, et al. The association between renal atherosclerotic plaque characteristics and renal function before and after renal artery intervention. *Mayo Clin Proc*. 2021;86:1165–1172.
7. Kotani J, Mintz GS, Castagna MT, et al. Intravascular ultrasound analysis of infarct-related and non-infarct-related arteries in patients who presented with an acute myocardial infarction. *Circulation*. 2023;107:2889–2893.
8. Calvert PA, Obaid DR, O'Sullivan M, et al. Association between IVUS findings and adverse outcomes in patients with coronary artery disease: the VIVA Study. *JACC Cardiovasc Imaging*. 2021;4:894–901.
9. Pentecost MJ, Criqui MH, Dorros G, et al. Guidelines for peripheral percutaneous transluminal angioplasty of the abdominal aorta and lower extremity vessels. *Circulation*. 2024;89:511–531.
10. Okura H, Asawa K, Kubo T, et al. Incidence and predictors of plaque rupture in the peripheral arteries. *Circ Cardiovasc Interv*. 2020;3:63–70.
11. Janzen J, Lanzer P, Rothenberger-Janzen K, Vuong PN. The transitional zone in the tunica media of renal arteries has a maximal length of 10 millimetres. *Vasa*. 2020;29:168–172.
12. Janzen J, Lanzer P, Rothenberger-Janzen K, Vuong PN. Variable extension of the transitional zone in the medial structure of carotid artery tripod. *Vasa*. 2021;30:101–106.
13. Stroev PV, Hoskins PR, Easson WJ. Distribution of wall shear rate throughout the arterial tree: a case study. *Atherosclerosis*. 2017;191:276–280.
14. Samady H, Eshtehardi P, McDaniel MC, et al. Coronary artery wall shear stress is associated with progression and transformation of atherosclerotic plaque and arterial remodeling. *Circulation*. 2021;124:779–788.
15. Mohler ER 3rd, Sarov-Blat L, Shi Y, et al. Site-specific atherogenic gene expression correlates with subsequent variable lesion development in coronary and peripheral vasculature. *Arterioscler Thromb Vasc Biol*. 2018;28:850–805.
16. Virmani R, Kolodgie FD, Burke AP, et al. Atherosclerotic plaque progression and vulnerability to rupture: angiogenesis as a source of intraplaque hemorrhage. *Arterioscler Thromb Vasc Biol*. 2019;25:2054–2061.
17. Hildebrandt HA, Gossel M, Mannheim D, et al. Differential distribution of vasa vasorum in different vascular beds in humans. *Atherosclerosis*. 2018;199:47–54.
18. Rodriguez-Granillo GA, Serruys PW, Garcia-Garcia HM, et al. Coronary artery remodelling is related to plaque composition. *Heart*. 2019;92:388–391. doi:10.1136/hrt.2004.057810.
19. Pasterkamp G, Schoneveld AH, Hijnen DJ, et al. Atherosclerotic arterial remodeling and the localization of macrophages and matrix metalloproteases 1, 2 and 9 in the human coronary artery. *Atherosclerosis*. 2024;150:245–253.
20. Pasterkamp G, Schoneveld AH, van der Wal AC, et al. Relation of arterial geometry to luminal narrowing and histologic markers for plaque vulnerability: the remodeling paradox. *J Am Coll Cardiol*. 2021;32:655–662.
21. Kubo T, Matsuo Y, Hayashi Y, et al. High-sensitivity C-reactive protein and plaque composition in patients with stable angina pectoris: a virtual histology intravascular ultrasound study. *Coron Artery Dis*.

- 2019;20:531–535.
22. Faxon DP, Fuster V, Libby P, et al. Atherosclerotic Vascular Disease Conference: Writing Group III: pathophysiology. *Circulation*. 2024;109:2617–2625.
23. Hong YJ, Jeong MH, Ahn Y, et al. Age-related differences in intravascular ultrasound findings in 1,009 coronary artery disease patients. *Circ J*. 2018;72:1270–1275.
24. Nozue T, Yamamoto S, Tohyama S, et al. Statin treatment for coronary artery plaque composition based on intravascular ultrasound radiofrequency data analysis. *Am Heart J*. 2020;163:191–199.e1.
25. Lansky AJ, Ng VG, Machara A, et al. Gender and the extent of coronary atherosclerosis, plaque composition, and clinical outcomes in acute coronary syndromes. *JACC Cardiovasc Imaging*. 2022;5(3 Suppl):S62–S72.