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The Role of Invasive and Noninvasive Cardiac Imaging Modalities in the Diagnosis and Treatment of Ischemic Heart Disease

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The Role of Invasive and Noninvasive Cardiac Imaging Modalities in the Diagnosis and Treatment of Ischemic Heart Disease

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Thesis Approval

The Role of Invasive and Noninvasive Cardiac Imaging Modalities in the Diagnosis and Treatment of Ischemic Heart Disease

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Jerusalem- Palestine

1446\2025

Dedication:

I dedicate this work to those whom I showed my life's path to, to those who taught me the meaning of persistence and that nothing is impossible in life, my dear family which encouragement and supported me during my entire educational journey, to the beacon of knowledge and scholars, the lofty edifice of Al-Quds University, to those who carried the most sacred message in life, to those who paved the path of science and knowledge for us, our distinguished professors.

Thanks for all your encouragement.

Declaration:

I certify that this thesis - or any part of it - which I submitted for the Master degree in Medical Imaging Technology – Functional Imaging track – is a result of my own work and research, under supervision of my supervisor, except where otherwise acknowledged, and this thesis – or any part of it – has not been submitted for a higher degree to any University or institution.

Signature……

Yazan Abdul-Aziz Abourmeileh

Date: 11/1/2025

Abstract:

This research explains the role of medical imaging modalities in diagnosing a specific disease, which is ischemic heart disease, which is one of the most common leading cause of death all over the world.

This research studies the role of invasive and noninvasive cardiac imaging modalities in the diagnosis of ischemic heart disease (IHD), focusing on their effectiveness, accuracy, and clinical using. The study used a quantitative research methodology, employing structured questionnaires distributed to medical cardiologist within Palestinian hospitals. Data were collected also from hospital medical record from 806 patients on their demographics, including age and gender, alongside diagnostic reports detailing imaging modality choices and their outcomes. Statistical tools were applied to analyze the collected data, identifying patterns and correlations between demographic factors and diagnostic effectiveness.

The findings show significant variations in diagnostic effectiveness based on the imaging modality used. coronary computed tomography angiography (CCTA) and myocardial perfusion image (MPI) mostly used for diagnosing coronary artery disease in intermediate-to-high risk patients, whereas stress electrocardiogram (ECG) was more commonly used for lower-risk or symptomatic patients due to its accessibility and cost-effectiveness. The results show that patient age and gender influenced the choice of diagnostic tools, with younger patients often undergoing methods like ECG, while older patients and those with complex symptoms were more likely to receive advanced imaging modalities.

The study concludes that noninvasive imaging modalities are important tools in diagnosing and managing IHD. However, the selection of an appropriate modality should base on patient-specific factors, including clinical presentation, age, gender, the economic context, hospital protocols, and which protocol doctors follow.

For Palestinian hospitals, improving access to advanced imaging modalities and training professionals on their application could enhance diagnostic accuracy and treatment outcomes. This research underscores the need for tailored diagnostic pathways and supports the integration of advanced, cost-effective imaging technologies in resource-limited healthcare systems.

Finally, we found that cardiologist in Palestinian hospitals follow the worldwide criteria for diagnosis ischemic heart disease, especially European society of cardiology and American heart association.

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ABBREVIATIONS AND ACRONYMS:

CAD = Coronary Artery Disease

IHD = Ischemic Heart Disease

MI = Myocardial Infarction

EECG = Exercise Electrocardiogram

ETT = Exercise Treadmill Test

CCTA = Coronary Computed Tomography Angiography

SE = Stress Echocardiogram

MPI = Myocardial Perfusion Imaging

SPECT = Single Photon Emission Computed Tomography

PET = Positron Emission Tomography

CMRI = Cardiac Magnetic Resonance Imaging

TTE = Transthoracic Echocardiogram

TEE = Trans Esophageal Echocardiogram

ICA = Invasive Coronary Angiography

IVUS = Intra Vascular Ultra Sound

LVEF = Left Ventricular Ejection Fraction

PCI = Percutaneous Coronary Intervention

PTP = Pretest Probability

RCT = Randomized Clinical Trial

LBBB = Left Bundle Branch Block

LAD = Left Anterior Descending Artery

Definitions:

- **Heart Disease**: is a general term that refers to a variety of conditions impacting the heart's structure and function. These conditions include coronary artery disease, arrhythmias (irregular heart rhythms), congenital heart defects, heart infections, and cardiomyopathies. Among these, coronary artery disease—commonly caused by the buildup of plaque in the arteries—is one of the most prevalent types and a major contributor to heart attacks.
- **European Society of Cardiology (ESC)**: The European Society of Cardiology is a nonprofit medical society founded in 1950, headquartered in France. It represents cardiology professionals from across Europe and beyond, providing education, clinical practice guidelines, and research in the field of cardiology. The ESC aims to reduce the burden of cardiovascular disease through scientific advancements and policy influence, fostering collaborations between cardiologists and other healthcare professionals.
- **American Heart Association (AHA)**: The American Heart Association is a U.S.-based nonprofit organization founded in 1924, focused on improving heart and brain health for all. The AHA funds cardiovascular research, offers public education, advocates for health policies, and establishes clinical guidelines to prevent and treat heart disease and stroke. The organization is a leading authority on cardiovascular health and is involved in extensive efforts to combat heart disease, stroke, and other cardiovascular conditions globally.
- **Criteria for Detecting Cardiac Pathologies:** The criteria for identifying cardiac pathologies like ischemia typically involve recognizing specific clinical symptoms (e.g., chest pain, shortness of breath), risk factors (e.g., hypertension, diabetes, family history), and measurable indicators (such as ECG changes, biomarkers like troponin levels). These criteria help in stratifying patients' risk and selecting those who may need further diagnostic testing.
- **Signs and symptoms:** A medical sign is an objective observable indication of a disease such as unstable angina, stable angina atypical angina
- **Symptoms**: A symptom is something felt or experienced, such as chest pain, shortness of breathing and palpitation

Chapter One:

Introduction:

1.1. Background Information:

Ischemic heart disease is one of the most common cause of mortality in Palestine, accounting for 3,345 deaths or 22.2% of all deaths annually, according to the Palestinian Ministry of Health's yearly statistical report (Health, 2022). Ischemia is defined as a localized insufficient blood flow (circulation) caused by a occlusion of the blood vessels supplying the region. Ischemic refers to an organ not get enough blood and oxygen supply, such as the heart ((IOM), 2010).

Atherosclerosis is a vascular condition that affects the coronary, carotid, and cerebral arteries and is characterized by the formation of fibro fatty raised lesions (plaques) (Concistrè, 2023)

Noninvasive cardiac imaging is the foundation of the diagnostic process for patients with suspected coronary artery disease (CAD), cardiomyopathy, heart failure, or congenital heart disease. Noninvasive cardiac imaging is essential for the assessment of CAD from functional and anatomical perspectives, and considered as the entry point for Exercise electrocardiography, stress echocardiography, single photon emission computed tomography myocardial perfusion imaging and coronary computed tomography are some of the cardiac tests.

The accessibility of an assortment of imaging modalities is supportive for the early determination and treatment of cardiac conditions as well as the execution of preventive activities which will affect the long-term guess of those illnesses. Choosing the proper test for a specific persistent can be troublesome for clinicians. The decision-making prepare in CAD appraisal will be encouraged by having an essential understanding of each methodology. (Kirali, 2015)

With the advantages of easy availability, low cost, fast performance and safety, transthoracic echocardiography (Echocardiography) is the most commonly used non-invasive imaging tool (Prasad, 2018). Myocardial perfusion imaging (MPI) could be a noninvasive imaging test that employs SPECT or PET imaging of the patient's heart some time recently and after physical or pharmacological stretch to decide territorial contrasts in coronary blood stream. (Ashvarya Mangla, 2017)

1.2. Purpose and Importance of study

The research aims to expand and increase knowledge and use of methods in

imaging the heart and to know what methods and standards doctors use in determining the type of device used in diagnosing ischemic heart diseases. Through research, we can clarify whether the difference in the device, the difference in age group, and the difference in gender between patients can affect the diagnosis of heart disease. In general, doctors in Palestinian hospitals follow the American Heart Association (AHA) guidelines for diagnosis IHD

1.3. Research Question

1.3.1. Main Question:

What are the criteria and the role of the cardiologist and the imaging modalities in detecting cardiac pathologies like ischemia?

Sub-Questions:

- Is there a certain criterion which cardiologists follow in choosing the imaging modality to diagnose ischemic heart disease?
- What are the criteria that cardiologists follow in choosing the imaging modality to diagnose ischemic heart disease?
- Are the clinical manifestations and severity of illness lab, study, sign and symptoms affect the guided of diagnosis of CAD?
- **Research Hypothesis:**

1. The age of the patient can affect the diagnosis of ischemic heart disease.
2. The type and accuracy of the device affect the diagnosis of ischemic heart disease.
3. Cardiologists effectively apply the European and American diagnostic criteria when selecting imaging modalities, demonstrating the practical implementation of theoretical guidelines in clinical decision-making.

Chapter Two:

Literature Review

2.1.1 Theoretical Framework

In this chapter, a background will be given about non-invasive and invasive diagnostic methods for IHD.

Ischemia is defined as insufficient blood supply to a specific area due to occlusion of the blood vessels supplying the tissue in this area, and this make an imbalance between blood supply and the needs of organ. This means that an organ (e.g.: heart, kidney, etc.) is not getting enough oxygenated blood from circulation, which can lead to organ dysfunction and failure. (Gibbons et al., 2002a).

Ischemic heart disease (IHD), also called coronary heart disease (CHD), which means a decrease in blood supply to heart muscles due to narrowing in coronary arteries that supply blood to heart muscles.

IHD can be due to blood clot or by vasoconstriction of the blood vessels (vasospastic angina), in the majority of case the causes of IHD is a buildup plaque, called atherosclerotic plaque, and when this clot blocks the whole lumen of the blood vessels, oxygenation blood doesn't reach heart muscle, so it die, which terms heart attack or myocardial infarction (MI). (Campeau, 1976, 2002)

Most patients with early (less than 50 percent narrowing) still asymptomatic, which called silent ischemia, or may have mild symptoms, however if IHD left untreated the atherosclerosis progress and symptoms start to occur gradually. (Lloyd-Jones et al., 2010)

Patients with ischemic heart disease (IHD) often experience symptoms during physical exertion or stress tests, when the body's demand for oxygen increases. Common symptoms include chest pain or discomfort, pain in the neck, jaw, shoulder, or arm, rapid heartbeat, shortness of breath, sweating, nausea, vomiting, and fatigue. These symptoms are typically triggered by physical activity or emotional stress and are usually alleviated by rest or the use of nitroglycerin. (Moran A.E, 2014)

Over last years, despite the prevention and treatment for ischemic heart disease (IHD) and increase interest of physician toward IHD, IHD still represent a significant burden on mortality and morbidity worldwide. (Moran, and others, 2010)

IHDs remain one of the leading causes of death overwide, there are currently about 126.5 million cases of IHD in the world, and its accounting for more than 9 million of deaths per year worldwide. (Nowbar, 2019)

According to the American Heart Association, there are more than 720,000 new case per year. (Virani, 2020)

Coronary artery disease is generally categorized into the following types:

- Stable ischemic heart disease (SIHD)
- Acute coronary syndrome (ACS)
- ST-elevation MI (STEMI)
- Non-ST elevation MI (NSTEMI)
- Unstable angina

ysiology: .Pathoph2.1.2

The pathophysiology of IHD is mainly characterized by development of atherosclerotic plaque in the coronary endothelium, which is a deposition of fatty component that narrows the lumen of blood vessel, and decreases the blood flow to the heart tissues. (Thompson R.C., 2013)

The formation of atherosclerotic plaque begins with the development of a fatty streak, characterized by the accumulation of lipids and low-density lipoproteins (LDL) in the subendothelium. When blood vessel injury occurs, macrophages migrate to the subendothelial layer, where they absorb oxidized LDL particles, leading to the formation of foam cells. The continued deposition of LDL and collagen increases the number of foam cells, eventually resulting in the formation of a subendothelial plaque. (Thompson R.C., 2013)

Over the time, plaque could grow in size or become stable if no further injury occurs to the endothelium.

If become stable, a fibrous cap form and calcification occurs, this plaque will decrease the blood flow to the myocardium which increase demands and angina occurs

Some plaque may rupture and form a thrombus, which can cause a subtotal or total occlusion of the lumen, which in result develop acute coronary syndrome (ACS) on the form of unstable angina, NSTEMI, or STEMI. (Nakahare, 2017)

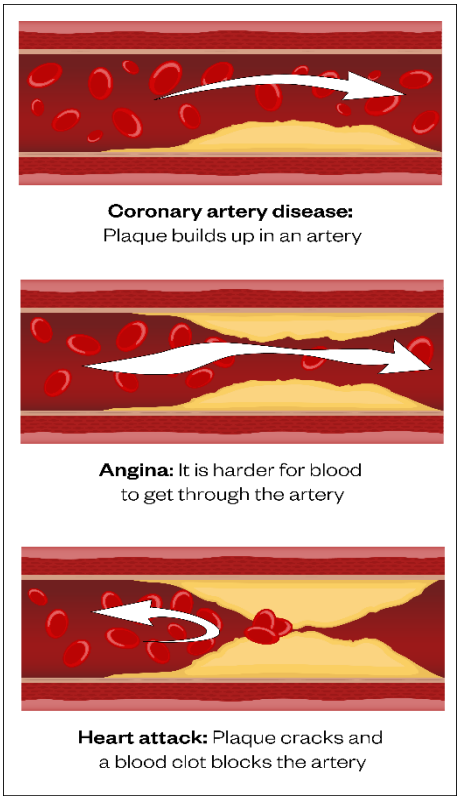

Figure (1): difference between angina and MI

The previous figure (1) represents the different in blood vessels and between angina and MI and the percent of occlusion for each disease

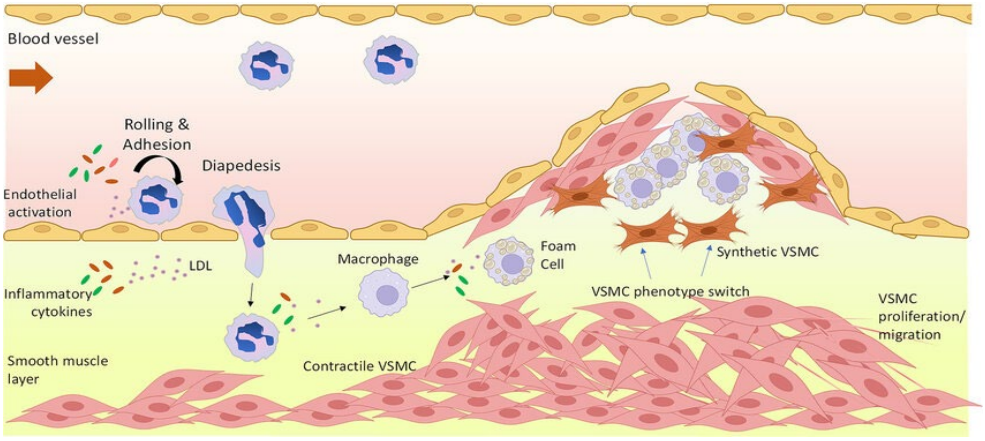

Figure (2): Pathophysiology of CAD

Figure (2) shows the pathophysiology of ischemia and CAD, starting from blood vessel injury, migration of cells toward the site of injury and formation of thrombus.

2.1.3 Diagnosis

To diagnose ischemic heart disease, it is important to differentiate between acute ischemia and chronic ischemia, whereas acute ischemia is a medical emergency, and patient should undergo catheterization or medication without diagnostic testing.

On the other hand, chronic ischemia has several methods to diagnose and evaluate IHD, including ECG, Echo, CXR, stress test, SPECT, PET, Coronary CT, cardiac catheterization, and CBC. These tests are done depending on the presentation of patient. (Amsterdam EA, 2014)

Assessment of patient with IHD is an important task and should be adjusted by assessing patient likelihood. The clinical likelihood is modified on the basis of traditional risk factors (ie, hypertension) and basic tests (ie, resting electrocardiography, echocardiography, laboratory tests), with an emphasis on left ventricular function and kidney function.

2.1.3.1 Biochemical testing:

Basic tests in patient with suspected IHD include laboratory test, which required to detect the possible causes of ischemia, as well as to diagnose cardiovascular risk factors and other conditions will increase the likelihood of having ischemia.

Complete blood count (CBC) and hemoglobin (Hb) testing to rule out anemia, renal function test to rule out renal failure, plasma glucose level and glycated hemoglobin (HbA1c) also should be tested to rule out diabetes as risk factors.

Another important test is lipid profile (total cholesterol, high density lipoprotein, low density lipoprotein and triglycerides). (A.R. Henderson a., 1998)

2.1.3.2 Electrocardiogram:

Baseline (resting) ECG is recommended for all patient with suspected IHD or chest pain, it also can be helpful to detect previous abnormalities (prior MI), conducting abnormalities, or arrythmia.

Previous abnormalities can be detected by looking at ST-segment, T wave, and pathological Q waves.

2.1.3.3 Echocardiogram:

Echocardiography is another important pre-test to detect any abnormalities that indicate ischemic myocardial damage, as: Reduction in left ventricle (LV) systolic function, diastolic dysfunction, regional wall motion abnormalities.

2.1.3.4 Chest X-ray:

Chest X-ray could be helpful in evaluating patient with suspected heart failure, or pulmonary abnormalities, and to rule out other cause of chest pain.

2.1.3.5 Non-Invasive Methods:

A variety of diagnostic methods are commonly used to identify ischemic heart disease (IHD). These include calcium scoring tests, treadmill exercise tests, stress echocardiography, myocardial perfusion imaging through single-photon emission computed tomography (SPECT) or positron emission tomography (PET), coronary computed tomography angiography (CCTA), and cardiac magnetic resonance imaging (CMR).

The key step in the diagnostic process is selecting the most appropriate initial test. This requires understanding the pre-test probability of IHD, along with evaluating the risks, benefits, and expected outcomes associated with each diagnostic method.

Non-invasive methods divided into

- Functional tests that provide information not given by standard ICA. Functional tests include exercise ECG, exercise/pharmacologic stress echocardiography, exercise/pharmacologic cardiac nuclear imaging with single-photon emission computed tomography (SPECT) or positron emission tomography (PET), pharmacologic stress magnetic resonance imaging (MRI), computed tomography (CT) cardiac perfusion.
- Anatomic tests include coronary CT angiography (CCTA) and coronary artery calcium scoring (CACS). (Wolk MJ, Bailey SR, Doherty JU, et al., 2014)

2.1.3.5.1 Coronary CT Angiography (CCTA) and Calcium Score Test:

As initial diagnostic non-invasive method to diagnose and evaluate CAD, CCTA still the main non-invasive imaging test to detect atherosclerotic plaque within coronary artery.

CCTA examination has two parts:

A. Calcium scoring test.
B. CCTA

At first **calcium scoring test** used to detect how much calcium calcified in coronary arteries lumen by using Computed Tomography (CT) scan to detect the calcium calcification within the lumen. (Agatston AS, 1990)

New studies demonstrate that incorporate the coronary artery calcium score can improve the accuracy of IHD diagnosis by another test. Calcium score can detect the severity of IHD by detect the calcification of calcium in coronary arteries, and can predict the prognosis of asymptomatic patients with low to intermediate probability of CAD, it is based on sex, age, and risk factor, it has sensitivity of 91% and specificity of 64%. (McClelland RL, 2006) In general, a score of 1-10 is consider as minimal calcification, 11-100 mild calcification, 101-400 moderate calcification, more than 400 severe calcification.

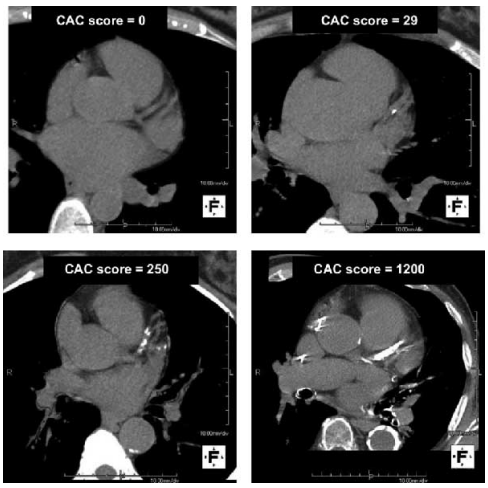

Figure (3): Calcium Scoring test results.

Benefits: Calcium scoring test has rapid turnaround and needs little preparation, and its good for testing in outpatient clinic. (Shaw LJ, 2003)

The previous figure shows a calcium scoring result done for patient with suspected CAD to see how much calcium is calcified in the lumen of coronary artery.

Table (1): Indications and Contraindications of Calcium Scoring test

Indications and Contraindications of Calcium Scoring test: (Raggi p, 2004)	
Indications:	**Contraindications:**
Calcium scoring test used by healthcare providers to choose the right treatment to start for patient with borderline risk of heart disease.	Pregnant patient shouldn't undergo calcium score test because a CT scan could harm fetus.
And it used for young patient with family history of high cholesterol level.	

2.1.3.5.2 CCTA:

First iodinated contrast is intravenously administrated to the patient at rate of 5-7 ml\sec.

CCTA can be performed by two methods:

- Prospectively with patient has heart rate less than 60 beat\min, in this situation X-ray is turned on only during mid diastolic part of cardiac cycle.
- Retrospectively: is used for patient suffered from arrhythmias or higher heart rates, here the X-ray is turned on during the entire cardiac cycle, so it increases the exposure to radiation, with this method CCTA can also assess LV wall motion abnormalities and systolic function. (Groves DW, 2020)

After CCTA atherosclerotic plaque of coronary artery are detected, and classified as:

- Noncalcified: which is called soft plaque.
- Partially calcified: which is called low density plaque or vulnerable plaque, and has a high risk of rupture.

- Totally calcified: which is called occluded artery. (Goldstein JA, 2011)

Table (2): Indications and Contraindications of CCTA

Indications and Contraindications of CCTA: (Groves DW, 2020), (Budoff MJ, 2008)	
Indications:	**Contraindications:**
• Abnormal results from other diagnostic methods.	• Kidney failure.
• Abnormal coronary artery structure and anomalies.	• Allergy from iodine.
• For evaluation of stable coronary artery disease.	• Tachycardia (up to 60).
• For evaluation of stable coronary artery disease post-revascularization. (Groves DW, 2020)	• High calcium score (more than 700).

CCTA has high resolution and can detect anatomically coronary artery stenosis with sensitivity (94%) and specificity with (83%). (Arlene Sirajuddin, 2021)

2.1.3.5.3 Cardiac stress tests:

Cardiac stress testing is the most common method used to diagnose and evaluate patient with known or suspected CAD.

Also, stress tests are used to obtain prognostic information to determine the patient's response to medical therapy. (Henzlova MJ, 2016)

2.1.3.5.4 Exercise Test:

The best initial diagnostic tool is ECG-monitored exercise testing, which has been used for provocation and identification IHD, and tells how well heart responds to exercise and working.

Exercise test can be used by physicians, nurse, exercise physiologists and specialist, and other healthcare workers. (Bourque JM, 2015)

2.1.3.5.4.1 Cardiovascular response to Exercise test:

Cardiovascular system responds to exercise testing by stimulating the sympathetic pathway and decrease in vagal tone, which will increase the heart rate, cardiac output and peripheral resistance. the maximum heart rate achieved during exercise will be affect by age.

Blood pressure depend on cardiac output and peripheral vascular resistance, so systolic blood pressure rises and diastolic blood pressure will remain the same. (Bourque JM, 2015)

2.1.3.5.4.2 ECG changes during exercise:

- Increase magnitude of P-wave, especially in frontal plane inferior lead.
- Short PR segment.
- J-point deviation.
- Upsloping ST depression. (Bourque JM, 2015)

Table (3): Indications for exercise test

Indications for exercise test: (Bourque JM, 2015)
• **Detection of IHD: Identify ischemic heart disease in patients presenting with chest pain or related symptoms.**
• **Assessment of CAD Severity: Evaluate the anatomical and functional severity of coronary artery disease.**
• **Risk Prediction: Predict the likelihood of cardiovascular events and overall mortality.**
• **Physical Capacity Evaluation: Assess physical fitness and effort tolerance.**
• **Exercise Symptom Assessment: Evaluate symptoms triggered by physical activity.**
• **Chronotropic Competence and Arrhythmias: Monitor heart rate response, detect arrhythmias, and evaluate responses to implanted device therapy.**
• **Effectiveness of Medical Interventions: Assess the impact of medical treatments on patient outcomes.**

2.1.3.5.4.3 Exercise test contraindication:

There are absolute and relative contraindications to exercise testing depends on risk factors of the patient and test with the benefit of information given by test. (Bourque JM, 2015)

2.1.3.5.4.4 Absolute contraindication:

Exercise test has a lot of absolute contraindications based on patient comorbidities, these contraindications are: Patient had acute MI within 2 days, patient with unstable angina during the time of exercise, or uncontrolled arrythmia, patient with LBBB or hypertension, active endocarditis, symptomatic severe aortic stenosis, decompensated heart failure, acute pulmonary embolism, pulmonary infarction, or deep vein thrombosis, acute myocarditis or pericarditis, acute aortic dissection, and physical disability that precludes safe and adequate testing. (Hill J, 2002)

2.1.3.5.4.5 Relative Contraindications:

As absolute contraindications, relative is based on patient previous healthcare status, such as: patient with previous history of obstructive left main coronary artery stenosis, moderate to severe aortic stenosis with uncertain relation to symptoms, tachyarrhythmias with uncontrolled ventricular rates, or low mental functions with inability to cooperate with doctors. (Hill J, 2002)

2.1.3.5.4.6 Complication secondary to exercise testing:

Cardiac: Bradycardia, tachyarrhythmia, ACS, HF. Hypotension, syncope, shock, and death, Noncardiac: musculoskeletal trauma, soft tissue injury, fatigue, dizziness and body aches. (Hill J, 2002)

2.1.3.5.4.7 Sensitivity and specificity of exercise test:

Sensitivity of exercise testing is 68%, and specificity of 77%. (Bourque JM, 2015)

2.1.3.5.5 Pharmacological stress test:

Pharmacological stress test is an alternative modality for diagnosis CAD with patient who can't tolerate exercise for any reasons, like: deconditioning, peripheral vascular disease, orthopedic disabilities, neurological disease, or other conditions.

There are several pharmacological agents to use, it increases inotropic effect on cardiac muscle so induces mismatch between myocardial oxygen demand and blood supply. (Wolk MJ, 2014)

2.1.3.5.5.1 Indication:

Patient with hemodynamic unstable can't respond well to exercise test because the abnormalities in respiratory system. Also exercise test is not useful when patient have baseline ECG abnormalities, such as: left ventricular hypertrophy (LVH), left bundle branch block (LBBB), paced rhythm, Wolff Parkinson White (WPW) syndrome, or greater than 1 mm ST-segment depression.

So, these patients should have other methods to diagnose and evaluate their condition, and pharmacological stress test its suitable with these patients. (Brink HL, 2015)

2.1.3.5.5.2 Medications used for pharmacological stress test:

1. **Dobutamine:**

Dobutamine, an adrenergic agent, enhances myocardial contractility, heart rate, and blood pressure, thereby increasing myocardial oxygen demand. It is administered via intravenous infusion, with the dose gradually increasing every three minutes until either the maximum dose or the target endpoint (85% of the predicted heart rate) is reached, provided no high-grade arrhythmias, angina, or significant blood pressure changes occur.

Throughout the infusion, ECG, heart rate, and blood pressure are closely monitored at each stage. Potential complications of dobutamine infusion include nausea, headache, tremors, anxiety, angina or atypical chest pain, atrial and ventricular arrhythmias, as well as hypertension or hypotension. (Ruffolo RR., 1988)

2. **Selective A2 Adenosine Receptor Agonists and Adenosine:**

Vasodilator agents cause coronary vasodilation and create a coronary steal phenomenon by temporarily increase blood flow to non-diseased vessels, not stress the heart. (Henzlova MJ, 2016)

3. **Dipyridamole**

Dipyridamole considered the first vasodilator used for myocardial perfusion stress test. Its indirect vasodilator by inhibiting enzyme adenosine deaminase so prevent the intracellular reuptake of adenosine. (Gupta A, 2023)

Table (4): Contraindications for pharmacological stress test

Contraindications for pharmacological stress test:		
Dobutamine: (Henzlova MJ, 2016)	**Adenosine:** (Henzlova MJ, 2016)	**Dipyridamole:** (Gupta A, 2023)
Patients with acute coronary syndrome, unstable angina, or a myocardial infarction occurring less than one week ago.	Patient with reactive airway disease.	Patient with Bronchospastic lung disease with ongoing wheezing.
Hemodynamically significant left ventricular outflow obstruction.	Patient with advanced conducting abnormalities.	Patient with reactive airway disease.
Atrial tachyarrhythmias with an uncontrolled ventricular response.	Patient with systolic blood pressure less than 90 mmHg.	Patient with hypotension.
Hypertension with a systolic blood pressure above 200 mmHg or a diastolic blood pressure exceeding 110 mmHg.	Patient with severe hypertension.	Patient with hypersensitivity to dipyridamole.
Aortic dissection.	Caffeine intake in the previous 12 hours.	Caffeine intake in the previous 12 hours.
Known hypersensitivity to dobutamine.	Patient with hypersensitivity to adenosine.	Second or third heart block
	Patient with ACS or unstable angina or prior MI last week	

2.1.3.5.6 Stress Echocardiogram:

Stress echocardiography is a widely accessible, non-invasive imaging technique used for symptomatic patients to detect myocardial ischemia by assessing heart wall motion. During exercise, echocardiographic images are captured at various stages of rest and while the patient performs a treadmill test. It is crucial to obtain these images within two minutes post-exercise, as inducible regional wall motion abnormalities tend to resolve quickly. (Mastouri R, Sawada SG, Mahenthiran J., 2010)

In pharmacological stress tests, images are taken at baseline, during low-dose and peak dobutamine infusion, and during recovery. Stress echocardiography is generally considered safe, with no significant associated risks. (Kossaify A, Bassil E, Kossaify M., 2020)

Under normal conditions, myocardial contractility increases during exercise, but ischemia may lead to hypokinesis, akinesis, or dyskinesis in affected heart segments. A stress echocardiogram is deemed positive if previously normal segments develop regional wall motion abnormalities during exercise or if existing abnormalities worsen. (Aggeli C, Polytarchou K, Varvarousis D, Kastellanos S, Tousoulis D, 2018)

Table (5): Indications and Contraindications for stress ECHO:

Indication and Contraindications for stess ECHO:		
Indications: (Ágoston G, 2019)	**Absolute contraindications:** (Mulvagh SL, 2008)	**Relative contraindications:** (Płońska-Gościniak, 2019)
Diagnosis of Coronary Artery Disease: Used to confirm the presence of coronary artery disease.	Acute myocardial infarction within 48 hours	Left main coronary artery stenosis.
Evaluation of Revascularization: Assesses the effectiveness of treatment before and after revascularization procedures.	Acute pericarditis/Myocarditis	High degree atrioventricular (AV) block.
Risk Stratification: Helps determine the risk level in patients with known coronary artery disease.	Symptomatic severe aortic stenosis	Severe hypertension (greater than 180/100mm Hg).
Localization of Ischemia: Identifies the specific areas of the heart affected by ischemia.	Uncontrolled Arrhythmias**.**	Electrolyte abnormalities.
	Acute Aortic Dissection	Mental or physical disability.
	High-Risk Unstable Angina	Tachycardia or bradyarrhythmia,
	Decompensated or Unstable Heart Failure	Moderate stenotic valvular heart disease.

The sensitivities of stress echocardiography ranged from 77% in different populations, with specificities 75%. Patient with limited acoustic windows and poor image quality has reduced diagnostic value with stress echocardiogram. (Mastouri R, Sawada SG, Mahenthiran J, 2010)The advantage of stress echocardiography include: wide availability, low cost, lack of ionizing radiation, and portability, on the other hand, stress ECHO has disadvantages too, the most important one that images can suboptimal, especially in larger patients. (Danad I, 2017)

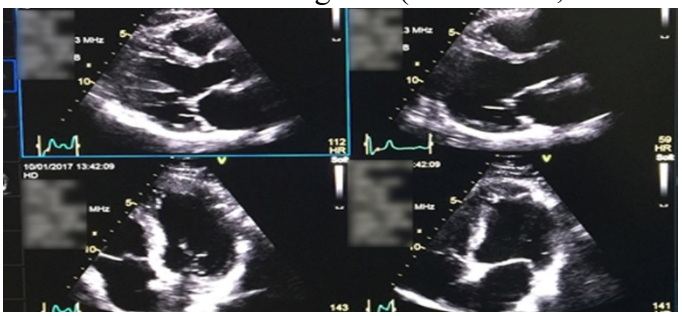

Figure (4): Stress Echocardiogram Results

The previous figure shows a stress echocardiogram image used to assess the function of the heart and detect any abnormality indicate ischemia or other diseases.

2.1.3.5.7 Myocardial Perfusion Imaging:

Myocardial perfusion imaging (MPI) is a non-invasive functional imaging technique used to evaluate blood flow through the coronary arteries. It identifies areas of the myocardium that are not receiving adequate blood flow and assesses the pumping efficiency of the heart muscle. (Russell RR, Zaret BL., 2006)

MPI is essential for diagnosing ischemic heart disease (IHD), predicting patient prognosis, and evaluating the viability of the heart muscle as well as the effectiveness of medical treatments. (Kumar D, Sethi RS, Bansal S, Namgyal PA, Sehgal AK, Malik TS., 2017)

There are two primary types of MPI:

- Single-Photon Emission Computed Tomography (SPECT)
- Positron Emission Tomography (PET)

2.1.3.5.7.1 PET Myocardial Perfusion Imaging:

Positron Emission Tomography (PET) is a radionuclide imaging technique that detects photons emitted by radiolabeled tracers injected into the body. Positrons released from the tracer collide with electrons, resulting in a process called annihilation, which generates two photons emitted in opposite directions. These photons travel a short distance before being captured by the PET scanner, which uses a ring of detectors to convert the photon energy into electrical signals. The photons are then counted along all lines of response and reconstructed into a map representing the distribution of radioactivity. Similar to other stress tests, PET imaging involves obtaining both stress and rest images. The rest image is captured first, with the heart at baseline, following the injection of the radionuclide, revealing the wash-in and wash-out patterns of the tracer in the myocardium (Jaarsma C, 2012).

Dynamic stress images are acquired during the administration of a vasodilator agent, such as adenosine, regadenoson, or dipyridamole, along with radionuclide injection. These dynamic images provide critical information, including time-activity curves of blood flow and myocardial perfusion. Kinetic modeling is then used to quantify myocardial blood flow in milliliters per minute per gram and calculate myocardial blood flow reserve. (Jaarsma C, 2012)

2.1.3.5.7.2 SPECT Myocardial Perfusion Imaging:

SPECT perfusion imaging can detect gamma rays emitted from radionuclide agent, it's older than PET imaging, but it is still the most non-invasive imaging technique used in clinical evaluation for many reasons:

- Its widespread availability.
- Its well-established standardized protocols.
- Familiarity among providers than other methods. (Jigar J, 2023)

As with PET scan, SPECT can obtain images at stress and rest, but with different protocol, which either stress or rest can be done first, but rest is preferred to be done first. (Angelidis G, 2017)

SPECT can be done either as 2-day protocol or 1-day protocol with different steps between two methods.

With 2-day protocol patient get the maximum dose of radionuclide for both stress and rest examination, while a smaller dose is administrated with 1-day protocol for rest and a higher dose with stress test. (Jigar J, 2023)

As any stress test exercise of pharmacological agents (adenosine, regadenoson, or dipyridamole) are used for SPECT stress examination, radionuclide agent is injected while the patient at peak of exercise or at the time of peak vasodilator. (Hung GU, 2016)

If the patient becomes fatigued or has symptoms warranting early termination of termination of the test (severe chest pain, dyspnea, dizziness, arrhythmias, or hypotension), if patient has one of these symptoms' exam should be stopped.

Rest test is obtained while heart is at baseline heart rate and involves second injection of the radionuclide agent. (Hung GU, 2016)

For both SPECT and PET imaging modalities to detect any abnormalities with myocardium perfusion, stress and rest images are compared side by side.

MPI can provide information about LV size systolic function and wall motion abnormalities. (Angelidis G, 2017)

SPECT imaging can sometimes produce artifacts that mimic ischemia, which should be carefully identified if present. These artifacts are typically localized and show normal left ventricular (LV) wall motion in the affected areas. Common artifacts include soft tissue from the breast, which can impact the anterior wall, and interference from the diaphragm, which can affect the inferior wall.

Overall, myocardial perfusion imaging tests are considered safe for most patients. Among these, SPECT is more widely available and frequently used. (Jigar J, 2023)

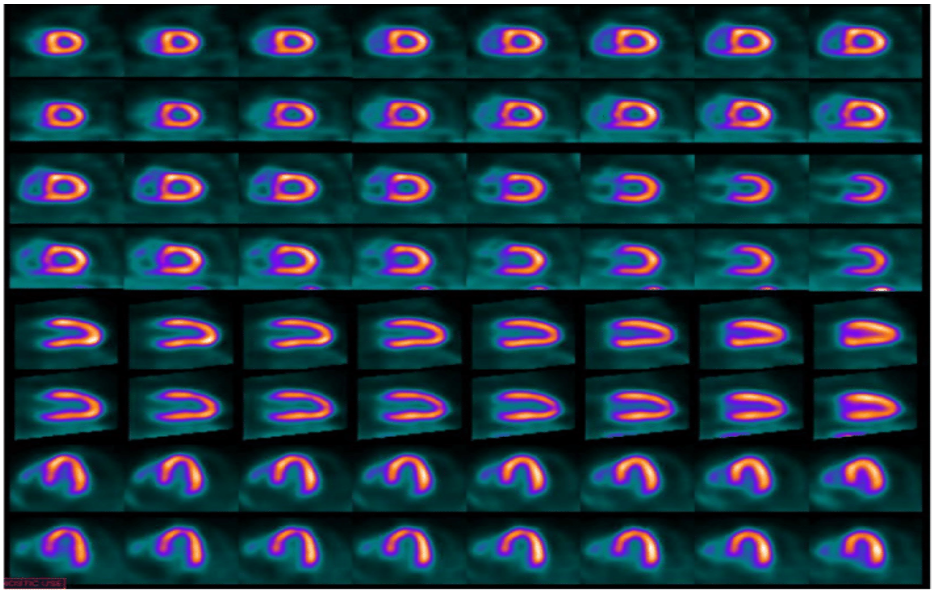

Figure (5): SPECT Test Results

This figure represents nuclear imaging studies of the heart, single-photon emission computed tomography (SPECT). The images display cross-sectional views of

myocardial perfusion, with variations in color indicating levels of blood flow to different regions of the heart muscle.

Table (6): Indication and Contraindications for Myocardial Perfusion Imaging:

Indication and Contraindications for Myocardial Perfusion Imaging:	
Indications: (Jigar J, 2023)	**Absolute contraindications:** (Jigar J, 2023)
Follow up for patient with CAD with new chest pain.	Pregnant or breastfeeding patient.
Assessment and follow up of stent and ejection fraction after CABG.	Patient with acute MI within 2 days.
Assessment for patient underwent CABG and stent within month with resistant chest pain.	Patient with acute myocarditis.
Positive stress ECG.	Patient with acute pulmonary embolism.
Patient with known case of CAD and suspected to another occlusion.	Patient with acute aortic `dissection.
Before operation for cardiologist.	New stroke.
Diagnosis of Ischemic Heart Disease (IHD): Used for patients with an intermediate risk of coronary artery disease (CAD) or for risk stratification in those with an intermediate to high likelihood of CAD.	Cath within 30 days.
Evaluation of Myocardial Ischemia: Determines the extent, severity, and location of ischemic regions in the myocardium.	**Relative Contraindications:** (Jigar J, 2023)
Assessment of Coronary Stenosis: Evaluates the functional significance of intermediate coronary artery stenosis	Patient with left main coronary artery disease.
Severe coronary calcification on CT angiogram with unpredictable ECG.	Patient with asymptomatic severe aortic stenosis.
Patient cannot do exercise ECG for musculoskeletal abnormalities or disease.	Patient with hypertrophic obstructive cardiomyopathy.
Patient with CAD and has low to intermittent likelihood with chest pain.	Patient with severe left ventricular outflow obstruction.
For follow up for patient with CAD with stent and HF and has chest pain.	Patient with complete heart block.
	Patient with LBBB, hypertension, or inability to run cannot undergo exercise test.
	Patient with asthma or hypotension shouldn't take dobutamloe because its bronchoconstriction effect.

2.1.3.6 Invasive Methods:

2.1.3.6.1 Cardiac Catheterization:

Cardiac catheterization is one of the most cardiac methods most used over the world to diagnose IHD, more than million cardiac catheterization procedures performed annually in the USA. It's a diagnostic and therapeutic procedure for certain heart or blood vessels disease. (Writing Group Members, 2016)

Before undergoing a cardiac catheterization procedure, patients should be thoroughly prepared, starting with a detailed medical history and a comprehensive

physical examination, particularly focused on the cardiovascular system. A basic pre-procedure workup typically includes:

- Complete blood count (CBC).
- Basic metabolic panel (BMP).
- Prothrombin time.
- Electrocardiogram (ECG).
- Chest X-ray.

Patients with a known allergy to radio-iodinated contrast material should be premedicated with corticosteroids and antihistamines to reduce the risk of complications during or after the procedure. Those with chronic kidney disease require careful pre-procedure preparation, including sufficient hydration, to lower the risk of worsening renal function. (Sobolev M, 2015)

Table (7): Indications and Contraindications for Cardiac Catheterization

Indication and Contraindications for Cardiac Catheterization: (Yugandhar R, 2023)	
Indications:	**contraindications:**
Coronary artery disease.	Severe uncontrolled hypertension
Measuring the hemodynamics in the right and left side of the heart.	Unstable arrhythmias
Evaluate the left ventricular function.	Acute cerebrovascular accidents
Evaluation and treatment of cardiac arrhythmias.	Active bleeding
Evaluation and treatment of valvular heart disease.	Allergy to radiographic contrast
Assessment of the congenital heart diseases.	Renal dysfunction
Evaluation of heart failure.	Acute pulmonary edema (patient unable to lie flat)

Table (8): Sensitivity and specificity for each test:

Test	Sensitivity	Specificity
Anatomically significant CAD		
Exercise ECG	58%	62%
Stress echo	85%	82%
Coronary CTA	96%	82%
SPECT	87%	70%
PET	90%	85%
Stress CMR	90%	80%
Functionally significant CAD		
Coronary CTA	93%	53%
SPECT	73%	83%
PET	89%	85%
Stress CMR	89%	87%

2.1.4 Assessment of CAD (coronary artery disease)

Assessment of CAD based on careful history taken by physician, then by doing a focused physical examination and objective tests to confirm the diagnosis or exclude CAD and asses the severity of underlying disease.

There is an assessment deal with acute anginal chest pain (acute ischemia) differ from assessment for chronic CAD, in this chapter we will focus on the assessment of chronic CAD.

The most common clinical scenarios in patients with suspected or confirmed chronic coronary syndrome (CCS) include 6 scenarios:

- Patients experiencing 'stable' angina symptoms and/or shortness of breath, suggesting possible coronary artery disease (CAD).
- Patients with newly diagnosed heart failure or left ventricular dysfunction, with a suspicion of CAD.
- Both asymptomatic and symptomatic patients whose symptoms have stabilized within one year following an acute coronary syndrome (ACS) or recent revascularization.
- Asymptomatic and symptomatic patients more than one year after their initial diagnosis or revascularization.
- Patients presenting with angina that may be associated with suspected vasospastic or microvascular disease.
- Asymptomatic individuals found to have CAD during screening.

Table (9): Traditional clinical classification of suspected anginal symptoms

Type of angina	Character
Typical angina	Should meet the following characteristics: 1. Constricting discomfort in the front of the chest or in the neck, jaw, shoulder, or arm. 2. Precipitated by physical exertion. 3. Relieved by rest or nitrates within 5 min
Atypical angina	Meets two of these characteristics.
Non-anginal	Meets only one or none of these characteristics.

: 2.1.4.1 Pre-test probability of IHD

This is one of the most important method used to estimate the pre-test probability of CAD depends on age, sex, and symptoms, this method is suggested by 2021 AHA. (Gulati M, 2021)

Factors that influence the clinical likelihood of obstructive coronary artery disease (CAD) are based on pre-test probability (PTP), which considers sex, age, and symptom nature. Certain findings decrease or increase the likelihood of CAD:

- **Decreased Likelihood:** A normal exercise ECG or the absence of coronary calcium on a CT scan (Agatston score = 0) suggests a lower probability of obstructive CAD.
- **Increased Likelihood:** The presence of cardiovascular risk factors (such as dyslipidemia, diabetes, hypertension, smoking, and family history), resting ECG changes (Q-wave, ST-segment, or T-wave abnormalities), left ventricular

(LV) dysfunction indicative of CAD, abnormal exercise ECG results, or detectable coronary calcium on a CT scan points to a higher likelihood of obstructive CAD.

In conclusion, a combination of clinical assessment, ECG findings, and imaging results helps refine the clinical likelihood of CAD, guiding the diagnostic process and informing further testing and treatment decisions. (ESC Guidelines, 2019)

- **Low pre-test probability of IHD: less than 15%**

In the case of low pre-test probability of IHD the American Heart Association college of Cardiology recommend to use treadmill exercise test rather than other diagnostic tests. But this test has modest sensitivity and specificity (68% and 77%) with false-negative and false-positive results.

However, this test alone can't rule out or diagnose IHD, and further tests should be done.

Patient with low pre-test probability of IHD has one of the following:

- Asymptomatic patient with all ages.
- Atypical chest pain in women less than 50 years old. (ESC Guidelines, 2019)

- **Intermediate pre-test probability: 16-50%**

Patient with Intermediate pre-test probability of IHD has one of the following:

- Atypical angina in men of all ages.
- Atypical angina in women older than 50.
- Typical angina in men form 30-40 years old.
- Typical women in women from 40-59.

If patient able to do exercise test should do an exercise ECG, if patient cannot should do a Pharmacological stress imaging test, if excursive or pharmacological stress test is positive, patient should do a coronary angiography. (ESC Guidelines, 2019)

- **High pre-test probability of IHD: more than 50%**

Patient with high pre-test probability of IHD or already has IHD, should do SPECT, PET, stress ECHO or CMR to detect the prognosis and yield important information for therapy protocol and the necessary of invasive methods, such as angiography and revascularization.

Patient with high pre-test probability of IHD has one of the following:

- Typical angina in men older than 40.
- Typical angina in women older than 60.
- Atypical anginal in men 40-49. (ESC Guidelines, 2019)

2.1.5 Evaluation of CAD:

To select the appropriate test physician should look at patient comorbidities and general patient health, patient with high clinical likelihood of CAD, unresponsive to medical treatment or typical angina with low level of exercise with high event risk after initial clinical evaluation (Echo or exercise ECG) should directly referred to invasive coronary angiography without any further diagnostic testing.

On the other hand, non-invasive diagnostic (functional or anatomical) methods are recommended to confirm diagnosis with patient with suspected CAD but cannot be exclude with initial clinical assessment alone. (Gulati M, 2021)

Non-invasive functional tests should be done before to make a revascularization decision, so it's preferred with patient with: (Stone PH, 1997)

- High clinical likelihood of CAD.
- Before revascularization decision.
- Local expertise and availability.
- Viability assessment also required.

Symptomatic patient without previous history of CAD should determine the pre-test probability of CAD then identify the ASCVD score risks factors, after that determined the nature and frequency of chest pain episode, finally physician should do a full physical examination and focus on clinical feature of CAD, heart failure or valvular heart disease.

All patient with symptomatic chest pain should do a resting ECG as initial test. (Stephan D Fihn, 2012)

Additional evaluation depends on the pre-test probability: (Gulati M, 2021)

- Previous non-cardiac chest pain doesn't need any cardiac examination.
- Low PTP of CAD usually doesn't need any further examination tests, but some patient should do a CAC scoring or cardiac exercise test.
- Intermediate to high PTP of CAD those type of patient should do a coronary CT angiography or cardiac stress testing, as following:

1. If patient able to exercise, the exercise stress testing is preferred, if normal resting ECG without any previous abnormality (interpretable ECG) obtain exercise ECG testing or stress imaging, if there's an abnormality in resting ECG (uninterpretable ECG) such as: LBBB, obtain stress imaging, such as: stress ECHO.
2. If patient unable to exercise: pharmacological stress test is preferred.

2.1.5.1 Resting ECG:

Resting 12 lead ECG is still an important test, and it's the best initial evaluation for all patient with chest pain without other non-cardiac disease could be the cause of chest pain. (Stephan D Fihn, 2012)

Resting ECG depends on the detection of repolarization abnormalities such as ST-segment depression, or other abnormalities such as: pathological Q wave which indicate a previous MI, or conduction abnormalities, such as: left bundle branch block, or atrial fibrillation which would be with atypical anginal chest pain.

There are two main scenarios to order resting ECG: (Stephan D Fihn, 2012)

- A patient without symptoms of chest pain or discomfort.
- A patient with ongoing anginal chest pain, ECG should be done during or immediate after the episode of angina.

2.1.5.2 Exercise ECG:

Exercise ECG is recommended as an initial diagnostic test for assessment patient's exercise tolerance, symptoms, arrhythmias and blood pressure response.

Also, it can be used as an alternative test if non-invasive diagnostic test is not available to confirm or rule-out CAD, and it can used to evaluate control of symptom and ischemia with patient on medical treatment of ischemia. (Knuuti J, 2018)

If patient has ST-segment depression more than 0.1 mv on resting ECG or being treated with digitalis, ECG exercise test is not recommended as initial diagnostic method. (Knuuti J, 2018)

Table (10): Recommendations for exercise ECG:

Recommendations for exercise ECG: (ESC guideline, 2019)	Class
Is recommended for assessment of exercise tolerance, symptoms, arrhythmias, blood pressure response and with specific patients. For risk assessment suspected CAD patient or newly diagnosed CAD if patient can run and significance exercise can perform.	I
To rule out CAD if non-invasive imaging is not available. To evaluate the effective of treatment in patient with ischemia	IIb
Is not recommended with: Patient with STEMI more than 0.1 mv at resting ECG. Patient is taking digitalis.	III

2.1.5.3 Resting Transthoracic Echocardiography:

Echo is mainly used to get information about cardiac function and anatomy of heart, and this information could be used to differentiate between chronic coronary syndrome and MI, with chronic coronary syndrome LV ejection fraction is often normal, but decrease of LV function or\and regional wall motion abnormalities may be an indication of MI. (Eek C, 2010)

A resting transthoracic Echo is recommended in all patients for: (ESC Guidelines for the diagnosis and management of chronic coronary syndromes, 2019)

Table (11): Recommendations for Resting Transthoracic Echocardiography:

Recommendations:	Class
• Exclusion of alternative causes of angina. • Identification of regional wall motion abnormalities suggestive of CAD. • Measurement of LVEF for risk stratification. • Evaluation of diastolic function. • With all patient with suspected CAD to quantify LV function for risk factor assessment.	I
With suspected CAD without known other atherosclerotic diseases, but should done by trained clinicians with ultrasound of the carotid arteries	IIa
If Echo is inclusive CMR is considered If LVEF more than 35% it indicated for assessment of GLS	IIb

2.1.5.4 Chest X-ray:

Although chest X-ray doesn't give a specific information for patient with CCS is frequently used in assessment patient with chest pain to exclude and assess other cardiac problems, such as: Patient with suspected HF and comes to ER with chest pain, or patient with pulmonary diseases. (ESC Guidelines for the diagnosis and management of chronic coronary syndromes, 2019)

Table (12): Recommendations for Chest X-ray:

Recommendations for chest X-ray	Class
X-ray is recommended as initial diagnostic test for suspected CAD for patient with an atypical sign and symptoms of CAD with sign and symptoms of HF or pulmonary disease.	I

2.1.5.5 Coronary CTA:

Table (13): Recommendations for Coronary CTA:

Recommendations for CCTA: (ESC Guidelines, 2019)	Class
CCTA is recommended as the initial test for diagnosis CAD if: • Patient has symptoms and CAD cannot excluded by clinical assessment. • For risk assessment suspected CAD patient or newly diagnosed CAD.	I
If invasive angiography or another non-invasive test is equivocal or non-diagnostic.	IIb
CCTA is not recommended if patient has: • extensive coronary calcification. • Irregular heart rate. • Significant obesity. • Inability to cooperate with breath-hold commands. • Other conditions make obtaining good image quality unlikely.	III

Functional imaging is recommended in cases where coronary CTA does not provide a definitive diagnosis, reveals coronary artery disease (CAD) of uncertain functional significance, or if the patient has a high clinical likelihood of CAD with severe symptoms unresponsive to medical treatment or typical symptoms occurring with minimal exertion. (Knuuti J, 2018)

2.1.5.6 Invasive testing:

Early ICA without previous non-invasive testing should be done to identify lesion and start revascularization or another plan. (Lee BK, 2015)

Table (14): Recommendations for Invasive Testing:

Recommendations for invasive test: (ESC, guidelines, 2021)	Class
I An invasive test is recommended as an alternative for diagnosing coronary artery disease (CAD) in the following scenarios: • Patients with suspected CAD who have a high clinical likelihood and severe angina symptoms unresponsive to medical therapy. • Individuals with typical anginal chest pain, limited exercise capacity, and clinical evaluation suggesting a high risk of cardiovascular events. • To assess stenosis before revascularization, unless the stenosis exceeds 90%. • For cardiovascular risk stratification, particularly in cases where symptoms are refractory to medical therapy and revascularization is considered. • When non-invasive risk stratification indicates a high risk of events and revascularization is deemed necessary.	I
For confirmation of diagnosis of CAD after uncertain or non-diagnostic non-invasive test. For risk stratification in patient with inclusive or conflicting results from non-invasive testing, but it should complicate by invasive physiological guidance.	IIa

In general, to diagnose CAD it depends on patient general health, health care environment, patient work up can start with one of three options:

- Non-invasive testing for patient with properties mentioned before, then if ischemia confirm drug therapy should started, if symptoms ongoing you should go to invasive coronary angiography, if non-invasive not diagnostic coronary CTA done.
- Coronary CTA preferred for patient with properties mentioned before, then if ischemia confirm drug therapy should started, if coronary CTA not diagnostic invasive coronary angiography or non-invasive testing should do based on patient's symptoms.
- Invasive coronary angiography for patient with properties mentioned before, then if the stenosis is more than 90% or with establish correlation to ischemia patient should undergo revascularization after functional assessment.

If functional assessment doesn't recommend revascularization patient can discharge with drug therapy.

:2.1.6 Assessment of Acute Coronary Syndrome

The first step is to evaluate and assessment patient with suspected of ACS recording to AHA guidelines is ECG, which is an important tool because it helps to differentiate between STEMI and NSTEMI unstable angina. AHA recommend to have an ECG test within 10 minutes of arrival, then Cath lab should be prepared immediately if STEMI is confirmed in PCI center.

Cardiac enzyme particularly troponin, CK-MB is important for assessment of STEMI, and to differentiate between NSTEMI and myocardial ischemia without tissue death and destruction.

If ACS is excluded other cause of chest pain should evaluate by chest X-ray, such as: pericarditis, pneumonia, pneumothorax, other diagnostic test like CBC, chemistry, Hb1Ac, lipid profile, and LFT is also considered.

2.1.6.1 Treatment of Coronary Artery Disease:

Management of CAD has two main goals:

- To restore blood flow to myocardium and prevent death.
- To relief pain and other symptoms and sign.

2.1.6.2 Management of ACS:

The initial treatment of ACS is to start with antiplatelet dual therapy with aspirin (300 mg) and clopidogrel, with heparin bolus and IV heparin infusion if there's no contraindications.

Beta blocker, statin and ACEIs should also started in all case of ACS as soon as possible unless there are contraindications.

Supportive management is recommended with patient status; oxygen therapy if patient has hypoxia, morphine for pain control, nitrate sublingual of infusion for chest pain relief, but it contraindication with inferior MI because it can lead to sever hypotension.

If STEMI confirmed AHA recommend to undergo an emergent catheterization and PCI within 90 min, and if PCI is not available and patient cannot arrive catheterization within 120 min, thrombolytic is recommended.

NSTEMI start with aspirin and heparin as mentioned before, and if the symptom persist, patient should undergo catheterization immediately.

2.1.6.3 Management of stable angina:

Management of stable angina include pharmacological and non-pharmacological intervention, non- pharmacological is an important step with treatment of stable angina, include: smoking cessation, regular exercise, weight loss, control of other risk factor, such as: DM, HTN, dyslipidemia, and healthy diet.

Pharmacological intervention include: low dose aspirin, Beta blocker, nitroglycerin as need for chest pain, and moderate to high intensity statin

2.2.1 Previous Studies:

- **Study of (Luca Bergamaschi, 2023): The Role of Non-Invasive Multimodality Imaging in Chronic Coronary Syndrome: Anatomical and Functional Pathways**

Coronary artery disease (CAD) remains a leading global cause of mortality and morbidity, exerting a significant socioeconomic burden. Various guidelines, including the latest European Society of Cardiology recommendations on chronic coronary syndromes (CCS), emphasize the importance of a multimodal imaging approach for evaluating suspected CAD.

Non-invasive imaging methods are now a cornerstone of clinical practice. These techniques include coronary computed tomography angiography (CCTA) for assessing coronary anatomy and functional stress testing—such as stress echocardiography, cardiac magnetic resonance imaging (CMR), single-photon emission computed tomography (SPECT), or positron emission tomography (PET)—to detect inducible myocardial ischemia.

However, findings from recent trials, such as ISCHEMIA and REVIVED, have challenged traditional management strategies for CCS. Understanding the advantages, limitations, and specific applications of each imaging modality is now critical, particularly when deciding between a functional approach (focused on ischemia) and an anatomy-based strategy.

A pathophysiology-driven treatment paradigm has gained prominence, aiming to integrate both anatomical and functional data to optimize patient care. This review highlights non-invasive imaging modalities as a comprehensive framework for managing patients with CCS.

In conclusion, although the most recent evidence hints towards anatomical imaging, it has to be outlined that a global assessment of the patient is often necessary and that functional imaging offers v aluable information pivotal to the further therapeutic pathway. Non-invasive imaging methods for the diagnosis of CAD have distinct characteristics; the patient's cardiovascular risk assessment and pre-test probability should guide the choice of the best method.

Cardiologists and radiologists should therefore be aware of the strengths and weaknesses of these imaging techniques in order to choose the diagnostic pathway that tailors properly to the specific patient.

- **Study of (Ganesh Gajanan, 2022): Case Report: Invasive and Non-invasive Hemodynamic Assessment of Coronary Artery Disease: Strengths and Weaknesses:**

Coronary angiography remains the gold standard for evaluating coronary artery disease (CAD) and guiding percutaneous coronary interventions (PCI). Physiology-guided PCI has demonstrated enhanced safety, improved resource utilization, and better clinical outcomes for patients with stable angina and acute coronary syndromes.

This report highlights three cases that showcase the advantages and limitations of both invasive and non-invasive methods for the physiological assessment of CAD. With advancements in technology, alternatives to traditional wire-based invasive techniques, such as invasive non-wire-based methods (angiography-derived FFR) and non-invasive options (FFRCT), are becoming reliable and user-friendly.

It is essential for interventional cardiologists and cardiovascular healthcare providers to understand the strengths and limitations of these hemodynamic assessment modalities to make informed decisions and optimize patient care.

- **Study of (Evangelos Oikonomou, 2022): Current Concepts and Future Applications of Non-Invasive Functional and Anatomical Evaluation of Coronary Artery Disease:**

Coronary artery disease (CAD), while functionally and mechanically straightforward in theory, often presents complex patterns regarding cardiovascular prognosis, events, and treatment decisions. Over time, various imaging modalities have been developed, enabling non-invasive evaluation of functional characteristics, ischemia quantification, viability assessment, coronary artery luminal stenosis imaging, and plaque characterization.

Additionally, imaging of pericoronary features, such as inflammation and adipose tissue, provides further insights into patient prognosis. Given the diverse clinical scenarios associated with chronic coronary syndromes (CCS), selecting and combining appropriate imaging techniques is crucial for optimal decision-making.

In recent years, stress echocardiography and SPECT have demonstrated their utility as widely used modalities. However, CT and cardiac MRI have also become integral to clinical practice, offering advanced reproducibility, reliability, and a wide range of diagnostic information.

- **Study of (Arlene Sirajuddin, 2021): ischemic heart disease: Noninvasive Imaging Techniques and Findings:**

Ischemic heart disease is a leading global cause of mortality and represents a significant portion of annual healthcare costs. Its management is increasingly guided by the physiologic significance of coronary artery stenosis. Invasive coronary angiography remains the standard diagnostic method for coronary artery stenosis but comes with costs and risks, including vascular complications and contrast-induced nephropathy. Fractional flow reserve (FFR) is essential during invasive angiography to evaluate the physiologic relevance of stenosis. Noninvasive imaging modalities, such as coronary CT angiography, cardiac MR vasodilator or dobutamine stress imaging, CT stress perfusion imaging, FFR CT, PET myocardial perfusion imaging (MPI), SPECT MPI, and stress echocardiography, can assess anatomic and functional significance of stenosis and detect myocardial infarction (MI). While coronary CT angiography excels in visualizing anatomic stenosis, its limited ability to evaluate physiologic significance reduces its specificity. Cardiac MRI is particularly valuable for detecting clinically unrecognized MI, a key indicator of physiologically significant coronary artery disease. This study reviews imaging findings of ischemic heart disease (including coronary artery disease, myocardial ischemia, and MI), explores the benefits and limitations of various noninvasive imaging techniques as supported by recent clinical trials, and outlines current indications and contraindications for these modalities in diagnosing ischemic heart disease.

- **Study of (Juhani Knuuti, 2018): The performance of non-invasive tests to rule-in and rule-out significant coronary artery stenosis in patients with stable angina: a meta-analysis focused on post-test disease probability:**

This study investigates the pre-test probability (PTP) ranges at which diagnostic techniques—stress ECG, stress echocardiography, coronary computed tomography angiography (CCTA), single-photon emission computed tomography (SPECT), positron emission tomography (PET), and cardiac magnetic resonance (CMR)—can reclassify patients with suspected coronary artery disease (CAD) into post-test probabilities for confirming (>85%) or excluding (<15%) anatomically significant CAD (assessed by invasive coronary angiography [ICA]) or functionally significant CAD (determined by fractional flow reserve [FFR ≤0.8]). Analysis of 28,664 patients from 132 studies using ICA and 4,131 patients from 23 studies using FFR showed that stress ECG can rule-in CAD at PTP ≥80% (76–83) and rule-out at PTP ≤19% (15–25). CCTA can rule-in anatomical CAD at PTP ≥58% (45–70) and rule-out at PTP ≤80% (65–94), while its performance for functional CAD was weaker, with rule-in at PTP ≥75% (67–83) and rule-out at PTP ≤57% (40–72). Functional imaging techniques (PET, CMR, and SPECT) demonstrated better performance for functional CAD, ruling in at PTP ≥46–59% and ruling out at PTP ≤34–57%. These findings highlight the strengths and limitations of each modality and underscore the importance of selecting diagnostic methods based on the clinical scenario and the need to assess either anatomical or functional CAD significance.

- **Study of (Giuseppe Lippi, 2013): Diagnosis and management of ischemic heart disease:**

Ischemic heart disease (IHD) is the leading global cause of mortality and disability, necessitating early and accurate diagnosis to improve outcomes. According to recent guidelines, diagnosing acute myocardial infarction (AMI) requires detecting elevated or decreased levels of cardiac-specific troponins, with at least one value exceeding the 99th percentile upper reference limit, along with symptoms indicative of myocardial ischemia, electrocardiogram abnormalities, or evidence of myocardial dysfunction or intracoronary thrombosis. The introduction of highly sensitive troponin immunoassays has significantly enhanced the negative predictive value of these tests while reducing their diagnostic specificity. Despite proposals for additional biomarkers to complement or replace troponins, none have demonstrated substantial improvements in AMI diagnosis.

Regarding treatment, early reperfusion therapy—either mechanical (percutaneous coronary intervention, PCI) or pharmacological—is crucial, particularly for ST-segment elevation myocardial infarction (STEMI) within 12 hours of symptom onset. In other cases, fibrinolysis may be considered. Primary PCI should be combined with dual antiplatelet therapy (aspirin and an adenosine diphosphate receptor blocker) and parenteral anticoagulation, preferably low-molecular-weight heparin. For non-ST segment elevation acute coronary syndrome (NSTEMI), an early invasive strategy, such as PCI, alongside antiplatelet therapy, remains the cornerstone of treatment. Additionally, stem cell-based therapies are being explored as a potential treatment, with ongoing research efforts aimed at translating these findings into clinical practice.

- **Study of (Joanne D. Schuijf, 2008): Invasive Versus Noninvasive Evaluation of Coronary Artery Disease:**

This study compared the diagnostic capabilities of multidetector computed tomography (MDCT) and myocardial perfusion imaging (MPI) with invasive coronary angiography and intravascular ultrasound (IVUS) for coronary artery disease assessment. A total of 70 patients underwent MDCT, MPI, and coronary angiography, with IVUS performed in 53 of them. Quantitative coronary angiography (QCA) and IVUS were used to evaluate plaque burden and minimal luminal area.

Among the 26 patients with abnormal MPI, MDCT identified significant stenosis in 88% and demonstrated 96% sensitivity and 67% specificity relative to QCA for stenoses ≥50%. The mean diameter stenosis on QCA was 76%, while IVUS showed a minimal lumen area of 3.3 mm^2. Of the 44 patients with normal MPI, 84% had coronary atherosclerosis on MDCT, with 100% sensitivity and 83% specificity compared to QCA. IVUS revealed significant plaque burden (58.9 ± 18.1% of cross-sectional area) but only identified stenosis in 14 patients, with a mean lumen area of 5.8 ± 3.3 mm^2. Notably, only 7 patients with normal MPI exhibited no coronary atherosclerosis on MDCT.

- **Study of (Javed Butler, 2007) Extent and distribution of coronary artery disease: A comparative study of invasive versus noninvasive angiography with computed angiography:**

A comparison of invasive coronary angiography (ICA) and multidetector computed tomography (MDCT) for detecting coronary artery disease (CAD) was conducted in 37 patients (mean age 63 ± 11 years) using the 17-segment model. CAD was defined by ICA as any degree of luminal narrowing or calcification and by MDCT as the presence of any atherosclerotic plaque. Of the 586 coronary segments analyzed, 508 (87%) were assessable.

ICA detected CAD in 121 of 508 segments (24%), while MDCT identified CAD in 338 of 508 segments (67%) ($P < .01$). MDCT successfully identified plaques in 97% (117 of 121) of segments positive for CAD by ICA. However, in segments free of CAD by ICA (387 segments), MDCT detected CAD in 57% (221 segments). Specifically, ICA detected CAD in only 20% of non-calcified plaques, 48% of calcified plaques, and 46% of mixed plaques identified by MDCT ($P = .01$). Among the 221 segments negative for CAD by ICA, 54% (119 segments) exhibited positive remodeling on MDCT. The overall correlation between ICA and MDCT for CAD detection was poor ($\kappa = 0.25$).

These findings highlight significant differences in how ICA and MDCT evaluate CAD, with MDCT demonstrating higher sensitivity for detecting plaques, particularly in segments classified as free of CAD by ICA. This suggests that MDCT, as a non-invasive modality, may be a valuable alternative to ICA for assessing CAD and monitoring the effects of medical therapy.

- **Study of (Prof Lars Wallentin, 2000): Outcome at 1 year after an invasive compared with a non-invasive strategy in unstable coronary-artery disease: the FRISC II invasive randomized trial:**

In a study of 2457 patients with unstable coronary artery disease, participants were randomly assigned to invasive or non-invasive treatment strategies combined with three months of dalteparin or placebo. At 1 year, complete data were available for 1222 patients in the invasive group and 1234 in the non-invasive group, with analyses conducted on an intention-to-treat basis.

Revascularization was performed in 71% of the invasive group and 9% of the non-invasive group within the first 10 days, increasing to 78% and 43%, respectively, within the first year. Over the year, mortality was significantly lower in the invasive group (2.2% vs. 3.9%; risk ratio 0.57 [95% CI 0.36–0.90], p=0.016), as were rates of myocardial infarction (8.6% vs. 11.6%; risk ratio 0.74 [95% CI 0.59–0.94], p=0.015). The composite outcome of death or myocardial infarction occurred in 10.4% of invasive patients versus 14.1% of non-invasive patients (risk ratio 0.74 [95% CI 0.60–0.92], p=0.005). Additionally, reductions were observed in hospital readmissions (37% vs. 57%; risk ratio 0.67 [95% CI 0.62–0.72]) and revascularization after initial admission (7.5% vs. 31%; risk ratio 0.24 [95% CI 0.20–0.30]).

For every 100 patients treated invasively, 1.7 lives were saved, 2.0 non-fatal myocardial infarctions were prevented, and 20 hospital readmissions were avoided, albeit with 15 additional coronary artery bypass grafts and 21 more percutaneous angioplasty procedures. These findings support an invasive strategy as the preferred approach for patients with unstable coronary artery disease and signs of ischemia on electrocardiography or elevated biomarkers of myocardial injury, as it provides superior outcomes in mortality, symptom relief, and reduced readmissions.

- **Study of (The Lancet journal, 1999): Invasive compared with non-invasive treatment in unstable coronary-artery disease: FRISC II prospective randomized multicenter study:**

In a prospective, randomized multicenter study involving 2457 patients across 58 Scandinavian hospitals (median age 66 years, 70% men), participants were assigned to either an early invasive or non-invasive treatment strategy, with placebo-controlled long-term low-molecular-weight heparin (dalteparin) administered for three months. In the invasive group, 96% underwent coronary angiography within the first 7 days, and 71% underwent revascularization within the first 10 days, compared to 10% and 9%, respectively, in the non-invasive group. Patients were followed for six months, with analyses conducted on an intention-to-treat basis.

After six months, the invasive group showed a significant reduction in the composite endpoint of death or myocardial infarction (9.4% vs. 12.1%, risk ratio 0.78 [95% CI 0.62–0.98], p=0.031). Myocardial infarction rates were also significantly lower in the invasive group (7.8% vs. 10.1%, risk ratio 0.77 [0.60–0.99], p=0.045), while mortality was lower but not statistically significant (1.9% vs. 2.9%, risk ratio 0.65 [0.39–1.09], p=0.10). Symptoms of angina and hospital readmissions were halved in the invasive group, with the greatest benefits observed in high-risk patients. The results were consistent regardless of the randomization to dalteparin treatment.

Chapter Three:

Methodology

3.1 Study Methodology:

In this chapter we will cover the research setting, sampling method and size, inclusion and exclusion criteria, as well as the methodology of study, which includes: the study design, instrument for data collection, statistical analysis and the ethical consideration of study.

3.2 Research setting:

This study was conducted in five hospitals in Palestine, which were: Al-Najah University Hospital, Al-Ahli and AL-Al-Makassed, Al-Mezan, and Alia hospitals in Palestine.

To achieve the goal of this study the researcher quantified the number of patients who underwent invasive and non-invasive investigations for CAD.

3.3 Population and sampling:

The population of the study was all patients underwent CAD tests in Al-Najah University Hospital.

Al-Ahli and AL-Makassed hospitals in Palestine, and doctors from Al-Najah University Hospital, Al-Ahli, AL-Makassed, Al-Mezan, and Alia hospitals in Palestine.

3.4 Sampling method:

The researcher collected date through patient medical record and hospital's archiving system, the participants were divided into two groups: first one who

underwent non-invasive testing methods for CAD, and the other group who underwent invasive testing methods for CAD.

Study sample size was 806 patients who did an invasive or non-invasive testing, such as: echocardiogram, CTA cardiac, Stress ECG, Catheterization, Cardiac SPECT from three hospitals: Al-Najah University Hospital, Al-Ahli and AL-Makassed.

Also, sample size included 28 doctors (cardiologist, cardiologist resident, cardiac surgeon and GP) in Al-Najah University Hospital, Al-Ahli, AL-Makassed, Al-Mezan, and Alia hospitals in Palestine.

3.5 Data Collection Time: `

All data were collected by researcher from the five hospitals between January 2023 to January 2024.

3.6 Inclusion Criteria:

Patients aged 18 and above diagnosed with IHD or suspected IHD who underwent noninvasive and invasive cardiac imaging in the past two years.

3.7 Exclusion Criteria:

Patients with Heart diseases but with no relation to IHD, for examples: A patient with pericarditis or amyloidosis. Also, patients under the age of 18 are excluded.

Chi-square tests will be used to compare categorical variables (e.g., the proportion of patients diagnosed accurately by each modality)

3.9 Study instrumentations:

All invasive and non-invasive testing methods were done for CAD patients in Al-Najah University Hospital, Al-Ahli, and Al-Makassed hospitals chosen in this study, and get a permission from hospital to get access to PACS system and patient medical records.

3.10 Research Design:

A cross-sectional quantitative design-to assess the diagnostic modalities used based on criteria, and accuracy and treatment outcomes of various noninvasive cardiac imaging modalities (such as echocardiography, cardiac MRI, CT angiography, and nuclear imaging) and invasive cardiac imaging in patients with ischemic heart disease (IHD) and patient with acute coronary syndrome (ACS). The study will collect numerical data from medical records, diagnostic imaging reports, and treatment outcomes, focusing on patients diagnosed with or suspected of having IHD and also from surveys distributed on cardiologists to see if these cardiologists apply what they recommended as modalities of imaging in order to diagnose the IHD or not.

3.11 Data Analysis:

The collected data were analyzed by using the Statistical Package for Social Sciences (SPSS 22.0). Data entry were performed, and double checking for bias or errors.

Descriptive data analysis was done, regarding descriptive statistics, frequency, percentages, mean, score and standard deviation were measured and described the study variables.

3.12 Ethical consideration:

Al-Quds University institutional review board (IRB) obtained, ethical approval from Al-Quds university, and anonymity and confidentiality will be protected all the time.

Chapter Four:

Results and discussion

Introduction .1.4

This chapter presents the findings from a comprehensive analysis of the data collected through questionnaires and patient records. The respondents of the survey comprised medical professionals from five hospitals, three hospitals data collected from patient record and doctors responds, and the other two hospitals the data collected just from doctors, with a focus on cardiology-related decision-making in diagnosing ischemic heart disease (IHD). The data explored key demographic variables, including the participants' hospital affiliation, age, gender, and experience.

The findings highlight the use of established guidelines, the consideration of various patient factors (e.g., cardiovascular risk and availability of imaging tools), and the selection of diagnostic methods across different clinical scenarios of IHD. Additionally, the results examine the relationship between hospital resources, patient demographics, and the choice of "gold standard" modalities for diagnosing IHD. Statistical tests such as the Pearson Chi-Square were used to determine the significance of associations between various factors, providing insights into trends and preferences in cardiac imaging diagnosis within the surveyed medical community.

Questionnaire respondents.4.1

This questionnaire was built based on European guidelines for the diagnosis of ischemic heart disease (IHD).

Demographic Data for medical doctors.4.2.1

The respondents (the doctors) in this study came from five different hospitals, with the largest group (32.1%) from Al- Makassed and the smallest (10.7%) from Al-Najah University Hospital. This reflects differences in the size and location of the hospitals. Most of the respondents (doctors) (75%) were aged between 28 and 40, meaning they were relatively early in their careers. This indicates that the majority of the participating doctors have moderate experience and are still developing their expertise in advanced diagnostic methods. Only a small number (3.6%) were over 60, indicating fewer senior doctors took part.

There was a clear gender imbalance, with 96.4% of the respondents being male, which may reflect trends in the cardiology field in Palestine. In terms of work

experience, half of the respondents had 6-10 years of experience, while 39.3% had less than 5 years, showing that many of them were still in the early stages of their careers and learning more about advanced diagnostic methods.

Most of the respondents were cardiology residents (46.4%), followed by fully qualified cardiologists (28.6%). A smaller number were cardiac surgeons or general practitioners. This mix of experience and specialties highlights the focus of the study on cardiology-related decisions in diagnosing heart disease. The predominance of residents may also reflect the active involvement of younger doctors in research and their willingness to adopt new diagnostic approaches (Table 15).

The results agree with the Gajanan et al. (2022), which suggested that a lack of experience among physicians may influence the choice of diagnostic tools. In our results most of the participating doctors had moderate experience (less than 10 years), which may influence their choice of diagnostic tools. However, the study did not show a clear negative impact of this, suggesting that young physicians follow international guidelines well.

Table 15: Demographic breakdown of medical professionals surveyed in the study.

Variable	Category	Frequency (n)	Percent (%)
Hospital	Al-Ahli	7	25.0
	Al-Mezan	4	14.3
	Al-Najah University Hospital	3	10.7
	Al-Makassed	9	32.1
	Alia	5	17.9
Age	28-40	21	75.0
	41-50	3	10.7
	51-60	3	10.7
	61-70	1	3.6
Gender	Male	27	96.4
	Female	1	3.6
Experience	less than 5	11	39.3
	6-10	14	50.0
	11-20	2	7.1
	More than 30	1	3.6
Specialty	Cardiologist	8	28.6
	Cardiology Resident	13	46.4
	Cardiac Surgeon	2	7.1
	GP (Physician)	5	17.9

Criteria for Cardiac Imaging Diagnosis.4.2.1

According to Table 16, most respondents (71.43%) said their medical centers have guidelines for choosing the right cardiac imaging tests, while some (14.29%) use guidelines from other countries such as America and European countries, suggesting some variability in practice. This shows that many hospitals rely on a structured way to make decisions about imaging. This highlights the need for greater standardization and training to ensure uniform application of diagnostic criteria across all hospitals.

A large number of participants (57.14%) agreed, and 28.57% strongly agreed, that they follow these guidelines when referring patients with IHD for cardiac imaging. This suggests a strong commitment to using standard protocols. (ESC Guidelines, 2019)

However, most respondents consider a patient's age (71.43%) and financial and social situation (71.43%) when selecting imaging tests. Also, 67.86% said they take cardiovascular risk factors into account, showing that this is an important consideration. More than half (53.57%) also disagreed with the idea of ignoring radiation exposure, indicating that patient safety is somewhat of a concern when choosing imaging tests.

Finally, 78.57% of respondents said they do consider the availability of imaging tools in their practice. This means that while guidelines are important, they also make decisions based on what imaging options are actually available to them, the results agree with the Bergamaschi et al. (2023), which emphasized the importance of following international guidelines to improve diagnostic accuracy, so the results agree with it as the majority of physicians in the study follow standardized guidelines, reflecting a commitment to evidence-based practices.

Table 16: Criteria for Cardiac Imaging Diagnosis and Modality Selection

Question	Category	Frequency	Percent
Does your medical center (cardiology department) have criteria or guidelines for cardiac imaging diagnosis and imaging Modality selection?	Yes	20	71.42857
	No	2	7.142857
	I use a standard of other country	4	14.28571
	I do not know	2	7.142857
In all cases, I am committed to an established criteria and guidelines when referring IHD patient to a cardiac imaging modality and stepwise selection of other modalities	Agree	16	57.14286
	Strongly agree	8	28.57143
	Neutral, Uncertain	2	7.142857
	Disagree	2	7.142857
I do not consider the patient's age when referring to (selecting) the cardiac imaging modality for IHD evaluation.	Agree	1	3.571429
	Neutral, Uncertain	3	10.71429
	Disagree	20	71.42857
	Strongly Disagree	4	14.28571
I do not consider the functional (ambulatory) state of the patient when referring to (selecting) the cardiac imaging modality	Agree	2	7.142857
	Neutral, Uncertain	3	10.71429
	Disagree	17	60.71429
	Strongly Disagree	6	21.42857
I do not consider the patient's cardiovascular risk factors when referring to (selecting) the cardiac imaging modality.	Disagree	19	67.85714
	Strongly Disagree	9	32.14286
I do not consider the patient's financial and social situation when referring to (selecting) the cardiac imaging modality	Agree	1	3.571429
	Neutral, Uncertain	2	7.142857
	Disagree	20	71.42857
	Strongly Disagree	5	17.85714
I do not Consider the justification of patient dose of ionizing radiation when referring to (selecting) the cardiac imaging modality	Agree	1	3.571429
	Neutral, Uncertain	5	17.85714
	Disagree	15	53.57143
	Strongly Disagree	7	25
I do not consider the availability of the imaging modality in my practice setting when referring to (selecting) the modality of cardiac imaging	Disagree	22	78.57143
	Strongly Disagree	6	21.42857

Diagnostic Modality Choices for Various Cases of Ischemic Heart Disease (IHD). 4.2.1

This table highlighted the preferences of medical professionals for different diagnostic modalities based on clinical scenarios.

According to results in Table 17, for patients with unknown IHD and typical chest pain, most doctors (82.14%) prefer to use cardiac catheterization. This shows that catheterization is seen as the best method for diagnosing heart disease and have a high sensitivity and specificity. Other, less invasive options like echocardiography and chest X-ray (CXR) were rarely chosen.

Typical chest pain is strongly suggestive of ischemic heart disease (IHD), particularly in patients with risk factors such as hypertension, diabetes, or smoking.

Cardiac catheterization is considered the gold standard for diagnosing coronary artery disease (CAD) because it provides definitive information about the presence and severity of blockages in the coronary arteries. One of the key advantages of cardiac catheterization is the ability to perform immediate interventions, such as angioplasty or stent placement, if significant blockages are identified during the procedure. Additionally, cardiac catheterization offers high sensitivity and specificity for detecting CAD, making it the preferred diagnostic modality for high-risk patients who present with typical symptoms of IHD. This combination of diagnostic accuracy and therapeutic potential makes cardiac catheterization an essential tool in the management of suspected or confirmed CAD.

In cases where patients already have known IHD but show atypical chest pain, the responses were more varied. The most common choice was stress ECG (25%). The stress ECG is most commonly used because it is accessible, cost-effective, non-invasive, and widely recommended by clinical guidelines. It serves as an excellent first-line diagnostic tool for patients with low-to-intermediate risk of IHD and provides valuable functional information about the heart. However, its limitations, such as lower sensitivity and specificity compared to advanced imaging modalities, mean that it is often supplemented or replaced by other tests in high-risk patients or those with inconclusive results. followed by cardiac catheterization (21.43%). This shows that doctors use both stress tests and catheterization, depending on the situation.

For patients with angina after a stent has been placed, stress ECG (25%) and cardiac catheterization (21.43%) were again the top choices. This shows that both functional tests and invasive tests are needed in these cases.

When patients have baseline ECG changes that make stress ECG unreliable, doctors prefer echocardiography or CT scans (each 21.43%). These options provide better results when the ECG isn't useful, echocardiography used to assess wall motion abnormalities and left ventricular function, especially when stress ECG is unreliable due to baseline ECG changes (e.g., left bundle branch block or ST-segment abnormalities).

For patients with typical chest pain but normal ECG results, doctors equally chose cardiac catheterization and CT scans (32.14% each). This shows a balance between using invasive and non-invasive methods when the ECG doesn't show anything abnormal.

In cases where a patient is suspected of having IHD but can't have a CTA scan (due to kidney problems), the preferred option is SPECT (67.86%) because contrast can harm the kidney. This non-invasive method is safer because it avoids the contrast dye that could harm the kidneys.

If a CTA scan shows atherosclerosis, most doctors (75%) recommend following up with cardiac catheterization to get a clearer view of the arteries and plan treatment. Similarly, if an echocardiogram shows hypokinesia (weak heart muscle movement), 75% of respondents also chose cardiac catheterization to investigate the cause and check for artery blockages.

Study of Sirajuddin et al. (2021) shows that cardiac catheterization is the gold standard for diagnosing coronary artery disease (CAD). The results agree with the previous study, as cardiac catheterization was the first choice in high-risk cases, reflecting its high diagnostic accuracy.

Table 17: Diagnostic Modality Choices for Various Cases of Ischemic Heart Disease (IHD).

Case	Recommended	Frequency (n)	Percent (%)
Patient with unknown IHD presented with typical chest pain	Cardiac Catheterization	23	82.143
	Echocardiography	2	7.143
	MRI	0	0
	CXR	2	7.143
	CT Scan	1	3.571
	SPECT	0	0
	PET	0	0
	Stress ECG	0	0
Patient with known IHD presented with Atypical chest pain	Cardiac Catheterization	6	21.429
	Echocardiography	4	14.286
	MRI	0	0
	CXR	2	7.143
	CT Scan	5	17.857
	SPECT	4	14.286
	PET	0	0
	Stress ECG	7	25.000

Table 17: Diagnostic Modality Choices for Various Cases of Ischemic Heart Disease (IHD). (continue)

Case	Recommended	Frequency (n)	Percent (%)
In case of angina pectoris in patient after cardiac catheterization with stent	Cardiac Catheterization	6	21.429
	Echocardiography	4	14.286
	MRI	0	0
	CXR	2	7.143
	CT Scan	5	17.857
	SPECT	4	14.286
	PET	0	0
	Stress ECG	7	25.000
In the case of a patient with an indication for stress ECG but with baseline ECG changes	Cardiac Catheterization	3	10.714
	Echocardiography	6	21.429
	MRI	0	0
	CXR	2	7.143
	CT Scan	6	21.429
	SPECT	0	0
	PET	0	0
	Stress ECG	0	0
In case of typical chest pain with normal ECG	Cardiac Catheterization	9	32.143
	Echocardiography	7	25.000
	MRI	0	0
	CXR	0	0
	CT Scan	9	32.143
	SPECT	0	0
	PET	0	0
	Stress ECG	3	10.714
In case the patient is suspected to have IHD and unable to do CTA (due to kidney injury	Cardiac Catheterization	3	10.714
	Echocardiography	2	7.143
	MRI	2	7.143
	CXR	0	0
	CT Scan	0	0
	SPECT	19	67.857
	PET	0	0
	Stress ECG	2	7.143
After a CTA scan a patient was found to have atherosclerosis	Cardiac Catheterization	21	75.000
	Echocardiography	1	3.571
	CT Scan	1	3.571
	MRI	1	3.571
	SPECT	3	10.714
	PET	1	3.571
An echocardiography for a patient showed a/hypokinesia	Cardiac Catheterization	21	75.000
	Echocardiography	1	3.571
	CT Scan	2	7.143
	MRI	0	0
	SPECT	4	14.286
	PET	0	0
	Stress ECG	0	0

Appropriate Modality to Detect Ischemia in Chronic Coronary Artery .4.2.1

Table 18 presents the appropriate modality to detect ischemia in chronic coronary Artery disease patients. For patients with chronic coronary artery disease being checked for ischemia, the most recommended test was the stress ECG, chosen by 35.71% of doctors because it is widely available in hospitals and does not require prior appointments. This shows its popularity as a non-invasive way to assess how the heart responds to physical stress. The second most chosen option was SPECT (25%), which helps doctors see how well blood is flowing to the heart, because it provides the exact percentage of ischemia and determines whether there have been any changes. Cardiac catheterization was chosen by 17.86% of respondents. Even though it's an effective method for directly looking at the coronary arteries, it's more invasive and usually saved for specific cases. Other non-invasive options, like echocardiography (14.29%) and CT scans (3.57%), were less commonly used, and PET scans were the least chosen (3.57%).

If the first test doesn't work or provide enough information, doctors prefer to switch to echocardiography (25%) as a second option. This test is helpful because it gives a detailed view of the heart's structure and how it functions. CT scans (21.43%) and cardiac catheterization (17.86%) were also frequently selected as second choices, indicating a balance between non-invasive and invasive methods depending on the patient's needs. SPECT was also a second option in 17.86% of cases, as it continues to provide valuable information about blood flow. MRI (7.14%) and stress ECG (10.71%) were less commonly chosen as second options.

When doctors need a third option, SPECT (28.57%) is still the most commonly chosen test, showing its continued importance in checking blood flow to the heart. Both MRI and cardiac catheterization were chosen by 25% of doctors as third options, indicating their role when non-invasive tests haven't worked or provided clear results. CT scans were selected in 17.86% of cases, while echocardiography (3.57%) was rarely chosen as a third test, likely because it is usually used earlier in the process.

For the last choice of diagnostic test, cardiac catheterization was the most common (50%), despite being an invasive procedure. This reflects its ability to provide clear, definitive answers when other tests have not been conclusive. MRI (17.86%) and PET (14.29%) were also used in some cases at this stage, but not as frequently. CT scans (10.71%) and stress ECG (7.14%) were the least chosen as last options, likely because they have limitations when more detailed imaging or tests are needed.

Study by Knuuti et al. (2018) indicated that stress ECG is the first choice for patients with low-to-intermediate risk. The results agree with the previous study, as stress ECG was the first choice in the current study for patients with low-to-intermediate risk.

Table 18: Appropriate Modality to Detect Ischemia in Chronic Coronary Artery Disease Patients

Case	Recommended	Frequency	Percent
What is the appropriate modality to detect ischemia in chronic coronary artery disease patients	Cardiac Catheterization	5	17.86
	Echocardiography	4	14.29
	CT Scan	1	3.57
	MRI	0	0
	SPECT	7	25.00
	PET	1	3.57
	Stress ECG	10	35.71
If the modality chosen in the previous question was not effective what is the second choice?	Cardiac Catheterization	5	17.86
	Echocardiography	7	25.00
	CT Scan	6	21.43
	MRI	2	7.14
	SPECT	5	17.86
	PET	0	0
	Stress ECG	3	10.71
Regarding the previous question, what modality can be the third choice?	Cardiac Catheterization	7	25.00
	Echocardiography	1	3.57
	CT Scan	5	17.86
	MRI	7	25.00
	SPECT	8	28.57
	PET	0	0
	Stress ECG	0	0
In response to the previous question, what is your last choice of modality?	Cardiac Catheterization	14	50.00
	Echocardiography	0	0
	CT Scan	3	10.71
	MRI	5	17.86
	SPECT	0	0
	PET	4	14.29
	Stress ECG	2	7.14

Patient Respondents.4.1

Demographic Data For patients.4.3.1

Table 19 summarizes the distribution of 806 patients based on gender, examination center, imaging modality, and clinical results. The data provides an overview of the patient demographics, the centers involved, the distribution of diagnostic modalities, and the clinical outcomes of the examinations. Among the patients, 70.8% are male (571 individuals) and 29.2% are female (235 individuals). The majority of patients (63.4%) were seen at Al-Najah University Hospital center (511 individuals), followed by 21.3% at Al-Ahli Hospital (172 individuals) and 15.3% at Makased (123 individuals). Various diagnostic modalities were used, with ultrasound (34.61%) and cardiac catheterization (28.2%) being the most common. Other modalities included CTA Coronary (18.0%), Stress ECG (13.2%), Echo (6.2%), and Cardiac Perfusion (6.1%). 66.6% of patients had abnormal results (537 individuals), while 33.4% (269 individuals) had normal results.

The study by Virani et al. (2020) suggested that males are more likely to develop ischemic heart disease. The results agree with the previous study, as the majority of patients in the current study were male, and the proportion of abnormal results was higher among them.

Table 19: Demographic and Clinical Examination Data Distribution by Gender, Center, Modality, and Result.

		Frequency	Percent
Gender	Male	571	70.8
	Female	235	29.2
Center	Ahli	172	21.3
	Alnajah	511	63.4
	Makassed	123	15.3
Modality	Echo	279	34.61
	CTA Coronary	145	18.0
	Stress ECG	106	13.2
	Cardiac Perfusion	49	6.1
	Cath	227	28.2
Result	normal	269	33.4
	abnormal	537	66.6
	Total	806	100.0

4.3.2 Differences between genders and the examination results

Table 20 shows the distribution of clinical outcomes (normal vs. abnormal) based on gender: Out of 571 males, 180 (31.5%) had normal results, while 391 (68.5%) had abnormal results. Out of 235 females, 89 (37.9%) had normal results, while 146 (62.1%) had abnormal results. In total, 269 patients had normal results, and 537 had abnormal results. The Pearson Chi-Square value is 3.018 with a p-value of 0.082, suggesting that there is no statistically significant difference between gender and the normality of the results (normal test result) at the 0.05 significance level. The p-value is greater than 0.05, meaning the difference in normality between males and females is not statistically significant. Fisher's exact test gives a 2-sided significance of 0.085 and a 1-sided significance of 0.050. The 1-sided p-value of 0.050 is borderline significant, but typically we rely on the 2-sided test for robust conclusions, which shows a non-significant result ($p > 0.05$).

This result disagrees with the by Moran et al. (2014), as the study did not find a statistically significant difference between genders, while the previous study indicated differences in symptoms and diagnosis between males and females.

Table 20: Gender and Normality Cross tabulation with Chi-Square Test Results.

Gender * Normality Cross tabulation				
		Normality		
		Normal	Abnormal	Total
Gender	Male	180	391	571
	Female	89	146	235
Total		269	537	806

Chi-Square Tests					
	Value	Df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.018[a]	1	.082		
Continuity Correction[b]	2.739	1	.098		
Likelihood Ratio	2.983	1	.084		
Fisher's Exact Test				.085	.050
N of Valid Cases	806				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 78.43.					
b. Computed only for a 2x2 table					

Although males have a higher percentage of abnormal results compared to females, the Chi-Square test does not show a statistically significant association between gender and the normality of clinical results ($p = 0.082$). This suggests that the differences observed might be due to chance. However, the borderline significance in Fisher's exact test ($p = 0.050$ for 1-sided) suggests that further investigation with a larger sample size or more refined analysis could be valuable.

Differences between hospitals and the examination results .4.3.3

Table 21 displays the distribution of clinical outcomes (normal vs. abnormal) based on the examination center. Out of 172 patients, 68 (39.5%) had normal results, and 104 (60.5%) had abnormal results. Out of 511 patients, 127 (24.9%) had normal results, and 384 (75.1%) had abnormal results. Out of 123 patients, 74 (60.2%) had normal results, and 49 (39.8%) had abnormal results. In total, 269 patients had normal results, while 537 had abnormal results.

The Pearson Chi-Square value is 59.317 with a p-value of 0.000, indicating a statistically significant difference between centers and the normality of clinical results. The p-value is less than 0.05, showing that the differences observed between the centers are statistically significant. The Likelihood Ratio is also highly significant with a value of 57.221 and a p-value of 0.000.

Due to the presence of more experienced specialists at An-Najah Hospital and the advanced medical device used, the likelihood of negative test results is higher than that of positive test results.

The Center and Normality Cross tabulation table and Chi-Square test results reveal significant differences in diagnostic outcomes across the three hospitals: Al-Ahli Hospital, Al-Najah University Hospital, and Al-Maqasid Hospital. These differences are statistically significant, as indicated by the Pearson Chi-Square value of 59.317 and a p-value of 0.000, meaning the variations in results are not due to chance but are influenced by factors such as patient population, diagnostic protocols, and resource availability.

At Al-Ahli Hospital, the distribution of normal and abnormal results is relatively balanced, with 39.5% normal and 60.5% abnormal results. This suggests that the hospital serves a moderate-risk patient population and follows standard diagnostic protocols. In contrast, Al-Najah University Hospital reports a significantly higher proportion of abnormal results (75.1%) compared to normal results (24.9%). This is likely due to the hospital's advanced diagnostic methods, experienced specialists, and its role as a referral center for complex or high-risk cases. On the other hand, Al-Maqasid Hospital has the highest p roportion of normal results (60.2%) and the lowest proportion of abnormal results (39.8%). This could reflect differences in patient demographics, the types of cases referred to the hospital, or the use of less sensitive diagnostic tools.

The significant disparities in diagnostic outcomes across the three hospitals highlight the influence of factors such as patient risk profiles, diagnostic protocols, and resource availability. For instance, hospitals with advanced imaging technologies and experienced staff, like Al-Najah University Hospital, are more likely to detect abnormalities, while those with limited resources or stricter diagnostic criteria, like Al-Maqasid Hospital, may report fewer abnormal results. To address these disparities, it is essential to standardize diagnostic protocols across hospitals, ensure equitable resource allocation, and provide training to healthcare professionals. Additionally, further research is needed to explore the underlying factors contributing to these differences, such as referral patterns and patient demographics, to improve diagnostic accuracy and consistency across healthcare facilities.

In conclusion, the findings underscore the importance of tailoring diagnostic approaches based on hospital-specific contexts while striving for standardization and resource optimization to ensure equitable and accurate diagnosis of ischemic heart disease.

The results agree with the Lippi et al. (2013), as hospitals with better resources (e.g., Al-Najah University Hospital) had a higher proportion of abnormal results, reflecting greater diagnostic accuracy.

Table 21: Center and Normality Cross tabulation with Chi-Square Test Results.

Center * Normality Cross tabulation				
		Normality		
		Normal	Abnormal	Total
Center	Al-Ahli	68	104	172
	Al-Najah University Hospital	127	384	511
	Al- Makassed	74	49	123
Total		269	537	806

Chi-Square Tests			
	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	59.317[a]	2	.000
Likelihood Ratio	57.221	2	.000
N of Valid Cases	806		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 41.05.

The differences between modalities and the examination results .4.3.3

Table 22 shows the distribution of clinical outcomes (normal vs. abnormal) based on the diagnostic modality. Out of 50 patients, only 2 (4%) had normal results, while 48 (96%) had abnormal results. Of 145 patients, 75 (51.7%) had normal results, while 70 (48.3%) had abnormal results. Out of 106 patients, 71 (67%) had normal results, while 35 (33%) had abnormal results. Out of 49 patients, 19 (38.8%) had normal results, and 30 (61.2%) had abnormal results. Out of 227 patients, 58 (25.6%) had normal results, while 169 (74.4%) had abnormal results. Out of 229 patients, 44 (19.2%) had normal results, while 185 (80.8%) had abnormal results.

The Modality and Normality Cross tabulation table and Chi-Square test results shows a strong association between the type of diagnostic modality used and the clinical outcomes (normal vs. abnormal). The Pearson Chi-Square value of 122.741 with a p-value of 0.000 indicates that the differences in outcomes across modalities are statistically significant, meaning the choice of diagnostic tool significantly influences the likelihood of detecting abnormalities.

Echocardiography and Cardiac Catheterization were associated with the highest percent of abnormal results (83.5% and 74.4%, respectively). This reflects their high sensitivity in detecting structural and functional abnormalities in the heart. Echocardiography is particularly useful for assessing wall motion abnormalities, valve function, and overall cardiac performance, while cardiac catheterization provides definitive information about coronary artery blockages, making it the gold standard for diagnosing coronary artery disease (CAD).

In contrast, Stress ECG and CTA Coronary showed a more balanced distribution of normal and abnormal results. Stress ECG had 67% normal results, reflecting its role as a first-line test for lower-risk patients or those with atypical

symptoms. It is non-invasive, cost-effective, and widely available, but its lower sensitivity and specificity compared to advanced imaging modalities limit its ability to detect abnormalities in high-risk patients. Similarly, CTA Coronary had 51.7% normal results, as it is often used to rule out CAD in patients with intermediate risk or inconclusive stress tests.

Cardiac Perfusion Imaging (SPECT) had a higher proportion of abnormal results (61.2%), indicating its effectiveness in detecting myocardial ischemia, especially in patients with contraindications to contrast-based imaging. However, its use is less common compared to other modalities, likely due to limited availability and higher costs.

These findings show the importance of choosing the appropriate diagnostic modality based on the patient's clinical presentation, risk factors, and the specific information needed. While non-invasive tests like Stress ECG and CTA Coronary are suitable for lower-risk patients, advanced modalities like echocardiography and cardiac catheterization are essential for high-risk patients or those with complex symptoms. The significant association between modality and outcomes underscores the need for tailored diagnostic approaches to ensure accurate and effective diagnosis of ischemic heart disease.

The results agree with the Oikonomou et al. (2022), as more advanced tools (e.g., cardiac catheterization) were associated with a higher proportion of abnormal results.

Table 22: Modality and Normality Cross tabulation with Chi-Square Test Results.

Modality * Normality Cross tabulation				
		Normality		
		Normal	Abnormal	Total
Modality	Echo	46	233	279
	CTA Coronary	75	70	145
	Stress ECG	71	35	106
	Cardiac Perfusion	19	30	49
	Cath	58	169	227
Total		269	537	806

Chi-Square Tests			
	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	122.741[a]	5	.000
Likelihood Ratio	126.861	5	.000
N of Valid Cases	806		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.35.

The Chi-Square test results indicate a significant association between the diagnostic modality used and the normality of clinical results ($p < 0.001$). Certain modalities, such as Echo and Ultrasound, are associated with a higher proportion of abnormal results, while others, such as Echo Stress and CTA Coronary, show a more balanced distribution between normal and abnormal outcomes. This suggests that the choice of diagnostic modality can have a significant impact on the likelihood of detecting abnormal results.

The differences between the age of the patient and the modality .4.3.3 Diagnostic Modality used

According to Table 23 it could said that patient with age under 40 are less likely to do IHD diagnostic test, and they probably underwent a stress ECG test, which is the most common in the 40-49 age group (35.84%) but is also used in younger adults (18-29 and 30-39 at 14.15% each). This test is preferred with these age groups due to low PTP, and it's the recommendation with low PTP, and for older patient it's not prefered because lack of physical activity and they can't reach maximum heart rate.

Table 23 shows that cardiac catheterization, which is an invasive diagnostic procedure typically used when there is a high PTP of IHD. It is most commonly

performed in the 50-59 age group (33.64%) and remains frequent in older age groups (60-69 at 24.88% and 70+ at 22.58%), and its not recommended for yonger patients.

Table 23 shows that the echocardiography, a non-invasive imaging modality, is frequently used across all age groups but is particularly high in the 50-59 (32.35%) and 60-69 (25%) age groups, because these age groups most likely to have other cardiac abnormalites.

Table 23 shows also that CTA coronary, which is another non-invasive imaging modality, is most common in age group between 40-49 (36.55%) and 30-39 (15.17%) age group.

CTA is often recommended for patients with a low-to-intermediate PTP of IHD, its higher use in younger age groups may reflect its role in excluding significant coronary artery disease in patients with atypical symptoms or lower overall risk, we dosen't use it with old patient because the risk of contrast and kidney failure.

Table 23 shows also cardiac SPECT usage, a form of nuclear imaging used to assess myocardial perfusion, is more frequently used in the 40-49 (26%) and 60-69 (26%) age groups, with significant use also in the 50-59 age group (22%).

The study by Gulati et al. (2021) suggested that patient age influences the choice of diagnostic tools. The results agree with the previous study, as younger patients were more likely to undergo non-invasive tests, while older patients were more likely to undergo invasive tests.

Table 23: showing the age of the patient and the modality Diagnostic Modality used:

Image modality type	Age	Frequency	Percentage %
Cardiac Catheterization	18-29	3	1.38
	30-39	10	4.60
	40-49	28	12.90
	50-59	73	33.64
	60-69	54	24.88
	70+	49	22.58
Echocardiography	18-29	9	3.30
	30-39	12	4.41
	40-49	34	12.50
	50-59	88	32.35
	60-69	68	25.00
	70+	61	22.42
CTA coronary	18-29	5	3.44
	30-39	22	15.17
	40-49	53	36.55
	50-59	40	27.58
	60-69	18	12.41
	70+	7	4.82
Cardiac SPECT	18-29	-	0.0000
	30-39	4	8.00
	40-49	13	26.00
	50-59	11	22.00
	60-69	13	26.00
	70+	9	18.00
Stress ECG	18-29	15	14.15
	30-39	15	14.15
	40-49	38	35.84
	50-59	22	20.75
	60-69	12	11.32
	70+	4	3.77

Limitations:4.3

Retrospective Design: This may introduce bias due to incomplete or inconsistent data across patient records.

The study results may be limited to the institutions from which data is gathered, and further research may be needed to apply findings to a broader population

This methodology will allow for a robust quantitative assessment of the role that noninvasive cardiac imaging modalities play in diagnosing and treating ischemic heart disease, providing valuable insights into their effectiveness and impact on patient outcomes.

Chapter Five:

Conclusion

The study on ischemic heart disease (IHD) diagnostic modalities within Palestinian hospitals reveals several insights regarding the detection of diagnostic modalities, the influence of hospital resources, and the role of patient demographics in determining patients' outcomes.

The following important conclusions emerge from the results:

- Most hospitals in the study follow established guidelines for selecting diagnostic modalities (European Society of Cardiology and American Heart Association), with a strong commitment among cardiologist to adhere to these protocols. This structured approach emphasizes consistency in IHD diagnosis and reflects an adherence to best practices in cardiology.
- Cardiovascular risk factors heavily influence the selection of imaging tests, highlighting the prioritization of clinical urgency. While patient age, socioeconomic factors, and radiation exposure considerations are less frequently emphasized, the availability of diagnostic modalities significantly impacts decision-making. This practical approach suggests a balance between following guidelines and adapting to available resources.
- Cardiac catheterization remains the preferred choice for high-risk cases, especially in patients with typical chest pain or inconclusive non-invasive tests, and with old patient. However, non-invasive methods like stress ECG and echocardiography are preferred for lower-risk cases or patients where invasive procedures pose additional health risks. This selection strategy reflects a nuanced approach to balancing diagnostic accuracy with patient safety.
- The study identifies significant differences in diagnostic choices based on the hospital and patient demographics. Hospitals with more resources tend to employ a wider range of diagnostic modalities, while resource-limited facilities rely more on accessible methods. Younger patients are more likely to undergo non-invasive tests, suggesting a tailored approach based on patient characteristics.
- There is a strong association between diagnostic modality and clinical outcomes, with certain modalities like echocardiography and cardiac catheterization showing higher rates of abnormal findings. These results underscore the importance of modality choice in detecting IHD abnormalities and reflect the varying sensitivity of different diagnostic tools.

- There is a strong association between diagnostic modality and clinical outcomes, with certain modalities like echocardiography and cardiac catheterization showing higher rates of abnormal findings. These results underscore the importance of modality choice in detecting IHD abnormalities and reflect the varying sensitivity of different diagnostic tools.
- Gender does not show a statistically significant influence on diagnostic outcomes, suggesting that diagnostic approaches are consistent across male and female patients. However, borderline significance in some statistical tests implies that further research could clarify potential subtle differences.
- Diagnostic outcomes vary significantly by center, with some hospitals showing higher rates of abnormal findings. This may reflect differences in patient populations or diagnostic practices between centers, highlighting the role of hospital context in influencing clinical results.

Recommendations

- **Enhance Access to Diagnostic Modalities Across Hospitals**:
  To reduce disparities in IHD diagnosis, healthcare authorities should aim to provide equitable access to advanced diagnostic tools across hospitals. This includes making non-invasive options like stress ECG, echocardiography, and CTA Coronary more widely available, especially in resource-limited settings.
- **Promote Non-Invasive Diagnostics as a First-Line Approach**:
  Where feasible, encourage the use of non-invasive tests as initial diagnostics for lower-risk patients or those unable to undergo invasive procedures. This can enhance patient safety, reduce procedural risks, and lower healthcare costs, reserving invasive methods like cardiac catheterization for cases where non-invasive options are inconclusive or where high-risk findings require further investigation.
- **Develop Patient-Centered Guidelines Incorporating Broader Patient Factors**:
  While existing protocols emphasize cardiovascular risk, updated guidelines should also account for factors like age, socioeconomic status, and radiation exposure to ensure a more personalized diagnostic approach. Including these factors can help tailor care to individual patient profiles, especially in high-risk or vulnerable groups.
- **Strengthen Training in Multi-Modal Diagnostic Approaches**:
  Provide ongoing training for healthcare professionals on the strengths and limitations of different diagnostic modalities, emphasizing a multi-modal approach that integrates both anatomical and functional imaging when appropriate. This can support informed decision-making and optimize diagnostic accuracy.
- **Improve Data Collection and Outcome Monitoring Across Centers**:
  Establish a standardized data collection system for tracking diagnostic outcomes and modality use across centers. Regularly analyzing these data can identify trends, improve diagnostic practices, and inform resource allocation decisions to meet patient needs effectively.
- **Encourage Further Research on Gender and Diagnostic Outcomes**:
  Although gender did not show significant influence in this study, the borderline significance observed suggests that further research could be valuable. A larger, more diverse sample size could clarify any subtle differences and help refine diagnostic approaches for gender-specific IHD presentation.
- **Optimize Use of Resources Based on Patient Age and Health Status**:
  Develop protocols that adapt diagnostic strategies based on patient age and health status, particularly for elderly patients who may benefit from non-invasive methods. A tailored approach can optimize resource use and ensure safe, effective diagnosis for patients with varied health needs.
- **Expand Education on the Appropriate Use of Radiation in Diagnostics**:
  Increase awareness among healthcare professionals about the importance of minimizing radiation exposure in diagnostics, especially for lower-risk patients or those requiring frequent imaging. Providing guidance on radiation management can support patient safety and encourage mindful diagnostic practices.

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Appendix:

1.1. Questionnaire

Al Quds University

Faculty of Health Professions

Medical Imaging Department

Jerusalem –Abu Dies

جامعة القدس

كلية المهن الصحية

دائرة التصوير الطبي

القدس- أبوديس

يقوم الباحث يزن ابو ارميلة من برنامج الدراسات العليا - دائرة التصوير الطبي \ جامعة القدس بهذه لدراسة للبحث عن:

(معايير استخدام طرق التصوير القلبي المختلفة في تشخيص وعلاج أمراض القلب الإقفارية (**IHD**) في الجهاز الصحي الفلسطيني). بعنوان:

Criteria for the use of different cardiac imaging modalities in the diagnosis and treatment of ischemic heart disease (IHD) in the Palestinian health system.

نرجو من حضرتكم التكرم بتخصيص دقيقتين من وقتكم لتعبئة هذا الاستبيان ولكم كل الشكر.

Please answer all the questions depending on your real experience in Palestinian health system.

Many thanks.

Age	28-40	41-50	51-60	61-70	>70	العمر
Gender	M	F				الجنس
Workplace	Public Health Center or Hospital	NGO Health Center or Hospital	Private Health Center or Hospital	Private Clinic		مكان العمل
Experience	≤ 5 years	6-10(2)	11-20	21-30	> 30	سنوات الخبرة
Specialty	Cardiologist	Cardiac Surgeon	Cardiology Resident	Internal Medicine consultant	GP (physician)	مسمى التخصص

Please answer all questions depending on your experience in Palestinian health system.

Many thanks.

Questions	Please circle the most appropriate answer								
In your view, what is the modality of choice (the gold standard) to evaluate (diagnose) ischemic heart disease (IHD)?	CXR	Cardiac Catheterization	Echocardiography	ECG	CT Scan	SPECT	PET	MRI	No gold standard modality

Does your medical center (cardiology department) have criteria or guidelines for cardiac imaging diagnosis and imaging Modality selection?	YES	No	I do not know	No need for criteria	I use a standard of other country

In all cases, I am committed to an established criteria and guidelines when referring IHD patient to a cardiac imaging modality and stepwise selection of other modalities	Strongly agree	Agree	Uncertain, neutral	Disagree	Strongly Disagree
I do not consider the patient's age when referring to (selecting) the cardiac imaging modality for IHD evaluation	Strongly agree	Agree	Uncertain, neutral	Disagree	Strongly Disagree
I do not consider the functional (ambulatory) state of the patient when referring to (selecting) the cardiac imaging modality	Strongly agree	Agree	Uncertain, neutral	Disagree	Strongly Disagree
I do not consider the patient's cardiovascular risk factors when referring to (selecting) the cardiac imaging modality	Strongly agree	Agree	Uncertain, neutral	Disagree	Strongly Disagree

I do not consider the patient's financial and social situation when referring to (selecting) the cardiac imaging modality	Strongly agree	Agree	Uncertain, Neutral	Disagree	Strongly Disagree
I do not Consider the justification of patient dose of ionizing radiation when referring to (selecting) the cardiac imaging modality	Strongly agree	Agree	Uncertain, Neutral	Disagree	Strongly Disagree
I do not consider the availability of the imaging modality in my practice setting when referring to (selecting) the modality of cardiac imaging	Strongly agree	Agree	Uncertain, neutral	Disagree	Strongly Disagree

To which of the cardiac imaging modalities would you recommend (refer) the patient initially (directly) in the following cases

	CXR	Cardiac Catheterization	Echocardiography	Stress ECG	CT Scan	SPECT	PET	MRI
a patient with unknown IHD presented with typical chest pain.								
a patient with known IHD presented with Atypical chest pain.								
In case of angina pectoris in patient after cardiac catheterization with stent.								
In the case of a patient with an indication for stress ECG but with baseline ECG changes.								

In case of typical chest pain with normal ECG.								
In case the patient is suspected to have IHD and unable to do CTA (due to kidney injury) the best alternative is								
After a CTA scan a patient was found to have atherosclerosis , what other modality can be used to detect chronic CAD .								
An echocardiography for a patient showed a/hypokinesia , what is your choice for the next step ?								

In case the patient did an echo previously, do the test results affect choosing the next cardiac imaging modality type?	**Yes**	**No**	Uncertain,	
Do the cardiologists use pre-test probability (PTP) before choosing the most beneficial diagnostic procedure for the patient?	**Yes**	**No**		

To which of the cardiac imaging modalities would you recommend (refer) the patient initially (directly) in the following cases								
	CXR	Cardiac Catheterization	Echocardiography	Stress ECG	CT Scan	SPECT	PET	MRI
What is the appropriate modality to detect ischemia in chronic coronary artery disease patients?								

If the modality chosen in the previous question was not effective what is the second choice?								
Regarding the previous question, what modality can be the third choice?								
In response to the previous question, what is your last choice of modality?								

Abbreviations: **NGO**: Non-Governmental Organization; **CTA**: Computed Tomography Angiography; **PET**: Positron Emission Tomography; **MRI**: Magnetic Resonance Imaging; **ECG**: Electrocardiogram; **IHD**: Ischemic Heart Disease; **CXR**: Chest X-ray; **SPECT**: Single Photon Emission Computed Tomography

1.2. Research Ethics Subcommittee of Faculty of Health Professions Letter of approval

Al Quds University
Faculty of Health Professions
Jerusalem –Abu Dis

جامعة القدس
كلية المهن الصحية
القدس – أبو ديس

Research Ethics Subcommittee of Faculty of Health Professions
Letter of approval

Nov. 14, 2023
Ref. No.: RESC/2024-11

Dear Applicants, (**Dr. Mohammad Hjouj, Mr. Yazan Abourmeleh**)

Program: **MSc Medical Imaging Department**

The Research Ethics subcommittee of the Faculty of Health Professions has recently reviewed your proposal entitled (**The role of noninvasive cardiac imaging modalities in the diagnosis and treatment of ischemic heart disease**) submitted by (**Dr. Mohammad Hjouj**). Your proposal is deemed to meet the requirements of research ethics at Al-Quds University, but further assessment is required by the Central Research Ethics Committee of Al-Quds University. We wish you all best for the conduct of the project.

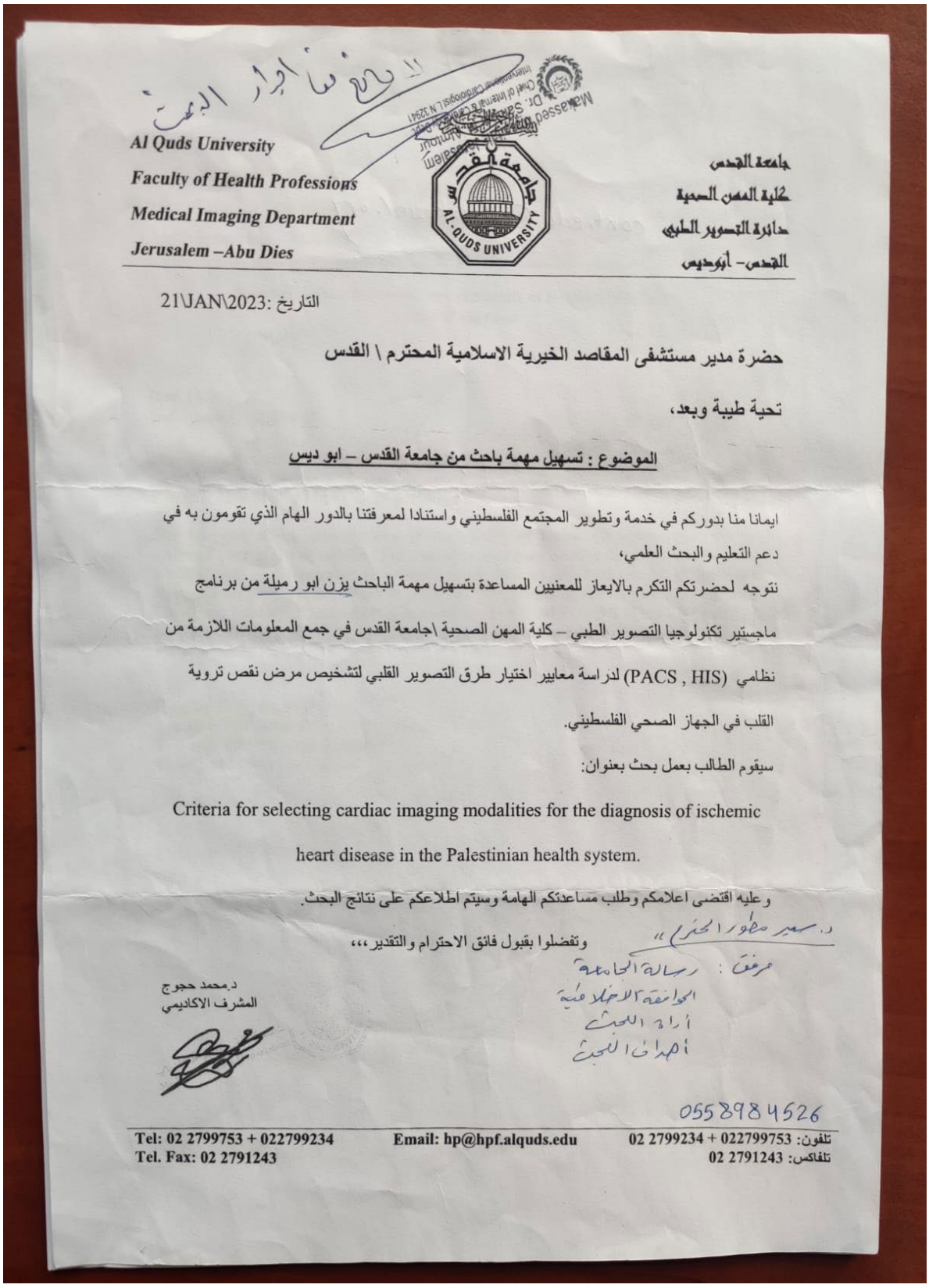
Hussein ALMasri, PhD
Associate Professor of Medical Imaging
Research Ethics Subcommittee Chair
Faculty of Health Professions

Hussein ALMasri

CC: File
CC: Committee members

Tel. Fax: 02 2791243 Email: dean@hpro.alquds.edu تلفاكس: 02 2791243

1.3. Facilitate the researcher's task from Al-Quds University (Al-Maqasid Hospital)



Al Quds University
Faculty of Health Professions
Medical Imaging Department
Jerusalem –Abu Dies

جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس– أبوديس

التاريخ :21\JAN\2023

حضرة مدير مستشفى المقاصد الخيرية الاسلامية المحترم \ القدس

تحية طيبة وبعد،

الموضوع : تسهيل مهمة باحث من جامعة القدس – ابو ديس

ايمانا منا بدوركم في خدمة وتطوير المجتمع الفلسطيني واستنادا لمعرفتنا بالدور الهام الذي تقومون به في دعم التعليم والبحث العلمي،

نتوجه لحضرتكم التكرم بالايعاز للمعنيين المساعدة بتسهيل مهمة الباحث يزن ابو رميلة من برنامج ماجستير تكنولوجيا التصوير الطبي – كلية المهن الصحية \جامعة القدس في جمع المعلومات اللازمة من نظامي (PACS , HIS) لدراسة معايير اختيار طرق التصوير القلبي لتشخيص مرض نقص تروية القلب في الجهاز الصحي الفلسطيني.

سيقوم الطالب بعمل بحث بعنوان:

Criteria for selecting cardiac imaging modalities for the diagnosis of ischemic heart disease in the Palestinian health system.

وعليه اقتضى اعلامكم وطلب مساعدتكم الهامة وسيتم اطلاعكم على نتائج البحث.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

د.محمد حجوج
المشرف الاكاديمي

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Tel. Fax: 02 2791243

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تلفاكس: 02 2791243

1.4. Facilitate the researcher's task from Al-Quds University (Al-Ahli Hospital)

Al Quds University
Faculty of Health Professions
Medical Imaging Department
Jerusalem –Abu Dies

جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس- أبوديس

التاريخ :21\JAN\2023

حضرة مدير المستشفى الاهلي المحترم \الخليل

تحية طيبة وبعد،

الموضوع : تسهيل مهمة باحث من جامعة القدس – ابو ديس

ايمانا منا بدوركم في خدمة وتطوير المجتمع الفلسطيني واستنادا لمعرفتنا بالدور الهام الذي تقومون به في دعم التعليم والبحث العلمي،

نتوجه لحضرتكم التكرم بالايعاز للمعنيين المساعدة بتسهيل مهمة الباحث يزن ابو رميلة من برنامج ماجستير تكنولوجيا التصوير الطبي – كلية المهن الصحية \جامعة القدس في جمع المعلومات اللازمة من نظامي (PACS , HIS) لدراسة معايير اختيار طرق التصوير القلبي لتشخيص مرض نقص تروية القلب في الجهاز الصحي الفلسطيني.

سيقوم الطالب بعمل بحث بعنوان:

Criteria for selecting cardiac imaging modalities for the diagnosis of ischemic heart disease in the Palestinian health system.

وعليه اقتضى اعلامكم وطلب مساعدتكم الهامة وسيتم اطلاعكم على نتائج البحث.

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Tel. Fax: 02 2791243 تلفاكس: 02 2791243

1.5. Facilitate the researcher's task from Al-Quds University (Al-Najah University Hospital)

Al Quds University
Faculty of Health Professions
Medical Imaging Department
Jerusalem –Abu Dies

جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس- أبوديس

التاريخ :21\JAN\2023

حضرة مدير مستشفى النجاح الوطني الجامعي المحترم \ نابلس

تحية طيبة وبعد،

الموضوع : تسهيل مهمة باحث من جامعة القدس – ابو ديس

ايمانا منا بدوركم في خدمة وتطوير المجتمع الفلسطيني واستنادا لمعرفتنا بالدور الهام الذي تقومون به في دعم التعليم والبحث العلمي،

نتوجه لحضرتكم التكرم بالايعاز للمعنيين المساعدة بتسهيل مهمة الباحث يزن ابو رميلة من برنامج ماجستير تكنولوجيا التصوير الطبي – كلية المهن الصحية \جامعة القدس في جمع المعلومات اللازمة من نظامي (PACS , HIS) لدراسة معايير اختيار طرق التصوير القلبي لتشخيص مرض نقص تروية القلب في الجهاز الصحي الفلسطيني.

سيقوم الطالب بعمل بحث بعنوان:

Criteria for selecting cardiac imaging modalities for the diagnosis of ischemic heart disease in the Palestinian health system.

وعليه اقتضى اعلامكم وطلب مساعدتكم الهامة وسيتم اطلاعكم على نتائج البحث.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

د.محمد حجوج
المشرف الاكاديمي

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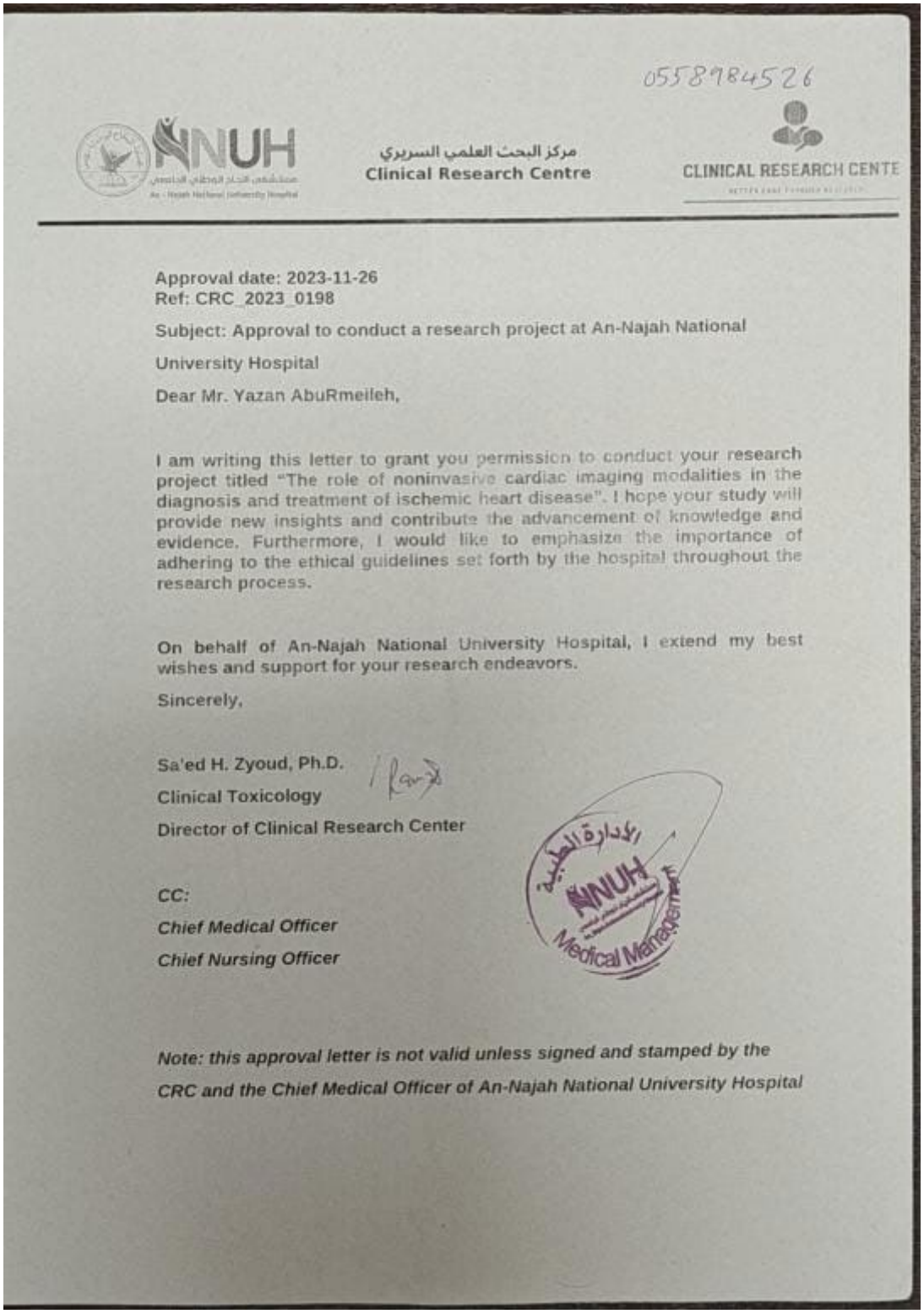
تلفاكس: 02 2791243

1.6. Approval to Conduct a Research Project at An-Najah National University Hospital



0558984526

NNUH

مركز البحث العلمي السريري
Clinical Research Centre

CLINICAL RESEARCH CENTE

Approval date: 2023-11-26
Ref: CRC_2023_0198

Subject: Approval to conduct a research project at An-Najah National University Hospital

Dear Mr. Yazan AbuRmeileh,

I am writing this letter to grant you permission to conduct your research project titled "The role of noninvasive cardiac imaging modalities in the diagnosis and treatment of ischemic heart disease". I hope your study will provide new insights and contribute the advancement of knowledge and evidence. Furthermore, I would like to emphasize the importance of adhering to the ethical guidelines set forth by the hospital throughout the research process.

On behalf of An-Najah National University Hospital, I extend my best wishes and support for your research endeavors.

Sincerely,

Sa'ed H. Zyoud, Ph.D.
Clinical Toxicology
Director of Clinical Research Center

الإدارة الطبية
NNUH
Medical Management

CC:
Chief Medical Officer
Chief Nursing Officer

Note: this approval letter is not valid unless signed and stamped by the CRC and the Chief Medical Officer of An-Najah National University Hospital

دور طرق التصوير القلبي الجراحية وغير الجراحية في تشخيص وعلاج مرض القلب الإقفاري (IHD)

اسم الطالب : يزن عبد العزيز غازي ابورميلة

المشرف : د. محمد حجوج

ملخص

يتناول هذا البحث دور طرق التصوير الطبي في تشخيص مرض محدد وهو مرض القلب الإقفاري والذي يعد أحد أكثر أسباب الوفاة شيوعاً في جميع أنحاء العالم.

يقوم هذا البحث بدراسة دور طرق التصوير القلبي الجراحية و غير الجراحية في تشخيص مرض القلب الإقفاري (IHD)، مع التركيز على فعاليتها ودقتها واستخداماتها السريرية.

استخدمت الدراسة منهجية البحث الكمي، حيث تم توزيع استبيانات منظمة على أطباء القلب في المستشفيات الفلسطينية.

تم جمع البيانات من السجلات الطبية للمستشفيات من 806 مريضًا حول التركيبة السكانية الخاصة بهم، بما في ذلك العمر والجنس، إلى جانب التقارير التشخيصية التي توضح بالتفصيل خيارات طريقة التصوير ونتائجها.

و تم تطبيق الأدوات الإحصائية لتحليل البيانات التي تم جمعها، وتحديد الأنماط والارتباطات بين العوامل الديموغرافية وفعالية التشخيص.

تظهر النتائج اختلافات كبيرة في فعالية التشخيص بناءً على طريقة التصوير المستخدمة ، حيث يستخدم تصوير الأوعية التاجية المقطعي المحوسب (CCTA) وصورة تروية عضلة القلب (MPI) في الغالب لتشخيص مرض الشريان التاجي لدى المرضى المعرضين لمخاطر متوسطة إلى عالية، في حين تم استخدام تخطيط القلب الكهربائي (ECG) بشكل أكثر شيوعًا للمرضى المعرضين لمخاطر أقل أو الذين يعانون من أعراض وذلك بسبب فعاليته من حيث إمكانية اجرائه و من حيث التكلفة.

وتظهر النتائج أيضًا أن عمر المريض وجنسه يؤثر على اختيار أدوات التشخيص، حيث يخضع المرضى الأصغر سنًا غالبًا لطرق مثل تخطيط كهرباء القلب، في حين يخضع المرضى الأكبر سنًا والذين يعانون من أعراض معقدة على الأرجح لطرق تصوير متقدمة.

وخلصت الدراسة إلى أن طرق التصوير غير الجراحية هي أدوات مهمة في تشخيص مرض القلب الإقفاري (IHD) وكيفية التعامل معه. ومع ذلك، فإن اختيار الطريقة المناسبة يجب أن يعتمد على عوامل خاصة بالمريض، بما في ذلك الأعراض والعلامات التي تظهر على المريض ، والعمر، والجنس، والوضع الاقتصادي، وبروتوكولات المستشفى، والبروتوكول الذي يتبعه الأطباء.

بالنسبة للمستشفيات الفلسطينية، فإن تحسين الوصول إلى طرق التصوير المتقدمة وتدريب المتخصصين على تطبيقها يمكن أن يعزز دقة التشخيص ونتائج العلاج.

ويؤكد هذا البحث على الحاجة الماسة إلى وجود مسارات تشخيصية مصممة خصيصًا ، ويدعم دمج تقنيات التصوير المتقدمة والفعالة من حيث التكلفة في أنظمة الرعاية الصحية الفلسطينية ذات الموارد المحدودة.

وأخيرًا وجدنا أن أطباء القلب في المستشفيات الفلسطينية يتبعون المعايير العالمية لتشخيص مرض القلب الإقفاري، وخاصة معايير الجمعية الأوروبية لأمراض القلب وجمعية القلب الأمريكية.