Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Artificial Intelligence-Assisted Quantitative Coronary Angiography in Percutaneous Coronary Intervention: A Systematic Review of Comparative and Validation Studies

Yasaswini Nimmagadda

nimmagaddayasaswini@gmail.com

Mallareddy Institute of Medical Sciences https://orcid.org/0009-0007-4058-9672

Himabindu Makkena

Katuri Medical College https://orcid.org/0009-0000-5226-1622

Systematic Review

Keywords: Artificial Intelligence, Quantitative Coronary Angiography, Percutaneous Coronary Intervention, Intravascular Imaging, Systematic Review

Posted Date: May 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9743777/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: The authors declare no competing interests.

Abstract

Background

Artificial intelligence-based quantitative coronary angiography (AI-QCA) enables automated, real-time assessment of coronary lesions during percutaneous coronary intervention (PCI). However, its comparative performance against intravascular imaging and clinical relevance remain incompletely defined.

Methods

We conducted a systematic review of studies evaluating AI-QCA in PCI, including comparisons with intravascular imaging or angiography-guided PCI, as well as validation studies against manual QCA or intravascular imaging. Studies were categorized as comparative or validation analyses. Due to heterogeneity in study design, outcomes, and reporting metrics, a narrative synthesis was performed.

Results

Nine studies met inclusion criteria, including one randomized controlled trial, observational cohorts, and validation studies. In the FLASH trial, AI-QCA-guided PCI demonstrated noninferiority to optical coherence tomography for post-procedural minimal stent area (6.3 ± 2.2 mm^2 vs 6.2 ± 2.2 mm^2; $p < 0.001$), although stent malapposition was more frequent with AI-QCA. Observational data showed shorter procedure time with AI-QCA-assisted PCI compared with angiography-guided PCI (34.9 ± 13.9 vs 39.5 ± 17.1 minutes; $p < 0.001$), without differences in contrast use or in-hospital mortality. Validation studies demonstrated strong agreement with manual QCA (intraclass correlation coefficients up to 0.93) and moderate to strong correlations with intravascular imaging-derived measurements ($r \approx 0.5–0.9$). No studies were powered to assess long-term clinical outcomes.

Conclusions

AI-QCA demonstrates consistent technical accuracy and may serve as an adjunct to angiography to improve procedural efficiency, particularly where intravascular imaging is not routinely used. However, intravascular imaging remains essential for complex lesions and procedural optimization, and outcome-driven studies are required before broader adoption.

INTRODUCTION

Coronary angiography remains the cornerstone of lesion assessment during percutaneous coronary intervention (PCI). However, angiography alone has limitations in accurately characterizing lesion severity and optimizing stent deployment. Intravascular imaging modalities, including intravascular

ultrasound (IVUS) and optical coherence tomography (OCT), have demonstrated improved procedural and clinical outcomes, yet their use remains limited due to cost, availability, and procedural complexity. [10–13]

Artificial intelligence-based quantitative coronary angiography (AI-QCA) has emerged as a novel approach to provide automated, real-time quantitative analysis of coronary lesions using standard angiographic images [4–7, 14, 15]. AI-QCA may offer an intermediate option between visual angiography and dedicated intravascular imaging.

Published studies on AI-QCA differ considerably in design, patient populations, and outcome definitions, which makes direct comparison difficult. To address this, we conducted a systematic review examining the role of AI-QCA in PCI, focusing on comparative outcomes and validation against established modalities. Given that the field is still evolving and comparative data remains limited, this review was intended to summarise the early evidence and highlight important areas for future research.

METHODS

Study Design

This study was conducted as a systematic review with narrative synthesis in accordance with the PRISMA 2020 guidelines [16]. A quantitative synthesis using correlation-based meta-analysis was considered but not performed due to heterogeneity in reported outcome measures (ICC, Pearson r, Spearman ρ), precluding statistical pooling.

Search Strategy

A comprehensive search of PubMed, Embase, and Cochrane was performed to identify studies evaluating AI-QCA in coronary intervention. The search strategy included combinations of keywords and MeSH terms related to “artificial intelligence,” “quantitative coronary angiography,” “PCI,” “OCT,” and “IVUS.” Searches were conducted from 2015- 2026 (Artificial Intelligence studies predominantly after this year). Two independent reviewers performed study selection and data extraction, with discrepancies resolved by consensus. Additional studies were identified through manual screening of reference lists to ensure comprehensive coverage. The detailed search strategy is provided in Supplementary Table S1.

Eligibility Criteria

Inclusion criteria:

- Studies evaluating AI-QCA in PCI
- Comparative studies (AI vs OCT/IVUS or angiography)
- Validation studies comparing AI-QCA with manual QCA or imaging

Exclusion criteria:

- No comparator
- Pure segmentation/model development studies
- Case reports, reviews

Study Selection

Titles and abstracts were screened using Rayyan, followed by full-text review of eligible studies.

Data Extraction

Extracted data included:

- Study design
- Population
- Comparator
- Outcomes

Outcomes included:

- Procedural outcomes (MSA, procedure time)
- Clinical outcomes (mortality)
- Agreement metrics (ICC, correlation coefficients)

Study Grouping

Studies were categorized into:

1. AI-QCA vs intravascular imaging
2. AI-QCA vs angiography
3. Validation studies
4. Contextual comparator trials

Risk of Bias

Risk of bias was assessed according to study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, while observational and validation studies were assessed using the Newcastle–Ottawa Scale (NOS). [18]

Among the randomized trials, the FLASH trial demonstrated an overall low risk of bias across most domains, with some concerns related to the measurement of outcomes due to reliance on imaging-based endpoints. The GUIDE-DES trial also showed low overall risk of bias, with robust randomization and outcome assessment procedures.

Overall, the observational and validation studies were judged to have a moderate risk of bias, mainly because many were retrospective and therefore vulnerable to confounding and selection bias. Although outcome measurement and reporting were generally adequate, the lack of randomization and limited adjustment for confounding variables remained important methodological limitations.

A summary of risk of bias across included studies is presented in Figure 3. Domain-level assessment for randomized trials using the RoB 2 tool is illustrated in Figure 4, while overall quality assessment for observational studies using the Newcastle–Ottawa Scale is summarized in Table 3.

This systematic review was not prospectively registered. However, the study was conducted in accordance with PRISMA 2020 guidelines with predefined eligibility criteria and systematic methodology.

RESULTS

1. Study Selection

A total of 234 studies were identified (226 via database searching and 8 via citation screening). After removal of duplicates and screening of titles and abstracts, 62 studies underwent full-text review. Of these, 9 studies met inclusion criteria and were included in the final analysis.

The study selection process is illustrated in Figure 1 (PRISMA flow diagram).

2. Study Characteristics

The included studies comprised a combination of randomized controlled trials, retrospective cohort studies, and validation studies evaluating artificial intelligence–based quantitative coronary angiography (AI-QCA).

Studies were categorized into three primary groups:

- AI-QCA versus intravascular imaging (IVUS/OCT)
- AI-QCA versus angiography-guided PCI
- Validation and agreement studies comparing AI-QCA with manual QCA or intravascular imaging

Additionally, selected non-AI comparator trials evaluating imaging-guided versus angiography-guided PCI were included for contextual interpretation.

A summary of study characteristics is presented in Table 1. Additional details of supporting studies are provided in Supplementary Table S2.

3. Comparative Outcomes from Eligible Studies

3.1 AI-QCA vs Intravascular Imaging

The FLASH randomized trial evaluated AI-QCA-guided PCI compared with optical coherence tomography (OCT)-guided PCI in patients undergoing coronary intervention [1].

A total of 395 patients were included. AI-QCA demonstrated noninferiority to OCT for minimal stent area (6.3 ± 2.2 mm² vs 6.2 ± 2.2 mm²; p<0.001), although stent malapposition was more frequent (13.6% vs 5.6%; p=0.007) [1].

Overall, AI-QCA-guided PCI achieved procedural outcomes comparable to OCT-guided PCI.

3.2 AI-QCA vs Angiography

Ahn et al. evaluated AI-QCA-assisted PCI compared with angiography-guided PCI in patients presenting with ST-elevation myocardial infarction [2].

The study included 164 patients in the AI-QCA group and 492 patients in the angiography group.

AI-QCA-guided PCI was associated with shorter procedure time compared with angiography-guided PCI (34.9 ± 13.9 vs 39.5 ± 17.1 minutes).

There were no significant differences in contrast volume or in-hospital mortality between the two groups. In-hospital mortality was low and comparable (AI-QCA: 4/164 vs angiography: 15/492) [2]

These findings suggest that AI-QCA may improve procedural efficiency without compromising short-term clinical outcomes.

3.3 Contextual Comparator Evidence

In a randomized comparison of QCA-guided PCI versus IVUS-guided PCI (GUIDE-DES), no significant difference was observed in target lesion failure at 12 months [3].

These findings provide contextual evidence regarding the performance of angiography-based quantitative approaches relative to intravascular imaging, although this study did not specifically evaluate AI-based QCA.

4. Narrative Synthesis: Validation and Agreement Studies

4.1 Agreement with Manual QCA

Across multiple validation studies, AI-QCA demonstrated strong agreement with manual QCA measurements.

Intraclass correlation coefficients varied across parameters, ranging from moderate agreement for certain measurements (ICC ~0.60) to excellent agreement for others (ICC up to 0.93). [4, 5]

These findings indicate high reproducibility and reliability of AI-based measurements compared with conventional quantitative analysis.

4.2 Agreement with Intravascular Imaging

Studies comparing AI-QCA with intravascular imaging modalities reported moderate to strong correlations for lumen and vessel measurements.

Correlation coefficients generally ranged from r ≈ 0.5 to 0.9, supporting the ability of AI-QCA to approximate IVUS and OCT derived measurements [6].

4.3 Workflow and Clinical Utility

Workflow focused studies suggested that AI-QCA enables rapid, automated quantitative assessment, potentially facilitating real-time decision-making during PCI procedures and reducing operator workload [2,7].

5. Cross-Modality AI Validation (CCTA Studies)

Although not directly comparable to invasive angiography-based AI-QCA, studies utilizing AI-based coronary CT angiography demonstrated excellent agreement with IVUS-derived plaque and lumen measurements, with correlation coefficients exceeding 0.9 in some analyses [8, 9] . CCTA-based AI studies were included as supportive evidence of cross-modality AI performance rather than direct comparators to invasive AI-QCA.

6. Risk of Bias

Randomized controlled trials were assessed as having low to moderate risk of bias. Observational studies were subject to potential selection bias and confounding. Validation studies demonstrated variable methodological quality, particularly with respect to external validation and generalizability [17, 18]. A detailed assessment of study quality is presented in Table 3. Risk of bias across included studies using RoB is given in Figure 3 and Figure 4.

7. Overall Synthesis of Evidence

The available evidence shows that AI-QCA aligns well with established modalities from a technical standpoint, while early data also suggest it may offer comparable procedural performance and improved efficiency. [1-9].

DISCUSSION

Principal Findings

The main finding of this review is that, in the FLASH trial, AI-QCA-guided PCI was procedurally noninferior to OCT-guided PCI, while validation studies also showed consistent agreement between AI-QCA and manual QCA measurements.

Evidence from the randomized FLASH trial suggests that AI-QCA can achieve procedural results comparable to OCT-guided PCI, particularly for post-procedural minimal stent area.[1] Observational studies also point to possible gains in procedural efficiency compared with angiography-guided PCI, although these results should be interpreted cautiously given the non-randomized study designs and risk of confounding.[2]

In addition, validation studies consistently demonstrate strong agreement between AI-QCA and manual QCA, with moderate to strong correlations observed with intravascular imaging-derived measurements. [4–6]

However, the evidence base is weighted heavily toward technical validation rather than clinical outcomes. While technical validation of AI-QCA is well-established across multiple studies, clinical outcome-driven evidence remains limited, with only a single randomized trial assessing procedural endpoints and no studies adequately powered for long-term clinical outcomes. Whether strong agreement metrics translate to improved patient outcomes remains unanswered.

AI-QCA Compared with Intravascular Imaging

Intravascular imaging with IVUS and OCT has been shown to improve stent optimization and clinical outcomes in multiple randomized trials [10–13]. In this context, the FLASH trial provides important evidence that AI-QCA may approximate imaging-guided PCI. AI-QCA demonstrated noninferiority to OCT in achieving post procedural minimal stent area, with comparable rates of most procedural complications. The higher rate of stent malapposition observed with AI-QCA in the FLASH trial (13.6% vs 5.6%) is clinically significant and warrants careful consideration. Malapposition has been associated with delayed endothelialisation and may contribute to late stent thrombosis in certain contexts. This finding suggests that angiography-based AI-QCA may not fully capture microstructural stent–vessel interactions, particularly in complex lesions. In current practice, this supports the continued role of intravascular imaging for post-stent optimization, and suggests that adjunctive imaging may still be necessary even when AI-QCA is used for procedural guidance.

AI-QCA Compared with Angiography-Guided PCI

In comparison with conventional angiography-guided PCI, AI-QCA demonstrated potential procedural advantages. In the study by Ahn et al., AI-QCA-assisted PCI was associated with shorter procedure time, suggesting improved efficiency and streamlined decision-making [2].

However, this finding should be interpreted with caution given the retrospective design, substantial group imbalance (1:3 allocation), and potential selection bias. As such, causal inference regarding efficiency benefits cannot be established.

Overall, while AI-QCA may have the potential to improve procedural efficiency by standardizing lesion quantification without requiring additional equipment or procedural steps, this hypothesis requires confirmation in prospective, randomized studies before clinical adoption.

Validation and Agreement with Established Modalities

A substantial portion of the available evidence consists of validation studies comparing AI-QCA with manual QCA and intravascular imaging. Across these studies, AI-QCA consistently demonstrated strong agreement with manual QCA, with high intraclass correlation coefficients across multiple parameters [4, 5]. Additionally, moderate to strong correlations were observed between AI-QCA and IVUS/OCT derived measurements [6].

Although these studies could not be pooled quantitatively due to heterogeneity in reported metrics, their consistency supports the technical reliability of AI-QCA. Across studies, AI-QCA measurements were reproducible and compared favorably with established reference standards.

Contextual Evidence from Imaging-Guided PCI Trials

Randomized trials comparing imaging-guided PCI with angiography-guided PCI have consistently demonstrated improved procedural optimization and clinical outcomes with intravascular imaging [10–13]. In the GUIDE-DES trial, QCA-guided PCI demonstrated similar short-term outcomes compared with IVUS-guided PCI, suggesting that quantitative angiographic approaches may approximate imaging-guided strategies under certain conditions [3].

Taken together with the findings of the present review, this contextual evidence raises the possibility that automated quantitative angiography could approximate the benefits of intravascular imaging in lower-complexity cases, though this requires prospective confirmation.

Cross-Modality Validation of AI-Based Coronary Analysis

AI-based coronary CT angiography studies have demonstrated strong agreement with intravascular imaging. These differences in imaging modality, workflow, and clinical application limit direct comparability with invasive AI-QCA, and these findings are presented for contextual reference only.

Clinical Implications

The findings of this review suggest that AI-QCA could be a useful addition to conventional angiography, especially in settings where intravascular imaging is not routinely available.

At the same time, the current evidence does not support using AI-QCA as a substitute for intravascular imaging. Instead, it is better understood as an adjunct that can strengthen visual angiographic assessment when intravascular imaging is not performed. Its value may be greatest in more routine cases, whereas intravascular imaging still remains important for complex lesions.

Practical implementation will depend on integration with existing catheterization laboratory workflows, regulatory approval of AI-QCA platforms, and cost considerations relative to intravascular imaging modalities.

Limitations

This study has several limitations. First, the number of studies directly comparing AI-QCA with intravascular imaging or angiography was limited, precluding robust meta-analysis. Second, the included studies were heterogeneous in design, populations, and reported outcomes. Third, a large proportion of the evidence consisted of validation and correlation studies, which, although supportive of technical performance, do not provide direct evidence of clinical benefit. Fourth, the predominance of retrospective and validation studies limits causal inference. Fifth, most non-randomized studies were subject to potential selection bias and confounding. Sixth, most studies were conducted in high-volume centres within a limited geographic region, potentially affecting generalizability to broader clinical practice settings. Additionally, the AI-QCA systems were developed and validated predominantly on Korean patient datasets, and performance may differ in populations with different lesion morphology, vessel caliber, or imaging equipment. Finally, long-term clinical outcomes associated with AI-QCA-guided PCI remain insufficiently studied.

Future Directions

More research is needed to better define the clinical role of AI-QCA. In particular, large prospective randomized trials comparing AI-QCA-guided PCI with intravascular imaging-guided strategies will be important to determine whether these AI-based approaches can improve long-term outcomes. Greater consistency in outcome measures and reporting across studies would also help support future meta-analyses and strengthen the overall evidence base.

Conclusion

AI-QCA shows consistent technical reliability and may have a useful role as an adjunct to angiography in routine PCI, especially in settings where intravascular imaging is not commonly used. Still, the higher rate of stent malapposition and the lack of outcome-driven evidence make it clear that intravascular imaging remains essential for complex lesions and procedural optimization. Wider adoption of AI-QCA should depend on future randomized trials that demonstrate meaningful clinical benefit.

Declarations

Conflicts of Interest:

None

FUNDING

No external funding was received for this study.

DISCLOSURES

The authors report no relevant conflicts of interest.

AI DISCLOSURE

Generative artificial intelligence tools (ChatGPT, OpenAI) were used for language editing, grammar refinement, and manuscript formatting assistance. All scientific content, study selection, data extraction, statistical analyses, interpretation of findings, and final manuscript decisions were performed and verified by the authors

DATA AVAILABILITY

The data underlying this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

Yasaswini Nimmagadda: Conceptualisation, Methodology, Data curation, Formal analysis, Writing-original draft, Visualisation.

References

1. Kim Y, Yoon HJ, Suh J, Kang SH, Lim YH, Jang DH et al (2025) Artificial intelligence-based fully automated quantitative coronary angiography vs optical coherence tomography-guided PCI: the FLASH trial. JACC Cardiovasc Interv 18(2):187–197. 10.1016/j.jcin.2024.10.025
2. Ahn JH, Park S, Lee SH, Oh S, Lim Y, Hyun DY et al (2026) Evaluating the efficacy of AI-assisted quantitative coronary angiography in reducing procedural time for primary PCI in STEMI patients: a retrospective analysis. J Korean Med Sci 41(8):e2. 10.3346/jkms.2026.41.e2
3. Lee PH, Hong SJ, Kim HS, Yoon YW, Lee JY, Oh SJ et al (2024) Quantitative coronary angiography vs intravascular ultrasonography to guide drug-eluting stent implantation: a randomized clinical trial. JAMA Cardiol 9(5):428–435. 10.1001/jamacardio.2024.0059
4. Kim DH, Kim SH, Chu HW et al (2024) Validation of artificial intelligence-based quantitative coronary angiography. Digit Health 10:20552076241306937. 10.1177/20552076241306937
5. Kim Y, Roh JH, Kweon J et al (2024) Artificial intelligence-based quantitative coronary angiography of major vessels using deep learning. Int J Cardiol 405:131945. 10.1016/j.ijcard.2024.131945
6. Moon IT, Kim SH, Chin JY et al (2023) Accuracy of artificial intelligence-based automated quantitative coronary angiography compared to intravascular ultrasound: retrospective cohort study. JMIR Cardio 7:e45299. 10.2196/45299

7. Kwon O, Yoon HJ, Lee JH et al (2025) Cardiologist user experience of artificial intelligence-based quantitative coronary angiography. Cardiovasc Diagn Ther 15(6):1113–1121. 10.21037/cdt-2025-269
8. Ihdayhid AR, Tzimas G, Peterson K, Ng N, Mirza S, Maehara A et al (2024) Diagnostic performance of AI-enabled plaque quantification from coronary CT angiography compared with intravascular ultrasound. Radiol Cardiothorac Imaging 6(6):e230312. 10.1148/ryct.230312
9. Narula J, Stuckey TD, Nakazawa G et al (2024) Prospective deep learning-based quantitative assessment of coronary plaque by computed tomography angiography compared with intravascular ultrasound: the REVEALPLAQUE study. Eur Heart J Cardiovasc Imaging 25(9):1287–1295. 10.1093/ehjci/jeae115
10. Hong SJ, Kim BK, Shin DH et al (2015) Effect of intravascular ultrasound-guided vs angiography-guided everolimus-eluting stent implantation: the IVUS-XPL randomized clinical trial. JAMA 314(20):2155–2163. 10.1001/jama.2015.15454
11. Zhang J, Gao X, Kan J et al (2018) Intravascular ultrasound versus angiography-guided drug-eluting stent implantation: the ULTIMATE trial. J Am Coll Cardiol 72(24):3126–3137. 10.1016/j.jacc.2018.09.013
12. Ali ZA, Maehara A, Généreux P et al (2016) Optical coherence tomography compared with intravascular ultrasound and with angiography to guide coronary stent implantation (ILUMIEN III: OPTIMIZE PCI): a randomised controlled trial. Lancet 388(10060):2618–2628. 10.1016/S0140-6736(16)31922-5
13. Ali ZA, Landmesser U, Maehara A et al (2023) Optical coherence tomography-guided versus angiography-guided PCI. N Engl J Med 389(16):1466–1476. 10.1056/NEJMoa2305861
14. Liao J, Huang L, Qu M, Chen B, Wang G (2022) Artificial intelligence in coronary CT angiography: current status and future prospects. Front Cardiovasc Med 9:896366. 10.3389/fcvm.2022.896366
15. Jukema RA, Blanke P, Khoo JK, Tzimas G, Ahmadi A, Danad I et al (2025) Artificial intelligence–based coronary plaque quantification using coronary CT angiography: current insights and future directions. Radiol Cardiothorac Imaging 7(5):e240568. 10.1148/ryct.240568
16. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372:n71. 10.1136/bmj.n71
17. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I et al (2019) RoB 2: a revised tool for assessing risk of bias in randomized trials. BMJ 366:l4898. 10.1136/bmj.l4898
18. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M et al (2014) The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa Hospital Research Institute, Ottawa

Tables

Tables 1 to 3 are available in the Supplementary Files section.

Figures

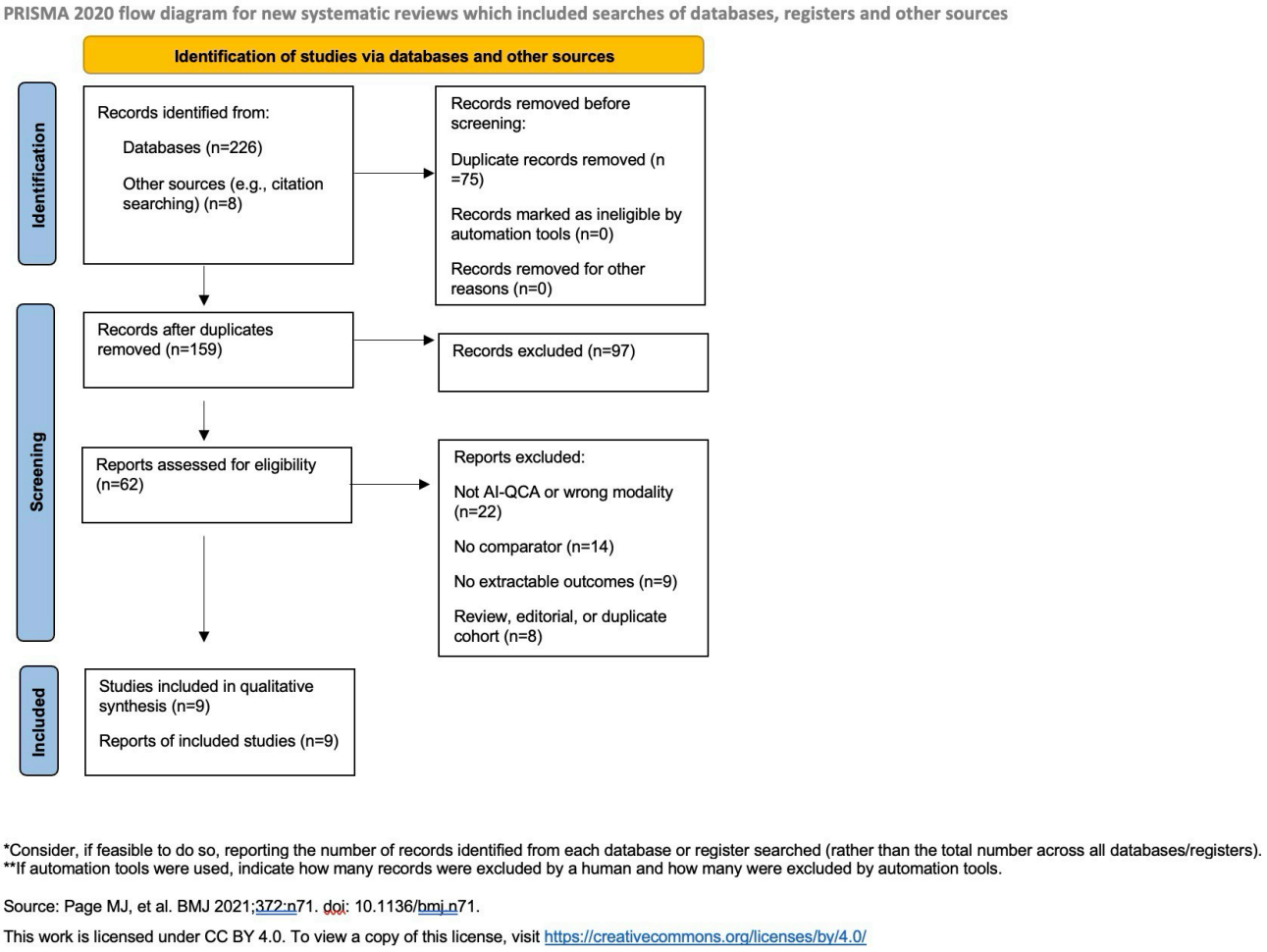


Figure 1

PRISMA 2020 flow diagram illustrating study identification, screening, eligibility assessment, and final inclusion of studies evaluating artificial intelligence-based quantitative coronary angiography (AI-QCA) in percutaneous coronary intervention.

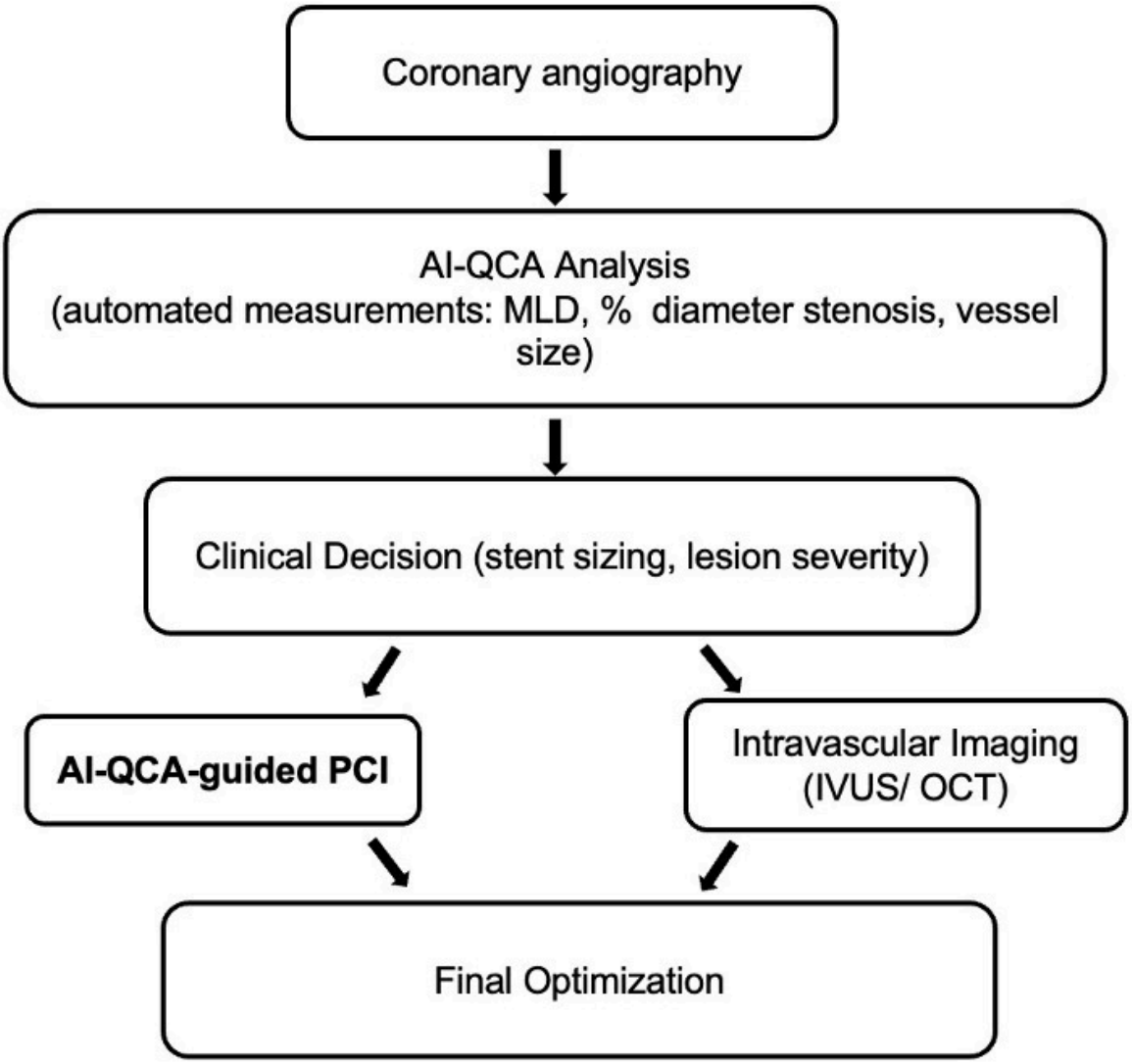


Figure 2

Conceptual overview of the AI-QCA workflow in percutaneous coronary intervention, including automated lesion assessment, procedural decision-making, and comparison with intravascular imaging–guided optimization.

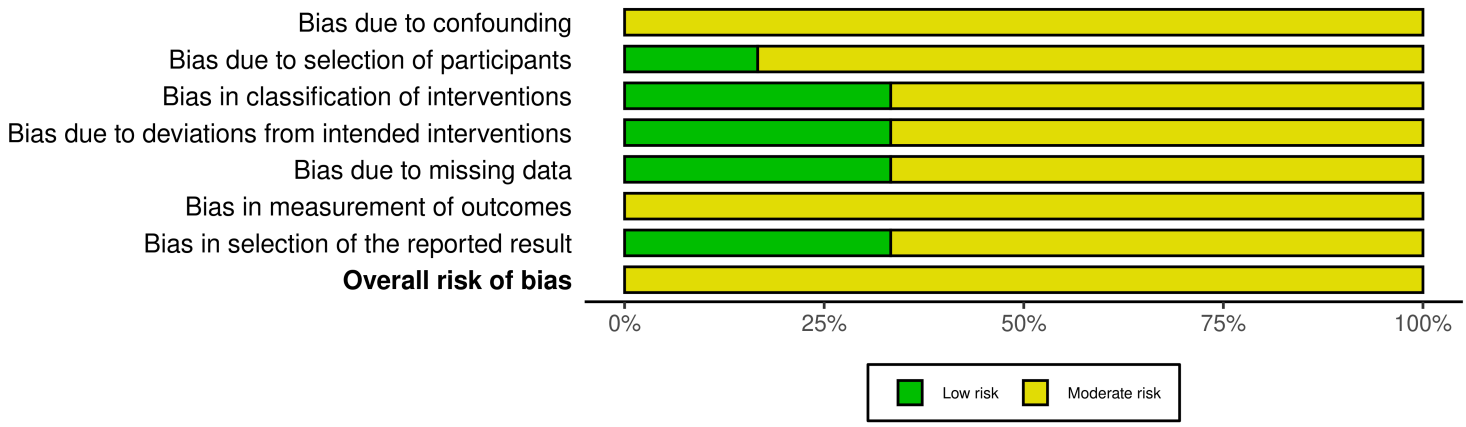


Figure 3

Summary of Risk of Bias Across Included Studies. Overall methodological quality assessment of randomized, observational, and validation studies included in the systematic review.

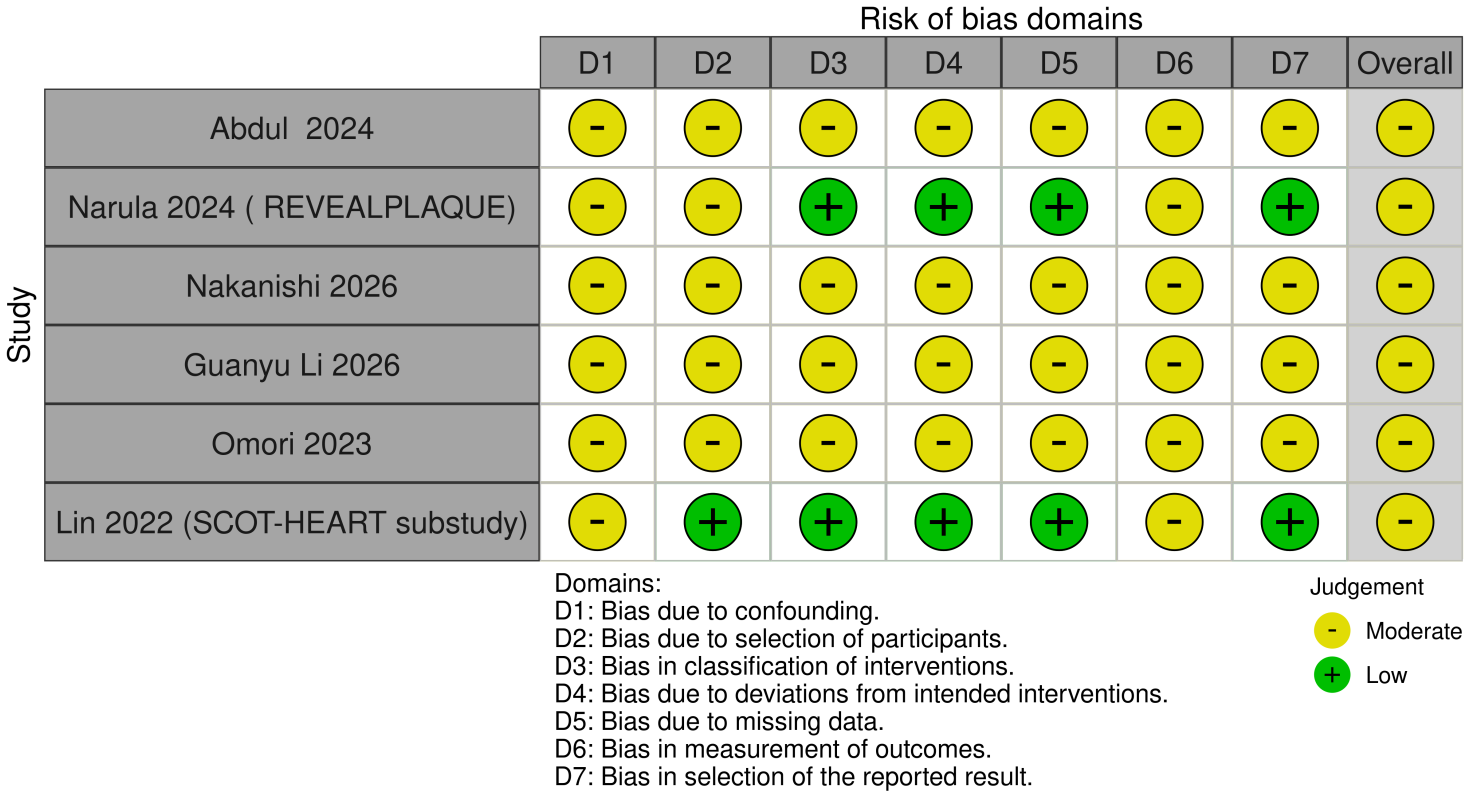


Figure 4

Domain-Level Risk of Bias Assessment for Randomized Trials. Traffic light plot illustrating RoB 2 domain assessments (D1–D7) for randomized studies included in the review.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- MaintablesAIQCA.docx
- SupplementaryTablesAIQCA.docx