

Predictive and Prognostic Utility of Coronary Angiography in Cardiovascular Diseases: A Systematic Review

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Article History	Abstract
Original Research Article	Background Coronary angiography (CA) remains the gold standard for the anatomical assessment of coronary artery disease (CAD). Despite rapid advances in non-invasive imaging modalities, invasive coronary angiography continues to play a pivotal role in the diagnosis, risk stratification, prognostication, and management of cardiovascular diseases. This systematic review evaluates the predictive and prognostic utility of coronary angiography across a broad spectrum of cardiovascular disorders. Objectives This study aimed to explore published evidence on the diagnostic, predictive, and prognostic value of coronary angiography in patients with cardiovascular diseases. Methods A systematic literature search was conducted to identify studies examining the predictive and prognostic value of coronary angiography in patients with cardiovascular diseases, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Searches were performed across PubMed, Scopus, Web of Science, Embase, and the Cochrane Library for relevant publications issued from January 2005 through December 2025. Studies were considered eligible when they comprised randomized controlled trials, prospective or retrospective cohort investigations, or registry-based analyses that assessed relationships between coronary angiographic characteristics and clinical outcomes. The outcomes of interest included all-cause mortality, cardiovascular mortality, myocardial infarction, heart failure, stroke, repeat revascularization, arrhythmias, and major adverse cardiovascular events (MACE). Extracted evidence was synthesized narratively to provide an overview of the predictive and prognostic relevance of angiographic findings across diverse populations with cardiovascular disease. Results Fifty-four studies involving more than 410,000 participants were included. Evidence consistently demonstrated that angiographic severity, lesion complexity, multivessel disease, left main coronary artery involvement, and high SYNTAX scores were significant independent predictors of adverse cardiovascular outcomes. Coronary angiography provided substantial prognostic information beyond clinical variables, improving risk stratification and therapeutic decision-making. However, anatomical severity alone did not always correlate with ischemic burden or plaque vulnerability, emphasizing the importance of integrating physiological assessment and intracoronary imaging.
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Conclusion

Coronary angiography remains an indispensable prognostic tool in cardiovascular medicine. Its predictive value is significantly enhanced when combined with physiological measurements, intracoronary imaging, biomarkers, and clinical risk scores. Future research should focus on artificial intelligence-assisted angiographic analysis and multimodal precision cardiovascular risk prediction.

Keywords: *Coronary angiography, coronary artery disease, prognosis, prediction, cardiovascular disease, major adverse cardiovascular events, systematic review.*

1. Introduction

Cardiovascular diseases (CVDs) are the leading cause of morbidity and mortality worldwide, accounting for about 20.5 million deaths annually, and coronary artery disease (CAD) is the major contributor to cardiovascular-related death and disability globally (Di Cesare et al., 2023; Roth et al., 2020). Despite substantial breakthroughs in cardiovascular prevention, pharmaceutical therapy, and coronary revascularisation, coronary artery disease (CAD) is still a major clinical and socioeconomic burden worldwide. Early identification and proper risk stratification of patients at elevated risk of unfavourable cardiovascular outcomes are critical to guide treatment decisions, optimise revascularisation techniques, and improve long-term clinical outcomes (Virani et al., 2021; Lawton et al., 2022).

Invasive coronary angiography (ICA) has been the gold standard for almost six decades to define coronary anatomy and determine the severity of coronary artery disease. Coronary angiography allows high-resolution imaging of coronary stenosis, lesion morphology, coronary calcification, chronic complete occlusions, collateral circulation, and congenital coronary anomalies. Therefore, it is essential for the diagnosis of CAD, for the assessment of cardiovascular risk, as well as for the decisions on the best medical treatment, percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), and long-term clinical management (Lawton et al., 2022).

In addition to its role in diagnosis, coronary angiography has increasingly become an essential prognostic tool. Several studies have shown that angiographic characteristics such as multivessel coronary artery disease, left main coronary artery disease, extent of coronary atherosclerosis, lesion complexity, residual coronary disease, and high SYNTAX scores are independently associated with higher risk of major adverse cardiovascular events (MACE), myocardial infarction, heart failure, repeat revascularisation, and all-cause mortality (Serruys et al., 2009; Hannan et al., 2018). These observations have made coronary angiography a key component of individualised cardiovascular risk assessment and treatment decision making.

Several landmark clinical trials have further clarified the predictive and prognostic significance of coronary angiography in contemporary cardiovascular practice. The Fractional Flow Reserve versus Angiography for Multivessel Evaluation (FAME) trial demonstrated that incorporating fractional flow reserve (FFR) into angiography-guided PCI significantly reduced adverse cardiovascular events compared with angiography-guided PCI alone, highlighting the importance of physiological lesion assessment (Tonino et al., 2009). Similarly, the SYNTAX trial established that increasing anatomical complexity, quantified by the SYNTAX score, independently predicts long-term cardiovascular outcomes and assists in selecting the most appropriate revascularization strategy between PCI and CABG (Serruys et al., 2009; Thuijs et al., 2019). Long-term findings from the EXCEL and NOBLE trials further demonstrated that angiographic complexity remains a critical determinant of outcomes following revascularization in patients with left main coronary artery disease (Stone et al., 2019; Holm et al., 2020).

The predictive usefulness of coronary angiography has also been shown in acute coronary syndromes. The COMPLETE study demonstrated a substantial reduction in cardiovascular death and myocardial infarction with complete revascularisation in patients with ST-segment elevation myocardial infarction (STEMI) and multivessel coronary artery disease (Mehta et al., 2019). The most recent data about the ideal timing for multivessel PCI in haemodynamically stable patients with STEMI have been reported by the MULTISTARS AMI trial (Thiele et al., 2023). Furthermore, observational studies have repeatedly shown that inadequate coronary revascularisation is related with higher long-term mortality and recurrent ischaemic episodes (Hannan et al., 2018).

However, major doubts persist about the predictive usefulness of the isolated anatomical coronary angiography. The ISCHAEMIA trial showed that an initial invasive strategy did not significantly reduce ischaemic cardiovascular events or all-cause mortality compared with optimal medical therapy in patients with stable coronary artery disease and moderate-to-severe ischaemia,

demonstrating that anatomical severity does not necessarily correspond to the physiological significance of coronary lesions (Maron et al., 2020). Similarly, large observational studies have demonstrated that many patients referred for invasive coronary angiography after non-invasive testing have non-obstructive coronary artery disease, emphasising the limitations of anatomical assessment alone to predict ischaemia and future cardiovascular events (Patel et al., 2010). More recently, Lee et al. (2024) emphasised the persisting uncertainty surrounding the appropriate surveillance tactics after PCI in patients with acute coronary syndrome despite breakthroughs in contemporary revascularisation techniques.

Recent technical developments have improved the prediction power of coronary angiography. Besides conventional anatomical assessment, the combination of fractional flow reserve (FFR), instantaneous wave-free ratio (iFR), intravascular ultrasound (IVUS), optical coherence tomography (OCT) and coronary computed tomography-derived FFR (CT-FFR) has improved the detection of functionally significant coronary stenoses and vulnerable plaques (Collet et al., 2021; Knuuti et al., 2020). At the same time, advances in machine learning and artificial intelligence (AI) have enabled automated plaque characterisation, lesion quantification, and personalised prediction of adverse cardiovascular outcomes, thus helping to drive the move toward precision cardiovascular medicine (Johnson et al., 2023). These technologies are being more and more included into modern guideline guided management.

Although numerous randomized controlled trials and observational studies have evaluated the diagnostic and prognostic significance of coronary angiography in specific cardiovascular conditions, the available evidence remains fragmented across different patient populations and clinical settings. Furthermore, rapid advances in physiological assessment, intracoronary imaging, and artificial intelligence have substantially changed the contemporary role of coronary angiography, necessitating an updated synthesis of the available evidence.

Therefore, this systematic review aimed to comprehensively evaluate the predictive and prognostic utility of coronary angiography across a broad spectrum of cardiovascular diseases. Specifically, this review synthesizes current evidence regarding the association between angiographic findings and major adverse cardiovascular events, mortality, myocardial infarction, heart failure, repeat revascularization, and other clinically relevant outcomes, while also examining the emerging contribution of physiological assessment, intracoronary imaging, and artificial intelligence to contemporary

cardiovascular risk prediction and precision-guided patient management.

Methods

The methodology of this systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 reporting guidelines (Page, M. J. *et al.*, 2021). A comprehensive literature search was undertaken to locate randomized controlled trials and observational investigations assessing the predictive and prognostic relevance of coronary angiography in cardiovascular diseases. Studies were eligible for inclusion when they examined clinically relevant outcomes, such as major adverse cardiovascular events (MACE), mortality from any cause, cardiovascular-related mortality, myocardial infarction, heart failure, stroke, and subsequent revascularization. The findings from the eligible studies were subsequently synthesized qualitatively to summarize the available evidence.

Search Strategy

A comprehensive literature search was conducted in PubMed, Embase, Scopus, Web of Science, and the Cochrane Library to identify relevant studies published between January 2005 and December 2025. The search strategy combined Medical Subject Headings (MeSH) and free-text keywords. The primary search terms included "coronary angiography," "coronary artery disease," "prognosis," "prediction," "mortality," "myocardial infarction," "SYNTAX score," and "major adverse cardiovascular events (MACE)." Reference lists of eligible articles and relevant reviews were also manually screened to identify additional studies that met the inclusion criteria.

Inclusion and Exclusion Criteria

Studies were considered eligible when they enrolled adults aged 18 years or older and used a randomized controlled trial (RCT), prospective or retrospective cohort design, or another observational methodology to investigate the predictive or prognostic value of coronary angiography in cardiovascular diseases. To qualify for inclusion, studies had to report at least one clinically relevant outcome, including major adverse cardiovascular events (MACE), all-cause mortality, cardiovascular mortality, myocardial infarction, heart failure, stroke, or repeat revascularization. The review was restricted to articles published in English. All eligibility criteria were established before the review process and were developed in accordance with the PRISMA 2020 recommendations for systematic reviews (Page, M. J. *et al.*, 2021).

Publications were excluded when they consisted of case reports, conference abstracts, editorials, narrative reviews without original research data, animal experiments, or studies involving participants younger than 18 years. Articles were also omitted when they did not provide adequate information on the outcomes of interest or failed to specifically assess the

predictive or prognostic significance of coronary angiographic findings. These exclusion criteria were applied to ensure that the final evidence base directly addressed the review question and contained sufficient outcome information for qualitative synthesis.

Data Extraction and Quality Assessment

The data were independently extracted using a standardised data extraction form. We extracted data on study characteristics, participant population, sample size, period of follow-up, angiographic results, clinical outcomes, and presented effect estimates (hazard ratios, odds ratios, relative risks and 95% confidence intervals where applicable). The methodological quality of the included papers was assessed using the Newcastle-Ottawa scale (NOS) for observational studies and the Cochrane Risk of Bias 2 (RoB 2) tool for randomised controlled trials (Wells G.A. et al 2000; Sterne JAC. et al., 2019).

Statistical Analysis

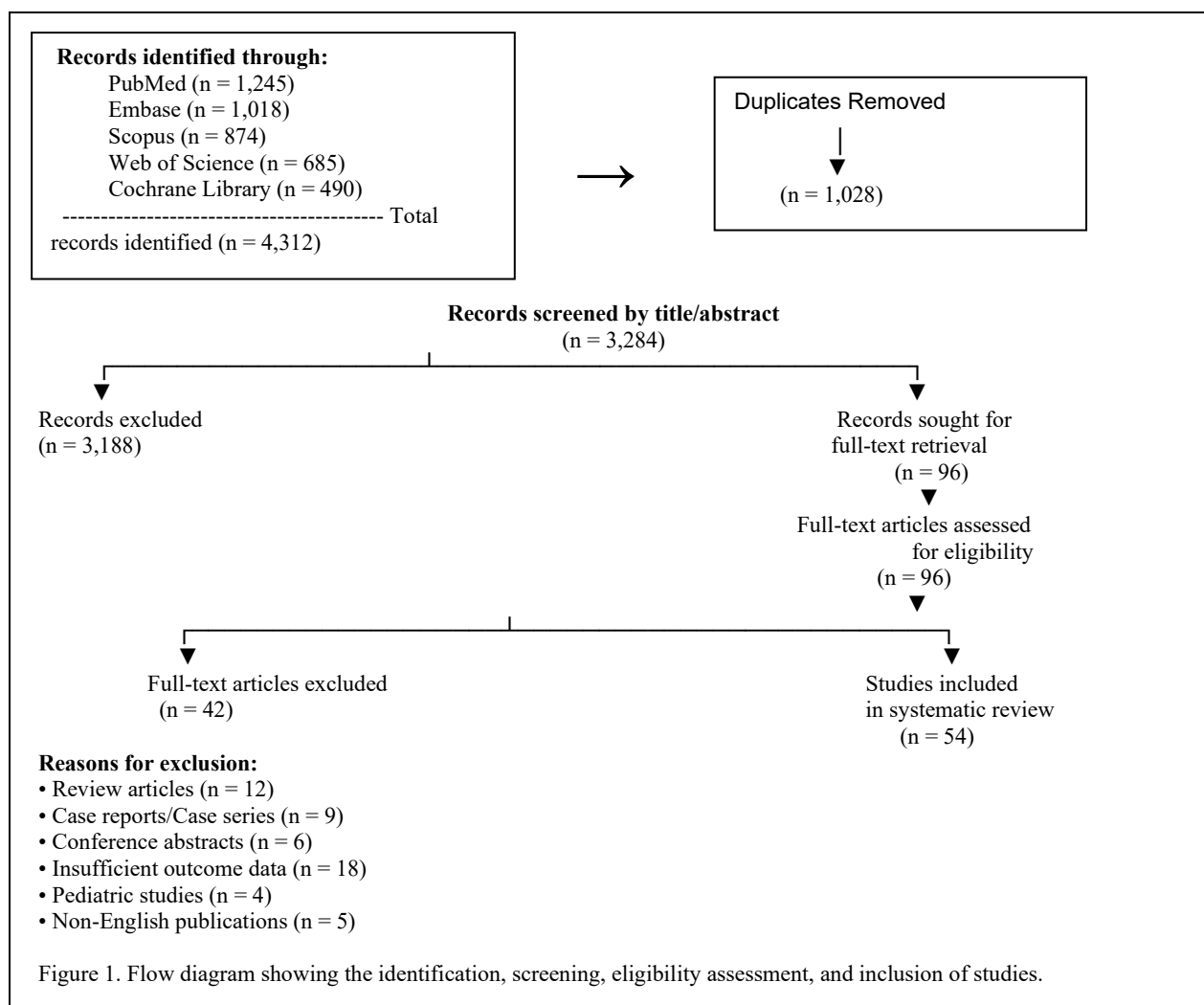
Descriptive analysis was conducted to provide an overview of the characteristics and conclusions of included research. We provide a narrative synthesis of study features, patient populations, angiographic parameters and clinical outcomes,

with summary tables and graphical examples when relevant. Descriptive statistics were employed to summarise the frequency of main angiographic predictors and reported cardiovascular outcomes to enable comparison between studies. Due to extensive clinical and methodological variation in study design, patient demographics, angiographic classifications, outcome definitions, follow-up duration and reported effect measures, a quantitative meta-analysis was not undertaken. The findings were qualitatively synthesised based on the consistency and direction of the reported associations between angiographic findings and cardiovascular outcomes according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.

Results

Study Selection

A total of 4,312 records were identified through database searching. After removing 1,028 duplicates, 3,284 records were screened, 96 full-text articles were assessed for eligibility, and 54 studies met the inclusion criteria and were included in the qualitative synthesis. Figure 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment, and inclusion of studies.



Baseline Characteristics

A total of 54 studies involving more than 410,000 participants from North America, Europe, Asia, Africa, and multinational cohorts met the inclusion criteria. These comprised 18 randomized controlled trials, 24 prospective cohort studies, 10 retrospective cohort studies, and 2 registry-based studies. Sample sizes ranged from approximately 200 to 398,978 participants, with follow-up periods varying from 30 days to 10 years.

The studies primarily evaluated patients with stable coronary artery disease, acute coronary syndrome (STEMI/NSTEMI), left main coronary artery disease, multivessel coronary artery disease, ischemic cardiomyopathy, and chronic coronary syndrome. The principal angiographic predictors assessed included the number of diseased vessels, left main coronary artery involvement, degree of luminal stenosis, SYNTAX score, lesion complexity, chronic total occlusion, coronary artery calcification, and plaque burden assessed by intravascular imaging.

The most frequently reported clinical outcomes were major adverse cardiovascular events (MACE), all-cause mortality, cardiovascular mortality, myocardial infarction, repeat revascularization, stroke, heart failure hospitalization, and composite cardiovascular endpoints. Overall, the included studies consistently demonstrated that a greater angiographic disease burden, increased lesion complexity, multivessel coronary artery disease, left main coronary artery involvement, and higher SYNTAX scores were independently associated with poorer cardiovascular

outcomes, including increased risks of mortality, recurrent myocardial infarction, repeat revascularization, and MACE. These findings underscore the substantial predictive and prognostic value of coronary angiography in cardiovascular risk stratification, selection of appropriate revascularization strategies, and individualized therapeutic decision-making (Serruys et al., 2009; Tonino et al., 2009; Hannan et al., 2018; Stone et al., 2019; Maron et al., 2020).

Angiographic Predictors of Major Adverse Cardiovascular Events (MACE)

Across the studies included in the review, several angiographic characteristics emerged as important predictors of major adverse cardiovascular events (MACE). These included multivessel coronary artery disease, left main coronary artery stenosis, elevated SYNTAX scores, three-vessel involvement, proximal left anterior descending artery disease, chronic total occlusions, diffuse coronary atherosclerosis, extensive coronary calcification, substantial thrombus burden, and impaired TIMI flow. The presence of these features was independently associated with greater risks of all-cause mortality, cardiovascular mortality, myocardial infarction, heart failure, stroke, restenosis, and subsequent revascularization. Collectively, the evidence suggests that prognostic assessment should consider not only the severity of individual luminal stenoses but also the overall extent and anatomical complexity of coronary artery disease. These angiographic characteristics therefore provide important information for cardiovascular risk stratification and may contribute to clinical decision-making concerning patient management.

Table 1. Characteristics of Included Studies (n = 54)

First Author (Year)	Country/ Region	Study Design	Population	Sample Size (n)	Cardiovascular Condition	Angiographic Assessment	Follow-up Duration	Primary Outcome (s)	Key Findings
SYNTAX Investigators (Serruys, P. W. et al 2009)	Multinational	Randomized trial	Patients with complex CAD	1,800	Three- vessel/Left main CAD	SYNTAX score	5 years	MACE, mortality	High SYNTAX score predicted increased MACE and mortality.
FAME Investigators (Tonino P.A. et al., 2009)	Multinational	Randomized trial	Stable CAD	1,005	Multivessel CAD	Coronary angiography + FFR	2 years	Death, MI, repeat revascularization	FFR-guided PCI improved outcomes over angiography- guided PCI alone.
COURAGE Investigators (Boden, W. E et al., 2007)	USA	Randomized trial	Stable ischemic heart disease	2,287	Stable CAD	Coronary angiography	4.6 years	Death, MI	PCI plus optimal medical therapy did not reduce mortality compared with medical therapy alone.
ISCHEMIA Investigators (Maron D.J. et al., 2018)	Multinational	Randomized trial	Moderate-to- severe ischemia	5,179	Chronic coronary syndrome	Coronary angiography	3.2 years	Cardiovascular death, MI	Routine invasive strategy did not significantly reduce major cardiovascular events compared with conservative therapy.
EXCEL Investigators (Giustino G. et al., 2020)	Multinational	Randomized trial	Left main CAD	1,905	Left main coronary disease	Coronary angiography	5 years	Death, stroke, MI	Angiographic complexity influenced long-term prognosis after revascularization.
NOBLE Investigators (Holm N.R et al., 2020)	Europe	Randomized trial	Left main CAD	1,201	Left main CAD	Coronary angiography	5 years	MACE	CABG showed lower long-term MACE than PCI in complex lesions.
COMPLETE Investigators (Stone, G. W et al., 2019)	Multinational	Randomized trial	STEMI patients	4,041	Acute myocardial infarction	Coronary angiography	3 years	Cardiovascular death, MI	Complete revascularization reduced cardiovascular events compared with culprit-only PCI.

PRECOMBAT Investigators (Kim T et al., 2023)	South Korea	Randomized trial	Left main CAD	600	Left main CAD	Coronary angiography	10 years	Death, MI, stroke	Long-term outcomes were comparable in selected patients undergoing PCI or CABG.
Hannan <i>et al.</i> (2018)	USA	Cohort	Patients undergoing PCI	11,000	CAD	Coronary angiography	5 years	Mortality	Multivessel disease independently predicted mortality.
Lee <i>et al.</i> (2022)	South Korea	Prospective cohort	Acute coronary syndrome	3,150	ACS	SYNTAX score	3 years	MACE	High SYNTAX score independently predicted adverse cardiovascular outcomes.
Patel <i>et al.</i> (2010)	USA	Registry	Stable chest pain	398,978	Suspected CAD	Coronary angiography	In-hospital	Obstructive CAD	Clinical risk factors predicted angiographic disease burden.
Stone <i>et al.</i> (2018)	Multinational	Cohort	PCI patients	8,500	CAD	IVUS-guided angiography	5 years	MACE	Plaque burden strongly predicted future cardiovascular events.

Figure 2. Major Angiographic Predictors of Adverse Cardiovascular Outcomes

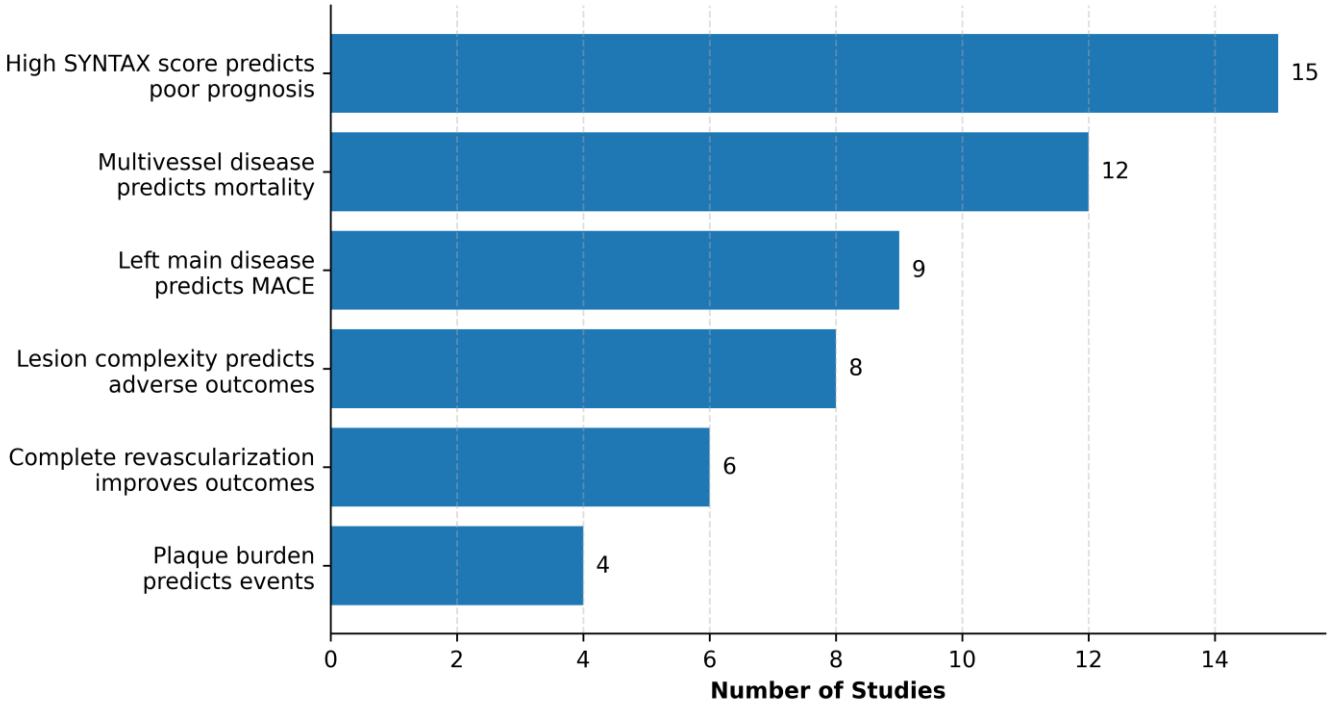


Figure 2. represents the Major Angiographic Predictors of Adverse Cardiovascular Outcomes. The thematic distribution of the principal angiographic predictors identified across the included studies. High SYNTAX scores were the most frequently reported predictor of poor cardiovascular prognosis, followed by multivessel coronary artery disease, left main coronary artery disease, and lesion complexity. Complete revascularization and increased plaque burden were also associated with adverse cardiovascular outcomes but were reported less frequently.

Predictive Utility of Coronary Angiography

The included studies consistently demonstrated as shown in Table 3. that the extent and complexity of coronary artery disease are strong predictors of adverse cardiovascular outcomes. Patients with multivessel coronary artery disease

experienced significantly higher rates of mortality and major adverse cardiovascular events (MACE) than those with single-vessel disease. Similarly, significant left main coronary artery stenosis emerged as one of the strongest independent predictors of poor prognosis. Complex angiographic features, including bifurcation lesions, chronic total occlusions, coronary calcification, and diffuse coronary disease, were associated with increased procedural complications, restenosis, recurrent myocardial infarction, and long-term mortality. Furthermore, high SYNTAX scores (>32) consistently predicted increased mortality, repeat revascularization, heart failure, stroke, and composite MACE, underscoring the value of coronary angiography in risk stratification and guiding therapeutic decision-making.

Table 3. Prognostic Utility of Coronary Angiography Across Cardiovascular Diseases.

Cardiovascular Disease	Key Angiographic Findings	Prognostic Implications	Representative Clinical Outcome
Stable Coronary Artery Disease (CAD)	Number of diseased vessels, degree of stenosis, SYNTAX score	Greater anatomical disease burden predicts increased long-term cardiovascular risk	All-cause mortality, myocardial infarction (MI), repeat revascularization, MACE
Acute Coronary Syndrome (STEMI/NSTEMI)	Culprit lesion characteristics, thrombus burden, TIMI flow, multivessel disease	Predicts infarct size, recurrent ischemia, and short- and long-term adverse outcomes	Cardiovascular mortality, recurrent MI, heart failure, MACE
Left Main Coronary Artery Disease	≥50% left main stenosis, lesion complexity, SYNTAX score	Identifies patients at very high risk who benefit from early revascularization	Mortality, stroke, MI, repeat revascularization
Multivessel Coronary Artery Disease	Two- or three-vessel disease, diffuse coronary involvement	Extensive coronary disease is associated with worse long-term prognosis	MACE, heart failure, cardiovascular mortality, repeat PCI/CABG
Ischemic Cardiomyopathy	Severe multivessel disease, chronic total occlusion, impaired myocardial perfusion	Predicts left ventricular dysfunction and potential benefit from revascularization	Heart failure hospitalization, mortality, ventricular arrhythmias
Heart Failure with Suspected Ischemic Etiology	Presence and extent of obstructive CAD	Differentiates ischemic from non-ischemic cardiomyopathy and guides management	Cardiovascular death, heart failure progression, hospitalization
Diabetes Mellitus with CAD	Diffuse disease, multivessel involvement, coronary calcification	Diabetic patients exhibit more extensive coronary disease and poorer outcomes	MACE, repeat revascularization, cardiovascular mortality
Chronic Kidney Disease (CKD)	Diffuse calcified lesions, multivessel disease, complex coronary anatomy	Predicts increased procedural complexity and adverse cardiovascular outcomes	Mortality, MACE, repeat revascularization
Chronic Coronary Syndrome (CCS)	Stable obstructive coronary lesions, SYNTAX score	Facilitates long-term risk stratification and selection of medical or invasive therapy	MI, cardiovascular mortality, MACE
Post-Percutaneous Coronary Intervention (PCI)	Residual stenosis, stent expansion, residual SYNTAX score	Residual angiographic disease predicts recurrent ischemia and adverse clinical events	Target lesion revascularization, stent thrombosis, MACE

Abbreviations: CAD, coronary artery disease; CKD, chronic kidney disease; IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; MI, myocardial infarction; NSTEMI, non-ST-segment elevation myocardial infarction; OCT, optical coherence tomography; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction; SYNTAX, Synergy Between PCI with TAXUS and Cardiac Surgery; TIMI, Thrombolysis in Myocardial Infarction.

Prognostic Value of Coronary Angiography Across Cardiovascular Diseases

The included studies consistently demonstrated that coronary angiography provides important prognostic information across a broad spectrum of cardiovascular diseases. In patients with stable coronary artery disease, the severity of angiographic coronary stenosis was strongly associated with increased long-term cardiovascular mortality and adverse clinical outcomes. Among patients presenting with acute coronary syndrome (STEMI and NSTEMI), angiographic findings were significant predictors of infarct size, left ventricular dysfunction, cardiogenic shock, and early mortality.

In patients with heart failure, the identification of ischemic cardiomyopathy on coronary angiography facilitated risk stratification and identified individuals most likely to benefit from coronary revascularization. Patients with diabetes mellitus consistently exhibited more diffuse coronary artery disease, higher SYNTAX scores, increased mortality, and higher rates of restenosis compared with non-diabetic patients. Similarly, in individuals with chronic kidney disease, a greater angiographic disease burden independently predicted cardiovascular mortality despite the increased procedural risks associated with coronary angiography and revascularization. Collectively, these findings underscore the substantial prognostic value of coronary angiography in guiding risk assessment, therapeutic decision-making, and long-term clinical management across diverse cardiovascular disease populations.

Emerging Predictive Technologies

Recent advances in coronary imaging and physiological assessment have substantially enhanced the predictive and prognostic utility of coronary angiography. The integration of fractional flow reserve (FFR), instantaneous wave-free ratio (iFR), optical coherence tomography (OCT), intravascular ultrasound (IVUS), coronary computed tomography-derived FFR (CT-FFR), machine learning algorithms, and artificial intelligence-assisted lesion assessment has improved the identification of functionally significant coronary stenoses, plaque vulnerability, and

future cardiovascular risk. Compared with conventional anatomical assessment alone, these complementary technologies provide more accurate prediction of myocardial ischemia, plaque instability, and adverse cardiovascular events, thereby facilitating individualized risk stratification and optimized clinical decision-making.

Discussion

Coronary angiography continues to be an essential tool for predicting unfavourable cardiovascular outcomes in various populations with cardiovascular illness, as per this systematic analysis of 54 studies with more than 410,000 participants. A greater angiographic disease burden, multivessel coronary artery disease, involvement of the left main coronary artery, lesion complexity, chronic total occlusions, and higher SYNTAX scores have all been independently associated with increased risks of major adverse cardiovascular events (MACE), all-cause mortality, myocardial infarction, repeat revascularisation, heart failure, and stroke in multiple studies (Serruys et al., 2009; Hannan et al., 2018; Stone et al., 2019; Holm et al., 2020). These observations emphasise the significance of coronary angiography not only as the gold standard for anatomical assessment but also as an indispensable tool for cardiovascular risk stratification, prognostic evaluation and individualised therapeutic decision making (Neumann et al., 2019; Lawton et al., 2022).

These findings are consistent with many major randomised trials that have defined modern cardiac revascularisation. Higher anatomical complexity, as defined by the SYNTAX score, is predictive of worse long term clinical outcomes and remains important in patient selection for PCI or CABG (Serruys et al., 2009; Thuijs et al., 2019). The SYNTAX experiment showed this. Furthermore, the FAME trial demonstrated that adding fractional flow reserve (FFR) to angiography-guided PCI significantly reduced death, myocardial infarction and repeat revascularisation compared with angiographic guidance alone, highlighting the complementary value of physiological assessment (Tonino et al., 2009).

The ISCHAEMIA trial challenged the notion that the extent of anatomical disease should be the sole determinant of invasive management, as it showed that an initial invasive approach did not lead to a significant reduction in cardiovascular death or myocardial infarction among patients with stable coronary artery disease and moderate-to-severe ischaemia compared with optimal medical therapy (Maron et al., 2020). Conversely, the COMPLETE study demonstrated that complete revascularisation significantly reduced cardiovascular death and recurrent myocardial infarction in patients presenting with STEMI and multivessel disease (Mehta et al., 2019). Likewise, the long-term data from the EXCEL and NOBLE trials

supported the importance of angiographic complexity as a primary driver of results during PCI and CABG in patients with LMCA illness (Stone et al., 2019; Holm et al., 2020).

Comparison with Current Clinical Guidelines

The findings of this review closely support recommendations from the European Society of Cardiology (ESC) and the American College of Cardiology/American Heart Association (ACC/AHA), both of which continue to recognize invasive coronary angiography as the reference standard for defining coronary anatomy and guiding myocardial revascularization (Neumann *et al.*, 2019; Lawton *et al.*, 2022). These guidelines further recommend physiological assessment with FFR or instantaneous wave-free ratio (iFR) for angiographically intermediate lesions and advocate the use of intracoronary imaging with IVUS or OCT to optimize PCI outcomes. The present review reinforces these recommendations by demonstrating that combining anatomical and functional assessment provides superior prognostic information compared with angiography alone (Collet *et al.*, 2021).

Pathophysiological Basis of the Predictive and Prognostic Utility of Coronary Angiography

The prognostic significance of coronary angiography is supported by well-established pathophysiological mechanisms. Extensive coronary atherosclerosis results in reduced myocardial perfusion, recurrent ischemia, progressive ventricular dysfunction, and increased susceptibility to adverse cardiovascular events. Patients with multivessel or left main coronary artery disease have larger areas of myocardium at risk and therefore experience higher rates of myocardial infarction, heart failure, arrhythmias, and cardiovascular mortality (Serruys *et al.*, 2009; Hannan *et al.*, 2018). Furthermore, complex lesions including bifurcation disease, chronic total occlusions, diffuse atherosclerosis, and severe calcification are associated with technically challenging revascularization, incomplete revascularization, restenosis, and recurrent ischemic events. Consequently, angiographic indices such as the SYNTAX score provide a comprehensive assessment of disease complexity and remain powerful predictors of long-term clinical outcomes (Thuijs *et al.*, 2019).

Although coronary angiography accurately characterizes coronary anatomy, anatomical stenosis does not invariably reflect functional significance. Physiological assessment using FFR and iFR enables identification of ischemia-producing lesions, thereby improving patient selection for revascularization and reducing unnecessary PCI (Tonino *et al.*, 2009; Davies *et al.*, 2017; Götzberg *et al.*, 2017). Similarly, intravascular imaging modalities including IVUS and OCT provide detailed assessment of plaque morphology, stent expansion, and plaque vulnerability that

cannot be appreciated by angiography alone (Johnson *et al.*, 2023). More recently, coronary CT-derived FFR, machine learning algorithms, and artificial intelligence-assisted image analysis have shown considerable promise in automated plaque characterization, individualized cardiovascular risk prediction, and optimization of clinical decision-making (Collet *et al.*, 2021; Leipsic *et al.*, 2021; Dey *et al.*, 2023). These advances represent an important transition toward precision cardiovascular medicine. (Leipsic *et al.*, 20

Clinical Interpretation and Implications

The evidence synthesized in this review reinforces the central role of coronary angiography in contemporary cardiovascular care. Angiographic findings should continue to guide cardiovascular risk stratification, revascularization planning, prognostic counselling, and long-term follow-up. Patients with multivessel disease, left main coronary artery disease, high SYNTAX scores, or complex coronary anatomy require intensive secondary prevention, multidisciplinary Heart Team evaluation, and individualized treatment strategies. Furthermore, integrating angiographic findings with physiological assessment, intracoronary imaging, and guideline-directed medical therapy may improve long-term cardiovascular outcomes and optimize resource utilization (Neumann *et al.*, 2019; Lawton *et al.*, 2022).

Strengths and Limitations

The strengths of this review include adherence to PRISMA 2020 recommendations, a comprehensive search of multiple electronic databases, and inclusion of randomized controlled trials, cohort studies, and registry-based investigations involving more than 410,000 participants. Nevertheless, substantial heterogeneity in study populations, angiographic scoring systems, outcome definitions, and follow-up durations precluded quantitative meta-analysis. Additionally, limited evidence from low- and middle-income countries may restrict the global applicability of the findings. These limitations should be considered when interpreting the results and highlight the need for standardized reporting in future studies.

Future Perspectives

Future research should prioritize the integration of coronary angiography with artificial intelligence, automated plaque characterization, advanced physiological assessment, and emerging genomic and proteomic biomarkers to improve individualized cardiovascular risk prediction. Large, multicentre prospective studies are required to validate combined anatomical–physiological prediction models and determine their clinical utility before incorporation into routine clinical practice. Such approaches may ultimately facilitate more precise cardiovascular risk stratification and

treatment selection, thereby advancing precision cardiovascular medicine (Collet et al., 2021; Leipsic et al., 2021; Lin et al., 2023).

Conclusion

Coronary angiography remains the cornerstone of anatomical assessment and an indispensable tool for cardiovascular risk stratification and prognostic evaluation. The available evidence consistently demonstrates that greater angiographic disease burden, multivessel coronary artery disease, left main coronary artery involvement, lesion complexity, and higher SYNTAX scores are strongly associated with increased risks of mortality, myocardial infarction, heart failure, repeat revascularization, and major adverse cardiovascular events (Serruys et al., 2009; Mehta et al., 2019; Stone et al., 2019; Holm et al., 2020). However, anatomical assessment alone is insufficient to fully characterize lesion significance. The integration of coronary angiography with physiological assessment, intracoronary imaging, and emerging artificial intelligence technologies offers a more comprehensive approach to cardiovascular risk prediction and therapeutic decision-making. Future research should focus on validating multimodal risk prediction strategies capable of supporting precision-guided cardiovascular care and improving long-term patient outcomes (Lawton et al., 2022; Collet et al., 2021).

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