Comparative Studies of Coronary Artery Disease: Insights into Risk Factors, Diagnostic Approaches, and Treatment Strategies

Muhammad Imran[1,2,] Rabia Javed[2], Muhammad Asif Raza[1*], and Perveen Akhtar[3]

[1]Department of Computer Science, BZU, Multan, Pakistan.

[2]Department of Computer Science, Times Institute Multan, Pakistan.
[3]Department of Computer Science, Institute of Southern Punjab, Multan, Pakistan.
[*]Corresponding Author: Muhammad Asif Raza. Email: asif79@bzu.edu.pk.

Abstract: Coronary artery disease is a coronary illness described by the deficient blood supply to the heart muscle because of restriction or blockage of the coronary veins. For the analysis of coronary vein sickness, diverse devices, and approaches assist in measuring the presence and level of heart issues. This study intended to analyze treatment procedures, risk factors, and analytic strategies, for coronary artery disease and give an understanding of the illness. Through an efficient survey and examination of huge information pertinent to CAD, we assembled an extensive variety of data and experiences. As far as risk factors, we tracked down that smoking, hyperlipidemia, diabetes, and hypertension were the primary elements of coronary artery disease. Furthermore, way of life factors like corpulence, family ancestry, stress, absence of activity, and lethargy are additionally emphatically connected with the development of the illness. For the analysis of coronary vein sickness, some different apparatuses and strategies assist in evaluating the presence and level of heart ischemia. One of the indicative devices for coronary artery infection is electrocardiography (ECG). It measures the electrical action of the heart and can distinguish weird heartbeats and indications of ischemia. It very well may be utilized both at rest and during actual work (for instance, on an ergometer) to evaluate the electrical movement of the heart under pressure. As far as other indicative strategies, we inspect different techniques and devices, including blood tests, coronary angiography, and X-ray, among others. These procedures assume a critical part in the early finding and evaluation of sickness seriousness. As far as treatment draws near, we investigated various strategies including drug treatment, interventional medical procedure, and cardiovascular detour medical procedure. The decision of these treatment procedures relies upon the seriousness of the illness and the particular patient's condition. We likewise feature the significance of cardiovascular reclamation and a sound way of life to forestall and oversee coronary veins infection. In outline, this concentrate exhaustively thinks about coronary supply route sickness, covering risk factors, symptomatic techniques, and therapy systems. These bits of knowledge will assist clinical experts with bettering their grasp of the infection and furnish patients with additional precise and customized judgments and treatment choices.

Keywords: Coronary Artery Disease; Vasculature; Comparative Studies, Heart Disease, SRL, Treatment Strategies, ECG, Angiography, Medical Images.

1. Introduction

CAD stays top of the main sources of horribleness and mortality around the world, representing a critical weight on general well-being frameworks [1]. It is a complex multifactorial condition described by the limiting or blockage of the coronary corridors, confining the bloodstream to the heart. Throughout the long term, broad exploration has been devoted to figuring out the different parts of coronary artery disease,

including its gamble factors, demonstrative methodologies, and treatment procedures. This paper plans to give complete experiences into the near investigations of coronary vein sickness, revealing insight into the different variables that add to its turn of events, the techniques utilized for exact analysis, and the advancing therapy methodologies that have shown promising outcomes. Understanding the treatment strategies related to CAD is critical for successful avoidance and the executives. Various conventional factors, like hypertension, dyslipidemia, smoking, diabetes, and stoutness, have been widely examined and connected to the advancement of atherosclerosis, the basic pathology of CAD [2]. In any case, ongoing examination has likewise distinguished arising risk factors, like hereditary inclination, aggravation, oxidative pressure, and way of life factors, which assume critical parts in the sickness cycle. Near examination of these wager variables will assist with explaining their overall significance and guide clinicians in risk evaluation and preventive mediation [3].

Demonstrative methodologies for CAD have developed over the long haul, with progressions in imaging strategies, research center tests, and painless methodology [4]. The relative assessment of these analytic modalities, including coronary angiography, stress tests, computed tomography angiography, and biomarker investigation, can give important experiences into their exactness, productivity, and cost viability. Such examinations are fundamental for enhancing analytic calculations and working with opportune and precise analysis, prompting fitting administration choices [5,7,9]. In addition, treatment methodologies for CAD have seen noteworthy advancement, going from way-of-life alterations and pharmacotherapy to interventional techniques and careful mediation. Relative examinations investigating the viability and well-being of different therapy draws near, for example, various treatment approaches, such as percutaneous coronary intervention, medical therapy, coronary artery bypass grafting, and emerging therapies like stem cell therapy or gene therapy, can assist with directing clinicians in pursuing informed choices custommade to individual patient profiles [6]. By basically investigating the current writing and introducing a thorough outline of relative examinations, this paper expects to solidify the momentum information encompassing coronary conduit illness. It looks to give clinicians, scientists, and medical services experts significant experiences in the gamble factors, symptomatic methodologies, and therapy systems related to CAD [8,10]. Eventually, this attempt expects to add to the improvement of patient consideration, the avoidance of intricacies, and the decrease of the worldwide weight of coronary corridor infection.

Moreover, understanding the near parts of coronary supply route infection across various populaces and segment bunches is fundamental for tending to wellbeing inconsistencies and fitting mediations as needs be. Varieties in hereditary inclination, social practices, financial elements, and medical care access can fundamentally affect the frequency, seriousness, and results of CAD. Similar examinations that investigate these distinctions among different populations give significant experiences into the subtleties of the infection and assist with distinguishing designated approaches for anticipation, early identification, and treatment. Such relative investigations can likewise add to the advancement of rules and strategies that advance impartial medical care conveyance and lessen the weight of coronary supply route illness on weak inhabitants [11]. One of the innovations that have taken place in the field of medicine is the use of robotics for surgery and nanotechnology [43-45].

Robotic heart medical procedure is a sort of negligibly obtrusive heart medical procedure that includes the utilization of automated gadgets, smaller-than-expected cameras, and accurate instruments to get to the heart without making a huge entry point or slicing through the breastbone. The specialist controls the careful instruments on slender mechanical arms through a PC console. This technique is at times called da Vinci medical procedure, robot-helped cardiovascular medical procedure, or shut chest heart medical procedure [46] as shown in Figure 1. Automated heart medical procedures might relish the upper hand over customary heart medical procedures, like less torment, dying, contamination, and scarring, however, it additionally has dangers and restrictions. The specialist concludes whether to do an automated heart medical procedure or a customary heart medical procedure given the patient's age, well-being, and heart problems [47].
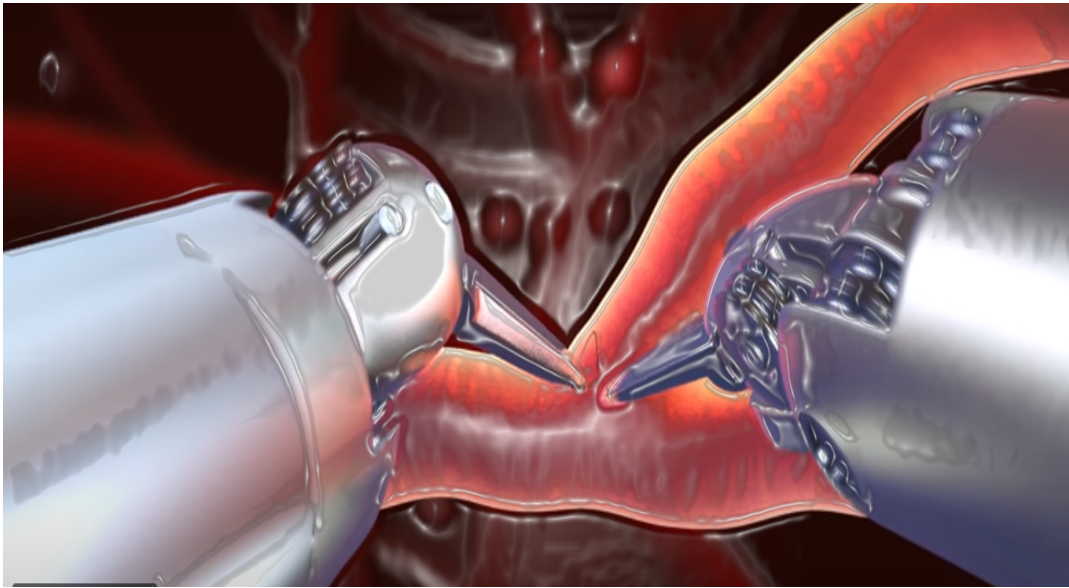
Figure 1. Robotic Coronary Surgery

Using a minimally invasive surgical approach, robotic surgery is carried out [12]. The robotic arms access relatively small incisions (often between 1 and 2 centimeters) to insert very small tools, directed by the surgeon, as opposed to making a big incision to expose the operative site and perform surgical procedures. As seen in Figure 2, the surgeon uses a computer to command the robotic arm.
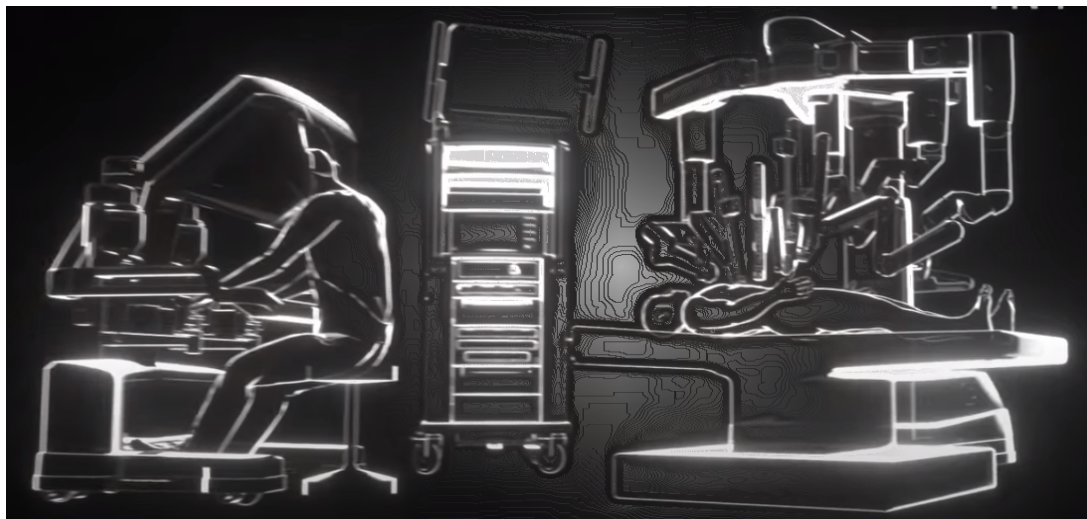
Figure 2. Robotic arms are controlled by a surgeon through a computer

While less pain, bleeding, infection, and scarring may be advantages of robotic heart surgery over traditional heart surgery, it still has hazards and restrictions. Based on the patient's age, health, and cardiac issues, the surgeon selects whether to perform robotic heart surgery or conventional heart surgery [48].

The organization of the work in this article is defined as follows. The existing CAD detection techniques for heart disease are discussed in section 2. The risk factors for coronary artery disease are discussed in section 3 and in section 4 diagnostic approaches are described with its analysis. Treatment strategies for CAD are discussed in section 5. Finally, section 6 concludes the work.

2. Methods

In a precise writing search, we recognized unique articles that monetarily assessed cardiovascular imaging procedures. We looked through the electronic information bases PubMed as a distributor, Embase, Web of Science, Medline (OvidSP), Cochrane monetary assessments library, and EconLit [13-15]. The hunt

comprised catchphrases relating to the file tests (MPS, SPECT, CTCA, PET, CACS, SE, xECG, FFR, CMRI), the reference test (CAG), the objective condition coronary artery disease, and cost-adequacy. The lifetime chance of creating coronary artery disease depends on age, orientation, identity, geographic area, and the presence of cardiovascular gamble factors and is assessed to be 38-51% in men also, 12-33% in women [16]. For patients who recently present with stable chest torment side effects, the assessment of thought coronary artery disease ordinarily incorporates an indicative workup to research the presence of CAD. The assessment ought to continuously start with a suitable history furthermore, actual assessment. Catheter-based coronary angiography (CAG), on occasion, joined with catheter-based fragmentary stream save (FFR) estimations, is the reference standard to analyze practically huge CAD [17]. Since it is expensive, obtrusive, and related to a significant gamble of major unfriendly occasions, CAG is suggested as an introductory test for patients with a high earlier likelihood of CAD.   Notwithstanding, research has shown that just 41% of patients going through elective strategies of catheter-based coronary angiographies are determined to have obstructive CAD [17-19]. These anxieties the need for better gamble delineation, which is underlined by choice examinations showing that the ideal decision of additional analytic examination in patients with stable chest torment relies principally upon the earlier likelihood of CAD. Settling on resulting indicative testing in patients with thought CAD is anyway troublesome, mostly due to the many testing choices at present accessible. We utilized different equivalents including both text words and Clinical Subjects to recognize financial assessment studies and choice models with deference to heart imaging tests [20].

2.1. Techniques Used for Diagnosis of Coronary Artery Disease

An exact and ideal analysis of coronary supply route sickness is pivotal for the proper administration and counteraction of entanglements. Throughout the long term, different demonstrative strategies have been created to assess the presence, degree, and seriousness of coronary supply route sickness [21]. One of the most usually utilized strategies is coronary angiography, which includes the infusion of a difference specialist into the coronary corridors followed by X-beam imaging. This method permits the representation of any blockages or restrictions in the coronary courses, supporting the identification of the impacted vessels and the assurance of the proper treatment technique [25]. Stress tests, for example, practice pressure tests and stress echocardiography, evaluate the heart's reaction to expanded responsibility, empowering the discovery of ischemic changes demonstrative of CAD [22]. Computed tomography angiography (CTA) has acquired ubiquity as a harmless imaging methodology that gives nitty gritty 3D pictures of the coronary corridors, assisting with distinguishing stenosis or plaque development [23]. Moreover, biomarker examination assumes a vital part in CAD finding, with heart-explicit markers, for example, troponin and C-responsive protein (CRP) used to evaluate myocardial harm and fiery action, separately. These methods, alongside other arising indicative modalities, add to the exhaustive assessment of CAD, empowering clinicians to go with informed choices regarding the proper treatment and the board methodologies [24]. There are main two categories of methods used for the diagnosis of CAD, invasive and non-invasive. In invasive methods, there is the usage of medicine and some sort of surgery. Invasive methods used for the diagnosis of CAD are shown in Table 1.

Table 1. Invasive Methods for CAD Diagnosis

Diagnostic Technique	Description
Coronary Angiography	It uses X-ray imaging and contrast dye to draw the arteries and blockages.
Cardiac Catheterization	It shows the pressure on the heart and obtains blood samples from it.
Fractional Flow Reserve (FFR)	It reflects blood pressure and flow across a conical coronary artery.

The selection between invasive and non-invasive techniques depends on conditions such as the patient's physical position, certain diagnostic objectives, the required level of information, the risks in vessels, and the accessibility to resources and skilled workers. It's important to note that while non-invasive methods are generally preferred for initial diagnosis, invasive procedures like FFR may be needed for convinced

cases where more direct data or interferences are required as shown in Figure 3. The choice of an exact indicative approach is best determined by medical experts based on the patient's requirements and clinical situations [26].
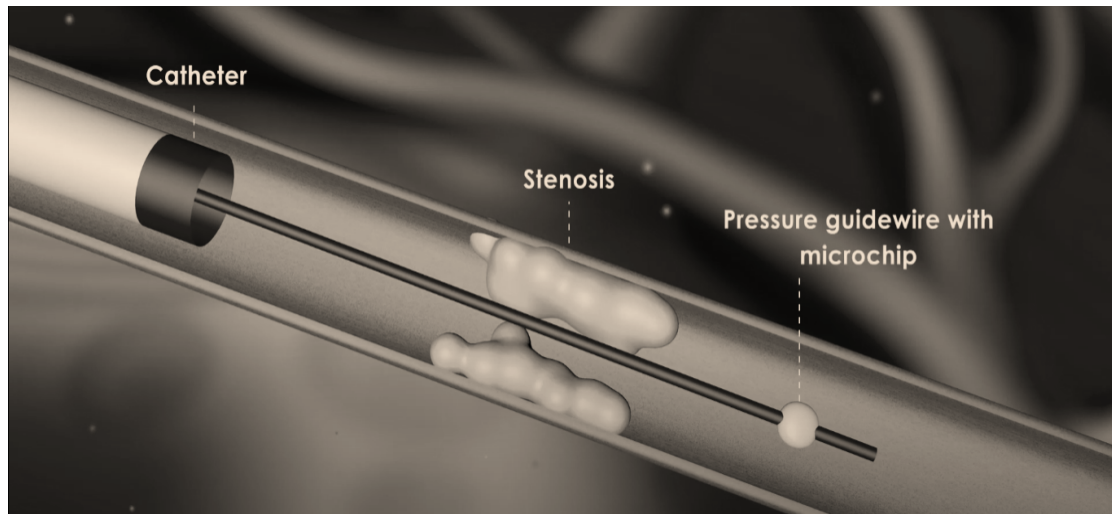
Figure 3. Fractional Flow Reserve procedure

Invasive methods encompass the insertion of medicines or medicinal devices while non-invasive techniques do not involve the injection of fluids or medical devices [52]. The non-invasive methods used for CAD diagnosis are reflected in Table 2.

Table 2. Non-invasive Methods for CAD Diagnosis

Diagnostic Technique	Description
Exercise Stress Test	It measures the heart's response to physical exertion, typically using a treadmill or exercise bike.
Nuclear Stress Test	It combines exercise or medication with nuclear imaging to assess blood flow to the heart.
Echocardiography	It's an imaging method that uses ultrasound to create images of the heart and assess its function.
CT Coronary Angiography	It's an imaging method that uses a CT scan to view the coronary arteries and detect blockages.
Cardiac Magnetic Resonance Imaging (MRI)	It's an imaging way that uses magnetic fields and radio waves to build images of the heart.
Myocardial Perfusion Imaging	It's a Nuclear imaging method that measures stresses on the heart at rest and pressure using radioactive tracers.
Cardiac Biomarkers	It's a blood test that measures certain substances released by the heart during episodes of ischemia or damage, such as troponin.

2.1.1. Coronary angiography

Coronary angiography is an operation used to envision the coronary corridors, which supply blood to the heart muscle. It is generally performed to analyze and evaluate the seriousness of coronary vein infection, a condition portrayed by the restricting or blockage of these conduits [27]. During coronary angiography, a slight, adaptable cylinder called a catheter is embedded into a vein, often in the crotch or wrist, and directed to the heart. The catheter is then strung through the veins until it arrives at the coronary supply routes. A unique color known as a contrast agent is infused through the catheter into the coronary supply routes. This color makes the veins noticeable on X-ray images, permitting the cardiologist to assess their narrowing, recognize any limiting or blockages, and decide the degree of the infection. The methodology is performed under locality sedation, and patients might get gentle sedation to assist them with unwinding. The X-ray images got during the technique are called angiograms and give point-by-point data about the state of the coronary conduits [53]. If critical blockages are recognized, the cardiologist might decide to carry out certain techniques during the angiography, like angioplasty or stenting, to reduce the blockages and further develop the bloodstream [28].

Coronary angiography is for the most part thought to be a protected technique, yet like any clinical mediation, it conveys a few dangers, for example, dying, vein harm, hypersensitive responses to the different colors, and in uncommon cases, cardiovascular failure or stroke [29]. Nonetheless, these inconveniences are moderately exceptional. It's vital to take note that coronary angiography is an invasive method and is commonly suggested when other non-invasive tests, for example, stress tests or CT scans, have demonstrated the chance of huge coronary artery disease [54]. The choice to go through coronary angiography is made given a singular's side effects, clinical history, and the general evaluation of their cardiovascular well-being by a cardiologist.

Some key points are given below about angiography:

- Preparation: Before the method, you will normally be approached to cease eating or drinking for a couple of hours. You might have to stop specific drugs briefly, particularly blood-thinning prescriptions, as they can build the chance of bleeding during the procedure [30]. It's fundamental to adhere to the directions given by your medical care group regarding any important arrangements.
- Procedure variations: While the groin is the most widely recognized site for catheter insertion, in some cases, the wrist (spiral vein) might be utilized all things being equal [35]. The decision of access site relies upon different elements, including the doctor's inclination, the patient's life structures, and any past intercessions or conditions.
- Potential sensations: During the procedure, you might encounter a few sensations, for example, a warm flush or a sensation of strain when the dye is infused [31]. You could likewise feel your heart hustling momentarily as the color moves through the coronary courses. If you find any distress or torment, it's critical to speak with the clinical group [32].
- Recovery: After the process, you will be observed for a couple of hours to assure that there are no complexities. The inclusion site might be closed with stitches or a conclusion gadget. You could have to lie level and cutoff progress for a specific period to decrease the chance of bleeding. Most patients are discharged that very day or the next day [33].
- Follow-up: The consequences of the coronary angiography will assist with directing further treatment choices. On the off chance that huge blockages are recognized, the cardiologist might suggest extra medications like coronary angioplasty and stenting to open up restricted supply routes [34]. At times, sidestepping a medical procedure may be thought of if different or extreme blockages are existing.

2.1.2. Stress tests

It is also famous as a treadmill or an exercise stress test to diagnose the heart's response to physical exertion. It is one of the initial non-invasive tests which is recommended to those patients who claim to have heart attack basic symptoms [36]. It aids to measure the overall cardiac working, finding potential heart issues, and determining suitable treatment plans for patients with known or assumed heart conditions. ECG machine is attached to the patient during exercise to measure the heartbeat and cardiac condition under pressure [53].

2.1.3. Computed tomography angiography

It is a non-invasive test to measure heart conditions. CT angiography (CTA) is an imaging procedure used to view the coronary arteries and detect obstructions or narrowing that may be revealing coronary

artery disease (CAD) [37]. It comprises the use of computed tomography (CT) scanning to generate detailed, cross-sectional descriptions of the heart and blood vessels. It delivers valued information about the occurrence, position, and severity of coronary artery obstructions, helping in the analysis and treatment planning for cardiac patients [38].

2.1.4. Biomarker analysis

It encompasses the measurement of certain substances released by the heart during incidents of ischemia or harm. There are different types of cardiac biomarkers, such as troponin, brain natriuretic peptide (BNP), and creatine kinase-MB (CK-MB) can be measured through blood examinations [39]. Higher levels of these biomarkers can show severe myocardial infarction (heart attack), heart failure, or heart muscle damage. The analysis of biomarkers shows a vital role in the examination, nursing of cardiac patients, and risk stratification, helping healthcare experts make informed decisions regarding patient supervision and treatment plans [40-44].

2.1.5. Comparative evaluation of diagnostic modalities

All diagnostic methods are used to find the certain condition of the heart, arteries, and blood. The summarized comparison of these techniques is shown in Table 3. It reflects the comprehensive analysis of these modalities for finding cardiac conditions [45]. It is necessary to note that Table 3 gives a general overview of diagnostic modalities for CAD and their features. The selection of diagnostic modality depends on numerous factors, including the level of suspicion for CAD patients, clinical presentation, the healthcare provider's expertise, and the availability of resources [50]. It's important to refer to a healthcare expert for personalized advice concerning diagnostic modalities and their suitability for individual cases [46].

3. Treatment Strategies for Coronary Artery Disease

Dealing with treatment strategies for CAD aims to accomplish the illness, alleviate symptoms, prevent disease advancement, and lessen the risk of complications. These approaches involve multifaceted methods, including pharmacotherapy, lifestyle modifications, surgical interventions, interventional procedures, and emerging therapies.

3.1. Lifestyle modifications

Lifestyle modifications play a vital role in handling CAD. It includes adopting a heart-healthy diet small in saturated and trans fats, maintaining a weight, performing regular physical activity, leaving smoking activity, handling stress, and monitoring conditions like diabetes, high blood pressure, and cholesterol level. These changes in lifestyle help to decrease the risk aspects related to CAD and improve overall cardiac health [47-49].

3.2. Pharmacotherapy

It involves the use of medications to control CAD. Pharmacotherapy usually prescribed for CAD includes antiplatelet elements (such as clopidogrel or aspirin), statins to manage cholesterol levels, beta-blockers to reduce heart load, angiotensin receptor blockers (ARBs) or ACE inhibitors to control blood pressure, and nitroglycerin to decrease angina symptoms. Medicines are prescribed to specific patient needs and purposes to manage symptoms, prevent further development of the disease, and reduce the risk of complications [51,52].

3.3. Interventional procedures

These procedures are nominally invasive methods performed to improve blood flow to the heart. The most common technique is coronary angioplasty, which comprises inflating a balloon in a narrowed coronary artery to broaden it and insertion of a stent to keep the artery open. Other interventions, such as rotational angioplasty or atherectomy, may be used in certain cases. These measures help restore blood flow, improve heart function, and alleviate symptoms.

Table 3. Comparative Analysis for CAD Diagnosis

Modality	Precision	Strengths	Weaknesses
Coronary Angiography	High accuracy for sensing	Visualization of coronary arteries	limited assessment of plaque

	blockages		composition
Exercise Stress Test	Limited accuracy, primarily detects significant blockages	Widely available, low cost, can evaluate exercise capacity	Limited sensitivity for detecting early-stage CAD, false-positive results possible
Nuclear Stress Test	Good accuracy for detecting perfusion abnormalities	Can evaluate blood flow to the heart, assesses the functional significance of blockages	Radiation exposure, longer procedure duration, limited anatomical details
Echocardiography	Good for evaluating heart structure and function	Non-invasive, no radiation exposure, can assess valve function	Limited assessment of coronary arteries, dependence on operator expertise
CT Coronary Angiography	High accuracy for detecting blockages, provides detailed anatomical information	Non-invasive provides detailed imaging of coronary arteries	Radiation exposure, the potential for false-positive results, limited assessment of plaque composition
Cardiac MRI	Good accuracy for assessing heart structure and function	Can evaluate heart function, tissue characterization, no radiation exposure	Longer scanning time, limited availability, contraindicated in certain individuals
Cardiac Biomarkers	Useful for risk assessment	Widely available, quick results	Requires other clinical findings

3.4. Surgical interventions

These interventions are measured for more extensive or multifaceted CAD cases. Coronary artery

bypass grafting (CABG) is a usually performed surgery where blood arteries from other portions of the body are used to bypass choked or narrowed coronary arteries, reinstating blood flow to the heart muscle. CABG is typically recommended for persons with severe obstructions, several vessel involvements, or certain high-risk situations [53].

3.5. Emerging therapies

These therapies for CAD involve state-of-the-art approaches that are being explored and developed. These may comprise novel medicines, stem cell therapies, gene therapies, or other progressive treatment modalities intended at preventing or retreating the development of CAD. These treatments are still in the investigational stage and may become accessible in the future to further enhance treatment choices for CAD patients. It's important to note that treatment policies for CAD are tailored to individual patient features, disease severity, and general health. The specific treatment strategy is determined by healthcare experts based on a complete assessment of each patient's state and needs [54].

3.6. Comparative analysis of treatment approaches and their outcomes

For CAD management a comparative analysis of treatment approaches and their outcomes for numerous medical situations is vital for optimizing patient care and improving medical outcomes. By evaluating different treatment modes, such as surgical interventions, medications, and non-invasive measures, healthcare experts can make informed verdicts tailored to individual patient needs. The analysis comprises assessing the safety, efficiency, and cost-effectiveness of each method used for CAD and is reflected by a graph on assumed data in Figure 4. Moreover, it considers the influence on patient quality of life, mortality, morbidity, and enduring prognosis. The data derived from such studies contribute to evidence-based medication, guiding clinicians in selecting the most suitable treatment plan for each patient [54]. Furthermore, ongoing research and improvements in medical expertise and therapies continue to enrich the comparative analysis landscape, fostering continuous development in patient care and coronary artery disease management.
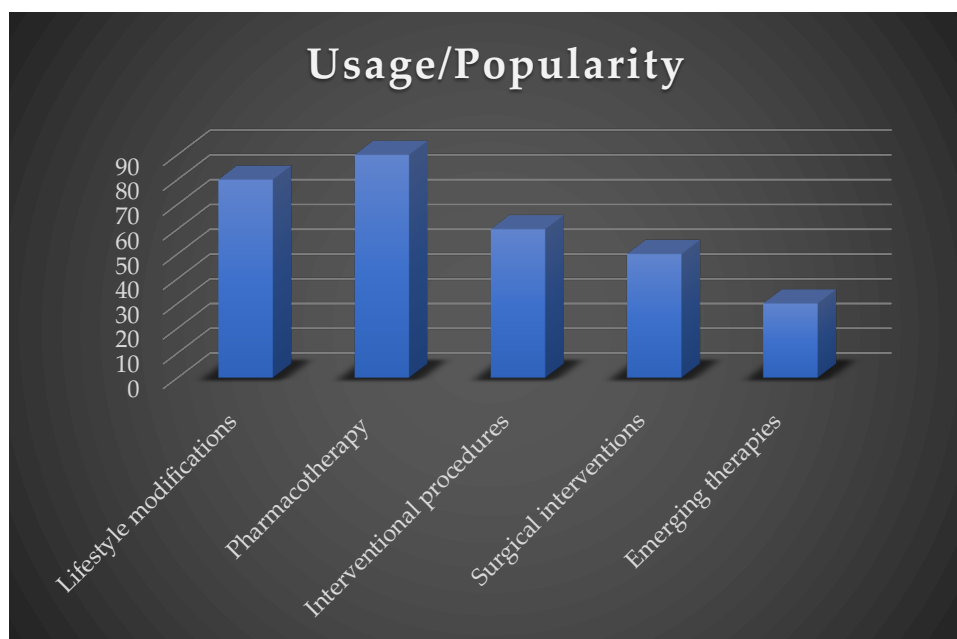
Figure 4. Graph of comparative analysis of treatment approaches

4. Healthcare access and its effect on diagnosis and treatment disparities

Healthcare access plays a key role in defining the diagnosis and treatment disparities among patients with coronary artery disease (CAD). Disparities in access to healthcare services, including screenings, preventive care, and intensive treatments, can significantly impact disease results. Factors such as terrestrial location, health insurance coverage, socioeconomic status, and cultural barriers can create walls to timely and suitable judgment and treatment. Patients from underserved or deprived communities may face challenges in accessing prime care, cardiovascular experts, or advanced investigative and therapeutic interventions. Therefore, delays in analysis and treatment initiation may occur, leading to more advanced disease

conditions and poorer prognoses. Addressing these inequalities requires a multi-faceted approach, concerning increased access to healthcare services, better health education, targeted outreach plans, and policy interventions to ensure equitable delivery of evidence-based treatments for all persons affected by CAD. Comparative studies on healthcare access can shed light on areas of improvement, enabling the expansion of strategies to enhance patient outcomes and reduce disparities in CAD care.

5. Conclusion

Despite extraordinary advancements in the cardiovascular examination, CAD stays quite possibly the most well-known cause of bleakness and mortality around the world. Nonetheless, huge cooperative endeavors between scientists, clinicians, and other related experts have prompted multi-layered and novel systems to be created to treat CAD and its related circumstances. However, a portion of these systems have solid proof supporting their clinical use, some others are still in the exploratory stage. Regardless of as it were early proof being accessible on a portion of these crafty treatment modalities, the outcomes are promising and also, hold the possibility to become options in contrast to current treatment choices later on. Since we live in a period of proof-based medication, additional proof as clinical preliminaries and long-haul follow-up investigations are expected before these intelligent treatment systems go into standard practice. With support proceeded with endeavors, the future for CAD therapeutics looks considerably encouraging.

References

1. Song Jiangping, Zheng Zhe, Wang Wei, Song Yunhu, Huang Jie, Wang Hongyue, Zhao Hong and Hu Shengshou. Assessment of Coronary Artery Stenosis by Coronary Angiography A Head-to-Head Comparison With Pathological Coronary Artery Anatomy. Cardiovascular Interventions 2013, ;6:262–268.

2. Rosamond W, Flegal K, Friday G, Furie K, Go A, Greenlund K, Haase N, Ho M, Howard V, Kissela B, Kissela B, Kittner S; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics–2007 update: 2007; 115:e69–171.

3. Husmann L, Leschka S, Desbiolles L, Schepis T, Gaemperli O, Seifert B, Cattin P, Frauenfelder T, Flohr TG, Marincek B, Kaufmann PA, Alkadhi H. Coronary artery motion and cardiac phases: dependency on heart rate – implications for CT image reconstruction. Radiology. 2007; 245:567–576.

4. Federspiel, J.M.; Gartner, J.; Lipp, P.; Schmidt, P.; Tschernig, T. Elderly with Varying Extents of Cardiac Disease Show InterindividualFluctuatingMyocardialTRPC6-Immunoreactivity.JCardiovasc.Dev.Dis.2023,10,26. //doi.org/10.3390/jcdd10010026.

5. Yamaguchi, Y.; Iribe, G.; Nishida, M.; Naruse, K. Role of TRPC3 and TRPC6 channels in the myocardial response to stretch: Linking physiology and pathophysiology. Prog. Biophys. Mol. Biol. 2017, 130 Pt B, 264–272.

6. Jacobs, T.; Abdinghoff, J.; Tschernig, T. Protein detection and localization of the non-selective cation channel TRPC6 in the human heart. Eur. J. Pharmacol. 2022, 924, 174972.

7. Bogdanova, E.; Beresneva, O.; Galkina, O.; Zubina, I.; Ivanova, G.; Parastaeva, M.; Semenova, N.; Dobronravov, V. Myocardial hypertrophy and fibrosis are associated with cardiomyocyte beta-catenin and TRPC6/Calcineurin/NFAT signaling in spontaneously hypertensive rats with 5/6 nephrectomy. Int. J. Mol. Sci. 2021, 22, 4645.

8. Al-Shammari, H.; Latif, N.; Sarathchandra, P.; McCormack, A.; Rog-Zielinska, E.A.; Raja, S.; Kohl, P.; Yacoub, M.H.; Peyronnet, R.; Chester, A.H. Expression and function of mechanosensitive ion channels in human valve interstitial cells. PLoS ONE 2020, 15, e0240532

9. Kato, S.; Nakamori, S.; Roujol, S.; Delling, F.N.; Akhtari, S.; Jang, J.; Basha, T.; Berg, S.; Kissinger, K.V.; Goddu, B.; et al. Relationship between native papillary muscle T1 time and severity of functional mitral regurgitation in patients with non-ischemic dilated cardiomyopathy. J. Cardiovasc. Magn. Reson. Off. J. Soc. Cardiovasc. Magn. Reson. 2016, 18, 79.

10. Waller, B.F.; Gering, L.E.; Branyas, N.A.; Slack, J.D. Anatomy, histology, and pathology of the cardiac conduction system: Part II. Clin. Cardiol. 1993, 16, 347–352.

11. Anderson, R.H. Clinical anatomy of the aortic root. Heart 2000, 84, 670–673.

12. Von Knorre, G.H. The 125th anniversary of the His bundle discovery. 125 Jahre Entdeckung des His-Bündels. Herzschrittmacherther. Elektrophysiol. 2018, 29, 116–121.

13. Kosiński, A.; Kozłowski, D.; Nowiński, J.; Lewicka, E.; Dąbrowska-Kugacka, A.; Raczak, G.; Grzybiak, M. Morphogenetic aspects of the septomarginal trabecula in the human heart. Arch. Med. Sci. AMS 2010, 6, 733–743.

14. Sridhar, A.R.; Padala, S.K. Isolated right bundle branch block in asymptomatic patients: Not inconsequential as previously thought? Heart 2019, 105, 1136–1137

15. Teragawa, H.; Uchimura, Y.; Oshita, C.; Hashimoto, Y.; Nomura, S. Frequency and Clinical Impact of Family History of Coronary Artery Disease in Patients with Vasospastic Angina. J. Cardiovasc. Dev. Dis. 2023, 10, 249. https://doi.org/10.3390/jcdd10060249

16. J.C.S.J.W. Guidelines for diagnosis and treatment of patients with vasospastic angina (Coronary Spastic Angina) (JCS 2013). Circ. J. 2014, 78, 2779–2801.

17. Jewulski, J.; Khanal, S.; Dahal, K. Coronary vasospasm: A narrative review. World J. Cardiol. 2021, 13, 456–463.

18. Rehan, R.; Weaver, J.; Yong, A. Coronary Vasospastic Angina: A Review of the Pathogenesis, Diagnosis, and Management. Life 2022, 12, 1124.

19. Li, L.; Shen, Y.; Yu, B.; Xu, C.; Zhao, X.; Lin, X.; Lin, Z. Coronary Artery Spasm: Risk Factors, Pathophysiological Mechanisms and Novel Diagnostic Approaches. Rev. Cardiovasc. Med. 2022, 23, 175.

20. Watanabe, K.; Shishido, T.; Otaki, Y.; Watanabe, T.; Sugai, T.; Toshima, T.; Takahashi, T.; Yokoyama, M.; Kinoshita, D.; Murase, T.; et al. Increased plasma xanthine oxidoreductase activity deteriorates coronary artery spasm. Heart Vessel. 2019, 34, 1–8.

21. Lin, X.; Lin, Z.; Zhao, X.; Liu, Z.; Xu, C.; Yu, B.; Gao, P.; Wang, Z.; Ge, J.; Shen, Y.; et al. Serum SELENBP1 and VCL Are Effective Biomarkers for Clinical and Forensic Diagnosis of Coronary Artery Spasm. Int. J. Mol. Sci. 2022, 23, 13266.

22. Yu, B.; Xu, C.; Tang, X.; Liu, Z.; Lin, X.; Meng, H.; Shi, C.; Ma, K.; Xiao, B.; Li, L. Endoplasmic reticulum stress-related secretory proteins as biomarkers of early myocardial ischemia-induced sudden cardiac deaths. Int. J. Legal. Med. 2022, 136, 159–168.

23. Ong, P.; Pirozzolo, G.; Athanasiadis, A.; Sechtem, U. Epicardial Coronary Spasm in Women With Angina Pectoris and Unobstructed Coronary Arteries Is Linked With a Positive Family History: An Observational Study. Clin. Ther. 2018, 40, 1584–1590.

24. Teragawa, H.; Oshita, C.; Ueda, T. History of gastroesophageal reflux disease in patients with suspected coronary artery disease. Heart Vessel. 2019, 34, 1631–1638.

25. Suzuki, S.; Kaikita, K.; Yamamoto, E.; Jinnouchi, H.; Tsujita, K. Role of acetylcholine spasm provocation test as a pathophysiological assessment in nonobstructive coronary artery disease. Cardiovasc. Interv. Ther. 2021, 36, 39–51.

26. Teragawa, H.; Oshita, C.; Orita, Y. Clinical significance of prolonged chest pain in vasospastic angina. World J. Cardiol. 2020, 12, 450–459.

27. Teragawa, H.; Oshita, C.; Uchimura, Y. Clinical Characteristics and Prognosis of Patients with Multi-Vessel Coronary Spasm in Comparison with Those in Patients with Single-Vessel Coronary Spasm. J. Cardiovasc. Dev. Dis. 2022, 9, 204.

28. Teragawa, H.; Oshita, C.; Ueda, T. The Myocardial Bridge: Potential Influences on the Coronary Artery Vasculature. Clin. Med. Insights Cardiol. 2019, 13, 1179546819846493.

29. Teragawa, H.; Oshita, C.; Uchimura, Y. The Impact of Myocardial Bridging on the Coronary Functional Test in Patients with Ischaemia with Non-Obstructive Coronary Artery Disease. Life 2022, 12, 1560.

30. Teragawa, H.; Fukuda, Y.; Matsuda, K.; Hirao, H.; Higashi, Y.; Yamagata, T.; Oshima, T.; Matsuura, H.; Chayama, K. Myocardial bridging increases the risk of coronary spasm. Clin. Cardiol. 2003, 26, 377–383.

31. Hokimoto, S.; Kaikita, K.; Yasuda, S.; Tsujita, K.; Ishihara, M.; Matoba, T.; Matsuzawa, Y.; Mitsutake, Y.; Mitani, Y.; Murohara, T.; et al. JCS/CVIT/JCC 2023 Guideline Focused Update on Diagnosis and Treatment of Vasospastic Angina (Coronary Spastic Angina) and Coronary Microvascular Dysfunction. Circ. J. 2023, 87, 879–936.

32. Sato, K.; Kaikita, K.; Nakayama, N.; Horio, E.; Yoshimura, H.; Ono, T.; Ohba, K.; Tsujita, K.; Kojima, S.; Tayama, S.; et al. Coronary vasomotor response to intracoronary acetylcholine injection, clinical features, and long-term prognosis in 873 consecutive patients with coronary spasm: Analysis of a single-center study over 20 years. J. Am. Heart Assoc. 2013, 2, e000227.

33. Nishimiya, K.; Suda, A.; Fukui, K.; Hao, K.; Takahashi, J.; Matsumoto, Y.; Mitsuishi, K.; Watanabe, T.; Ohyama, K.; Sugisawa, J.; et al. Prognostic Links Between OCT-Delineated Coronary Morphologies and Coronary Functional Abnormalities in Patients With INOCA. JACC Cardiovasc. Interv. 2021, 14, 606–618.

34. Kandaswamy E, Zuo L. Recent Advances in Treatment of Coronary Artery Disease: Role of Science and Technology. Int J Mol Sci. 2018 Jan 31;19(2):424. doi: 10.3390/ijms19020424. PMID: 29385089; PMCID: PMC5855646.

35. Bartel, T.; Rivard, A.; Jimenez, A.; Mestres, C.A.; Muller, S. Medical three-dimensional printing opens up new opportunities in cardiology and cardiac surgery. Eur. Heart J. 2017.

36. Valverde, I. Three-dimensional printed cardiac models: Applications in the field of medical education, cardiovascular surgery, and structural heart interventions. Rev. Esp. Cardiol. 2017, 70, 282–291.

37. Vukicevic, M.; Mosadegh, B.; Min, J.K.; Little, S.H. Cardiac 3D printing and its future directions. JACC Cardiovasc. Imaging 2017, 10, 171–184.

38. Wang, H.; Liu, J.; Zheng, X.; Rong, X.; Zheng, X.; Peng, H.; Silber-Li, Z.; Li, M.; Liu, L. Three-dimensional virtual surgery models for percutaneous coronary intervention (PCI) optimization strategies. Sci. Rep. 2015,5, 10945.

39. Javan, R.; Herrin, D.; Tangestanipoor, A. Understanding spatially complex segmental and branch anatomy using 3D printing: Liver, lung, prostate, coronary arteries, and circle of willis. Acad. Radiol. 2016, 23, 1183–1189.

40. Gao, L.; Kupfer, M.E.; Jung, J.P.; Yang, L.; Zhang, P.; Da Sie, Y.; Tran, Q.; Ajeti, V.; Freeman, B.T.; Fast, V.G.; et al. Myocardial tissue engineering with cells derived from human-induced pluripotent stem cells and anative-like, high-resolution, 3-dimensionally printed scaffold. Circ. Res. 2017, 120, 1318–1325.

41. McMahon, S.R.; Brummel-Ziedins, K.; Schneider, D.J. Novel oral anticoagulants in the management of coronary artery disease. Coron. Artery Dis. 2016, 27, 412–419.

42. Amini, M., Zayeri, F. & Salehi, M. Trend analysis of cardiovascular disease mortality, incidence, and mortality-to-incidence ratio: results from global burden of disease study 2017. BMC Public Health 21, 401 (2021). https://doi.org/10.1186/s12889-021-10429-0

43. Bonatti, J.; Vetrovec, G.; Riga, C.; Wazni, O.; Stadler, P. Robotic technology in cardiovascular medicine. Nat. Rev. Cardiol. 2014, 11, 266–275.

44. Suri, R.M.; Antiel, R.M.; Burkhart, H.M.; Huebner, M.; Li, Z.; Eton, D.T.; Topilsky, T.; Sarano, M.E.; Schaff, H.V. Quality of life after early mitral valve repair using conventional and robotic approaches. Ann. Thorac. Surg. 2012, 93, 761–769.

45. Smilowitz, N.R.;Weisz, G. Robotic-assisted angioplasty: Current status and future possibilities. Curr. Cardiol.Rep. 2012, 14, 642–646.

46. Granada, J.F.; Delgado, J.A.; Uribe, M.P.; Fernandez, A.; Blanco, G.; Leon, M.B.; Weisz, G. First-in-human evaluation of a novel robotic-assisted coronary angioplasty system. JACC Cardiovasc. Interv. 2011, 4, 460–465.

47. Weisz, G.; Metzger, D.C.; Caputo, R.P.; Delgado, J.A.; Marshall, J.J.; Vetrovec, G.W.; Reisman, M.;Waksman, R.; Granada, J.F.; Novack, V.; et al. Safety and feasibility of robotic percutaneous coronary intervention: PRECISE (Percutaneous Robotically-Enhanced Coronary Intervention) Study. J. Am. Coll. Cardiol. 2013, 61, 1596–1600.

48. Kypson, A.P. Recent trends in minimally invasive cardiac surgery. Cardiology 2007, 107, 147–158.

49. Srivastava, M.C.; Vesely, M.R.; Lee, J.D.; Lehr, E.J.;Wehman, B.; Bonaros, N.; Schachner, T.; Friedrich, G.J.; Zimrin, D.A.; Bonatti, J.O. Robotically assisted hybrid coronary revascularization: Does sequence of intervention matter? Innovations 2013, 8, 177–183.

50. Katz, M.R.; Van Praet, F.; de Canniere, D.; Murphy, D.; Siwek, L.; Seshadri-Kreaden, U.; Friedrich, G.; Bonatti, J. Integrated coronary revascularization: Percutaneous coronary intervention plus robotic totally endoscopic coronary artery bypass. Circulation 2006, 114 (Suppl. 1), 473–476.

51. Reicher, B.; Poston, R.S.; Mehra, M.R.; Joshi, A.; Odonkor, P.; Kon, Z.; Reyes, P.A.; Zimrin, D.A. Simultaneous "hybrid" percutaneous coronary intervention and minimally invasive surgical bypass grafting: Feasibility, safety, and clinical outcomes. Am. Heart J. 2008, 155, 661–667.

52. Schwalm JD, McKee M, Huffman MD, Yusuf S. Resource Effective Strategies to Prevent and Treat Cardiovascular Disease. Circulation. 2016 Feb 23;133(8):742-55. doi: 10.1161/CIRCULATIONAHA.115.008721. PMID: 26903017; PMCID: PMC4766731.

53. P Foëx, Innovations in management of cardiac disease: drugs, treatment strategies and technology, BJA: British Journal of Anaesthesia, Volume 119, Issue suppl_1, December 2017, Pages i23–i33, https://doi.org/10.1093/bja/aex327.

54. Kottke, Thomas E., Dennis A. Faith, Courtney O. Jordan, Nicolaas P. Pronk, Randal J. Thomas, and Simon Capewell. "The comparative effectiveness of heart disease prevention and treatment strategies." American journal of preventive medicine 36, no. 1 (2009): 82-88.