Evaluating Basic Two-Dimensional Echocardiography For Screening In Coronary Artery Disease

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Abstract

Background: Basic two-dimensional echocardiography (2D-echocardiography) screens for suspected coronary artery disease (CAD) by detecting impaired left ventricular function (LVF) which declines as atherosclerosis worsens.

Aim: To evaluate basic 2D-echocardiography for CAD screening.

Methods: CAD screening was performed with 2D-echocardiography. For global screening, left ventricular ejection fraction percentage (LVEF%) was determined and categorised into global systolic LVF. For regional screening, global average echocardiography score (GAES) was quantified, then categorised into functional impairment. After screening, high-risk patients underwent diagnostic coronary angiography. Abnormal angiography had >50% luminal stenosis. Angiography was also quantified with Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score, then categorised. Statistical Package for Social Science 25.0 analysed data.

Results: There were 471 patients screened for CAD; 154/471 (33%) underwent angiography. For angiography selection amongst 471 screened patients, GAES was higher ($p < 0.001$) and positively correlated (Pearson's coefficient 0.296); LVEF% was lower ($p = 0.002$) and negatively correlated (Pearson's coefficient -0.187). Amongst 154 patients, SYNTAX score correlated negatively with LVEF% (Pearson's coefficient -0.276) and positively with GAES (Pearson's co-efficient 0.180). For categories, angiography had 66/154 (42.9%) normal and 88/154 (57.1%) abnormal results. SYNTAX score had 134/154 (87.0%) low-risk and 20/154 (13.0%) medium-high-risk categories. GAES correlated positively with angiogram results (Spearman's coefficient 0.298) and SYNTAX categories (Spearman's coefficient 0.110). LVEF% correlated negatively with angiogram results (Spearman's coefficient -0.307) and SYNTAX categories (Spearman's coefficient -0.254).

Conclusions: The distribution of underlying atherosclerotic vessels resulted in regional wall abnormalities being more significant than global function on 2D-echocardiography. We conclude that basic 2D-echocardiography remains useful in CAD screening.

Introduction

Transthoracic echocardiography:

Worldwide, coronary artery disease (CAD) is a major cause of morbidity and mortality. This outcome creates a strong need for early CAD screening with reliable, accurate tools. Echocardiography has been a long-standing screening tool for CAD. The earliest known use of medical ultrasonic waves dates to the collaboration between Edler and Hertz in Lund in 1953. Over the decades, this basic tool has evolved into advanced imaging technology with a quantum leap into three-dimensional echocardiography application, speckle tracking and mobile pocket devices [3]. Advanced technology has revolutionised imaging, accuracy and reliability. The reality, however, is that most healthcare facilities across South Africa, particularly in public healthcare, are resource-limited. Such advanced technology is neither accessible nor affordable to many investigators. Two-dimensional transthoracic echocardiography (TTE) is a common method for cardiac imaging and remains the accessible, cost-effective, and lowest-risk imaging choice for many indications [4,2]. Basic two-dimensional echocardiography (2D-echocardiography) can provide non-invasive evaluation of cardiac structure and function in normal physiological states and in pathological conditions, increasing accuracy in diagnosis and non-invasive cardiac evaluation [1,2]. 2D-echocardiography can therefore be performed on patients with suspected CAD to non-invasively evaluate left ventricular function (LVF) and coronary blood supply [4,5]. We have revisited the fundamental principles and applications of basic 2D-echocardiography imaging to investigate suspected CAD.

Pathophysiology:

Atherosclerotic CAD leads to inadequate myocardial perfusion. Myocardial ischemia initially causes diastolic dysfunction followed by systolic dysfunction, both detectable on 2D-echocardiography. 2D-echocardiography can be used to assess

diastolic dysfunction, global systolic dysfunction, regional wall motion abnormalities, and dilatation in the left ventricle (LV). Angina and repolarization abnormalities on electrocardiogram (ECG) manifest later. Echocardiography therefore provides important information on myocardial hypo-perfusion prior to clinical symptoms or ECG changes. Consequently, early identification of systolic and diastolic dysfunction based on echocardiographic parameters may be of important clinical significance for predicting CAD burden prior to invasive angiography [4,6].

Diastolic dysfunction as a surrogate marker of CAD:

Diastolic dysfunction occurs due to the ineffectiveness of left atrial emptying to the LV, and impaired LV relaxation [7,8]. LV diastolic dysfunction leads to left atrial pressure or volume overload. Chronic overload causes remodelling and enlargement in the left atrium indicating LV diastolic dysfunction or increased filling volumes [9]. LV diastolic dysfunction is usually the result of impaired LV relaxation with or without reduced restoring forces (and early diastolic suction), and increased LV chamber stiffness, which increase cardiac filling pressures [10].

Ejection fraction percentage and global systolic LVF:

Diastolic dysfunction may often progress to systolic dysfunction. The term systolic LVF refers to the capacity of the LV to generate force during systole to eject blood [11]. LVF is key information sought from echocardiography as it is pivotal in the management of all cardiac patients [12]. Global systolic LVF can be indirectly assessed by echocardiography using end diastolic dimensions (EDD) and end systolic dimensions (ESD), as well as end diastolic volume (EDV) and end systolic volume (ESV). This may also be measured by global longitudinal strain. Myocardial strain represents the magnitude of myocardial deformation, which is an energy-requiring process. Longitudinal mechanics predominate in the ischaemia-vulnerable sub-endocardium, and abnormalities of myocardial deformation in the longitudinal axis are seen in the development of many pathophysiologic states, including CAD and myocardial infarction [13].

Global systolic LVF can also be measured by fractional shortening (FS). FS as indices of LVF is noted to be inaccurate in the setting of CAD and wall motion abnormalities and left ventricular ejection fraction percentage (LVEF%) which are changes in the LV dimensions and volumes between diastole and systole, respectively. LVEF% assumes that the fraction of blood displaced from the LV is proportional to the force generated in order to measure ventricular function during systole [11,14]. LVEF% is thereafter categorised into the global systolic LVF category. LVEF% dictate prognosis in patients with myocardial infarction, heart failure and other cardiac diagnoses [11].

Global abnormalities and regional wall motion abnormalities:

In patients with reduced LVEF%, the distinction between global and regional systolic LV dysfunction has major clinical implications. LVEF% is a global measure of systolic LVF, it is not sensitive enough to detect subtle impairment of LV contractile function during the early stages of diseases. Global systolic LV hypokinesia without any significant regional variation generally indicates non-ischaemic aetiology, whereas regional wall motion abnormalities are characteristic of the underlying CAD. However, exceptions are not uncommon as the patients with severe ischaemic LV systolic dysfunction may present with global hypokinesia whereas regional variations are known to occur even in the absence of coronary artery disease [12].

Regional LV wall imaging by TTE:

Regional function is assessed using the 17-segment division established by consensus between several scientific societies [11]. The 17-segment model provides the best agreement with the available anatomic data and has the best fit with other cardiac imaging studies [7,15]. The information regarding the segments and the coronary arteries distribution maintains reliability in this orientation. This standardisation makes the comparison of the different modalities much more reliable and accurate [5,7,15]. In patients with regional LV systolic dysfunction, the location of the wall motion abnormalities provides useful clue about the culprit artery which has prognostic and therapeutic implications [12].

Purpose of echocardiography regarding gold Standard testing:

Echocardiography can identify the high-risk patient needing angiography by detecting early myocardial hypo-perfusion prior to clinical chest pain and ECG changes. It can be used to assess haemodynamic stability, (clinically apparent with shock, poor tissues perfusion or congestive heart failure), complications (such as wall rupture) and to non-invasively assess myocardial infarction extent prior to angiography [16]. However, angiography remains the gold standard method for diagnostic testing.

Aim:

The aim of our study was to evaluate basic 2D-echocardiography for screening in coronary artery disease.

Method

Patient selection:

We retrospectively studied patients without typical angina, suspected of CAD, from January 2002 to December 2008 at Inkosi Albert Luthuli Hospital, Durban, South Africa. CAD was suspected based on demographic information, medical co-morbid risks, abnormal ECG, echocardiography and exercise stress test findings. Patients with known CAD were excluded. Written informed consent for investigation was obtained from patients. The study was approved by the Biomedical Research Ethics Committee (BREC) of University of Kwa-Zulu Natal Nelson R Mandela School of Medicine. This study complies with the Declaration of Helsinki. There was no conflict of interest.

Echocardiography:

2D-echocardiography was performed with Siemens Sequoia machine (Acuson, Germany) in the left lateral decubitus position using standard imaging planes. Data collected was EDD (mm), ESD (mm), LVEF%, FS%. M-mode measurements were obtained from a SAX (short axis) or a PLAX (parasternal long axis) view. Tricuspid, pulmonary, mitral and aortic valves were assessed for diameter and flow. The data was compared to the normal values for men and women [Table 1].

Firstly, global systolic LVF was assessed to detect early myocardial hypo-perfusion. FS was calculated in M-mode: $FS\% = ((EDD - ESD) / EDD) \times 100\%$; $LVEF\% = ((EDV - ESV) / EDV) \times 100\%$. LVEF% was thereafter categorised into the global systolic LVF, which were normal, mildly impaired, moderately impaired and severely impaired.

Secondly, for regional wall abnormalities the American Heart Association recommended 17-segment model was utilized [5,15]. For this method, all cardiac imaging modalities were defined, oriented, and displayed the heart using the long axis of the left ventricle and selected planes oriented at 90° angles relative to the long axis. For transthoracic 2D-echocardiographic system, the parasternal short axis plane approximated the short-axis views in the other modalities. The apical 2-chamber echocardiographic view approximated the vertical long-axis view. The apical 4-chamber echocardiographic view approximated the horizontal long-axis view. The heart was thereby divided into the 17 segments. These segments were grouped to align with the coronary blood supply to the myocardial territory for the left anterior descending artery, circumflex artery and right coronary artery. The locations of the segments follow the respective territory of the coronary arteries to expedite the evaluation of ischemia, same as for sestaMIBI. This approach maintained the integrity of the cardiac chambers and the distribution of coronary arterial blood flow to the myocardium. Therefore, this approach was optimal for use in research and for clinical patient management involving cardiac perfusion and function [7,15].

The severity of contractile dysfunction was, accordingly, scored visually for each of the 17 segments. The scores allocated are one for normal, two for hypokinesis, three for akinesis, four for dyskinesis, and five for an aneurysmal segment. A hypokinetic segment had noticeable reduction in contractility, an akinetic segment barely moved in systole; dyskinetic segment moved paradoxically in systole; and aneurysmal myocardium remained deformed during systole. The scores for all

17 segments were added and divided by 17 to determine the GAES. The GAES was discretely categorised into LV functional impairment: <1 was normal LV function, 1-2 was a small infarct, and >2 had complications [5].

Angiography:

Angiography remained the gold standard and was performed in selected patients. Firstly, angiography was reported as normal if vessels had non-occlusive (<50% luminal stenosis) atheroma, and abnormal if occlusive atherosclerotic disease (>50% luminal stenosis) was present. Left ventriculography was also performed during coronary angiography to assess function. Angiography LVF was categorised into normal, mildly impaired, moderately impaired and severely impaired [Table 1].

Secondly, coronary lesions on angiography were also quantified using The Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score. The SYNTAX score, developed from the SYNTAX trial, characterised coronary anatomy based on 9 anatomic criteria [17,18]. SYNTAX score used 2 factors: the segment weighing factors and the lesions adverse characteristics. Coronary arteries were divided into 16 segments representing the coronary tree [18] [Table 1]. Right and left coronary dominance had different trees. In the right coronary dominated system, the right coronary artery (RCA) and left main stem (LMS) supplied 16% and 84% of the blood to the LV, respectively. From the 84%, one third and two third flowed through the circumflex and left anterior descending (LAD) arteries, respectively. The left dominated system had no RCA supply; therefore, the LMS supply was 100%, and the RCA share of blood to the LV was from the circumflex. Each segment of the vessel was given a weighing factor representing the portion of blood supply through each vessel to the LV for the right or left dominated system of normal coronary vessels [19].

The degree of stenosis and other adverse characteristics were visually assessed on angiography. A stenotic lesion greater than 50% was considered significant. A significant stenosis (50%-99%) and total occlusions (100%) were assigned a diameter reduction value of 2 and 5, respectively. The weighing factor for each vessel in the arterial tree was multiplied by the appropriate diameter reduction value. The points for all the tree segments were then added. Further points were added for other adverse characteristics, such as trifurcations, tortuosity, total occlusion and thrombus etc. The total points formed the SYNTAX score. The total SYNTAX score was assigned to a risk category. A score ≤22 was low risk, 23-32 was intermediate risk, and ≥33 was high risk [17,18]. Higher SYNTAX scores indicated more complex disease, representing greater challenge therapeutically and potentially poor prognosis [19]. The online calculator was used for measurement key, available at <http://www.syntaxscore.com> [Table 1].

Data statistical analysis:

Table 2: Data analysed

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Echocardiography		Angiography	
Continuous	Categorised into	Continuous	Categorised into
EDD, ESD, FS	-	>50% luminal stenosis in main vessel	Normal or abnormal
LVEF%	Global systolic LVF category	-	Angiogram LVF
GAES	LV functional impairment category	SYNTAX score	SYNTAX category

The variables of data collected is tabulated [Table 2]. The study data was analysed with Statistical Package for Social Science (SPSS) version 25.0. The LVEF% and GAES were documented, and descriptive analysis was performed.

The cohort was divided in those who underwent angiography and those who did not. Data was compared between these two patient groups using independent samples t-tests, Spearman's correlation and chi-squared tests. Echocardiography and angiography were described in the group selected for angiography. The angiographic (STNTAX scores, SYNTAX risk

categories, angiogram results and LV function) was compared to echocardiography (LVEF%, GAES, global systolic LV category and functional impairment category). Correlation tests and chi-squared tests were used.

Results

Echocardiography and selection for angiography:

There were 471 patients screened for CAD who had complete data on 2D-echocardiography. Only 154 (33%) patients underwent coronary angiography and 317 did not.

The LVEF% and GAES between patients selected and not selected for angiography were compared. On independent samples t-tests, the group selected for angiography had a higher GAES ($p<0.001$) and lower LVEF% than those not selected ($p=0.002$). On Spearman's correlation, the LVEF% showed a weak negative correlation (correlation coefficient -0.187) and GAES showed a moderate positive correlation (correlation coefficient 0.296) with angiography selection. The LVEF% and GAES were categorised into global systolic LV function categories and functional impairment categories, respectively. Global systolic LV function category was not significant between those selected for angiography and those not selected ($p=0.868$). The functional impairment category was significant between those selected for angiography and those not selected ($p=0.028$) [Table 3].

Table 3: Echocardiography and selection for angiography

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Descriptive results for echocardiography in the cohort (n=471)									
	Min-max	Mean	Std. error	Std. dev.	Variance	Normal	Abnormal		
LVEF%	25 – 82	57.25	0.443	9.605	92.247	Global LV function			
						Good 396 (84.4%)	Impaired 75 (15.6%) <i>(*Mild 50 (9.5%); moderate 17 (3.2%); severe 8 (1.5%))</i>		
GAES	0.0 – 5.0	0.1497	0.214	0.464	0.215	Echocardiography functional impairment category			
						Normal 451 (95.6%)	Abnormal 20 (4.4%) <i>(*Small infarct 10 (2.2%); complication 10 (2.2%))</i>		
Echocardiography differences between in angiography selection (n=417)									
Independent samples t-test for patients selected for angiography (n=154) and not selected (n=317)									
	t	Mean			Mean difference	Std. error diff.	95%CI		P value
		Angiogram	No angiogram				lower	upper	
LVEF%	-3.130	58.510	54.660		3.847	0.986	1.906	5.788	<0.001
GAES	3.902	0.099	0.254		-0.155	0.049	-0.253	-0.576	0.002
Correlation of scores of patients selected for angiography (n=154) and not selected (n=317)									
Category		Score		Spearman's correlation co-efficient				P value	
Angiogram or not		LVEF%		-0.187				<0.001	
Angiogram or not		GAES		0.296				<0.001	
Pearson's chi-squared between patients selected for angiography (n=154) and not selected (n=317)									
			Angiogram done			Pearson's chi²	P value		
			No	Yes	Total				
Global systolic LVF category	Good		261 (66.6%)	131 (33.4%)	392 (100.0%)	0.713	0.868		
	Mildly impaired		31 (62.0%)	19 (35.3%)	50 (100.0%)				
	Moderately impaired		11 (64.7%)	6 (35.3%)	17 (100.0%)				
	Severely impaired		6 (75.0%)	2 (25.0%)	8 (100.0%)				
	Total		309 (66.2%)	158 (33.8%)	467 (100.0%)				
Functional impairment category	Normal		306 (67.8%)	145 (32.2%)	451 (100.0%)	7.117	0.028		
	Small infarct		8 (80.0%)	2 (20.0%)	10 (100.0%)				
	Complication		3 (30.0%)	7 (70.0%)	10 (100.0%)				
	Total		317 (67.3%)	154 (32.7%)	471 (100.0%)				

Echocardiography and angiography characteristics of 154 patients selected for angiography:

Data for echocardiography and angiography for the 154 patients was described. On echocardiography, there were 114/154 (74%) patients with normal LVEF% and 39/154 (26%) with impaired LVEF%. On GAES, there were 145/154 (94%) patients with normal scores and 9/154 (6%) with abnormal scores. Angiography demonstrated 66/154 (42.9%) normal and 88/154 (57.1%) abnormal results. On calculating the SYNTAX score, there were 134/154 (87.0%) low and 20/154 (13.0%) medium-high-risk categories. The angiogram LVF there were 113/154 (73.4%) patients with normal LVF and 38/154 (27%) impaired LVF [Table 4].

Table 4: Descriptive echocardiography and angiography of patients selected for angiography (n=154)

Table 4: Descriptive echocardiography and angiography of patients selected for angiography (n=154)					
Continuous data					
	Min-max	Mean	Std. error	Std. dev.	Variance
EDD	36 – 86	52.13	0.630	7.820	61.146
ESD	21 – 59	35.09	0.687	8.040	64.645
FS	10 – 49	31.27	0.656	7.656	58.614
LVEF%	25 – 72	55.02	0.777	9.616	92.467
GAES	0.00 – 3.24	0.2544	0.044	0.547	0.299
SYNTAX score	0.00 – 43.50	8.1753	0.802	9.947	98.933
Categories					
	Normal		Abnormal		
EDD	110 (71.4%)		44 increased (28.6%)		
ESD	96 (70.5%)		40 increased (29.5%)		
FS	108 (79.4%)		28 decreased (20.6%)		
LVEF%	Global systolic LVF category				
	Normal 114 (74%)		Impaired 39 (26%) <i>(*Mild 24 (15.6%); moderate 13 (8.4%); severe 2 (1.3%))</i>		
GAES	Functional impairment category				
	Normal 145 (94%)		Abnormal 9 (6%) <i>(*Small infarct 2 (1.3%); complication 7 (4.5%))</i>		
Angiogram result	Angiogram result				
	Normal 66 (42.9%)		Abnormal 88 (57.1%)		
SYNTAX score	SYNTAX category				
	Low 134 (87%)		Medium-high-risk 20 (13%) <i>(*Medium 15 (9.7%); high 5 (3.2%))</i>		
Angiogram LVF	Angiogram LVF category				
	Normal 113 (73%) <i>(**3 results not available)</i>		Impaired 38 (27%) <i>(*Mildly 6 (3.9%); moderate 19 (12.3%); severe 13 (8.5%))</i>		

Relationship between basic two-dimensional echocardiography and coronary angiography (n=154):

Amongst the 154 patients, LVEF% had a negative (Pearson’s correlation -0.276) and GAES had a positive correlation (Pearson’s correlation 0.180) to SYNTAX score.

GAES, LVEF% and the SYNTAX scores were categorised. LVEF% was negatively correlated with the angiogram result, SYNTAX category and angiogram LVF (Spearman’s correlation coefficient -0.307, -0.254 and -0.259, respectively). GAES was moderately positively correlation with angiogram result, SYNTAX category and angiogram LVF (Spearman’s correlation coefficient 0.298, 0.110 and 0.195 respectively).

The echocardiography and angiography categories were cross-tabulated. Significant results were global systolic LVF category and angiogram results (0.026); functional impairment category and angiogram results (0.007); global systolic LVF category and angiogram LVF (p=0.050) **[Table 5]**.

Table 5: Relationship between basic 2-D echocardiography and coronary angiography (n=154)

Table 5: Relationship between basic 2-D echocardiography and coronary angiography (n=154)						
Pearson's correlation for scores						
SYNTAX score	Other scores	Mean	Std. deviation	Pearson's correlation	P value	
Mean = 8.18	LVEF%	55.02	9.616	-0.276	0.001	
Std. deviation = 9.947	FS%	31.27	7.656	-0.140	0.103	
	GAES	0.25	0.547	0.180	0.025	
Spearman's Rho Correlation for scores and categories						
Scores		Categories		Spearman's Rho correlation	P value (2-tailed)	
LVEF%		Angiogram result		-0.307	<0.001	
		SYNTAX category		-0.254	0.002	
		Angiogram LVF		-0.259	0.001	
FS%		Angiogram result		0.030	0.727	
		SYNTAX category		-0.161	0.062	
		Angiogram LVF		-0.207	0.017	
GAES		Angiogram result		0.298	<0.001	
		SYNTAX category		0.110	0.175	
		Angiogram LVF		0.195	0.016	
SYNTAX score		Global systolic LVF category		0.149	0.066	
		Functional impairment category		0.180	0.025	
Comparisons of categories						
		Angiography			Cross tabulation	
Echocardiography		SYNTAX category				
		Low	Intermediate-high	Total	Fisher's exact	P value
Global systolic LVF category	Normal	101 (89.4%)	12 (10.6%)	13 (100.0%)	1.286	0.257
	Abnormal	33 (85.2%)	7 (17.5%)	40 (100.0%)		
	Total	134 (87.6%)	19 (12.4%)	153 (100.0%)		
Functional impairment category	Normal	127 (87.6%)	18 (12.4%)	145 (100.0%)	0.721	0.396
	Abnormal	7 (77.8%)	2 (22.2%)	9 (100.0%)		
	Total	134 (87.0%)	20 (13.0%)	154 (100.0%)		
		Angiogram result			Cross tabulation	

		Normal		Abnormal		Total	Fisher's exact	P value
Global systolic LVF category	Normal	55 (48.7%)		58 (51.3%)		113 (100.0%)	5.399	0.026
	Abnormal	11 (27.5%)		29 (72.5%)		40 (100.0%)		
	Total	66 (41.3%)		87 (56.9%)		153 (100.0%)		
Functional impairment category	Normal	66 (45.5%)		79 (54.5%)		145 (100.0%)	7.169	0.007
	Abnormal	0 (0.0%)		9 (100.0%)		9 (100.0%)		
	Total	66 (42.9%)		88 (57.1%)		154 (100.0%)		
		Angiogram LV function					Cross tabulation	
		Good	Mild	Moderate	Severe	Total	Fisher's exact	P value
Global systolic LVF category	Normal	90 (81.1%)	3 (2.7%)	11 (9.9%)	7 (6.3%)	111 (100.0%)	7.687	0.053
	Abnormal	23 (59.0%)	2 (5.1%)	8 (20.4%)	6 (15.4%)	39 (100.0%)		
	Total	113 (75.3%)	5 (3.3%)	19 (12.7%)	13 (8.7%)	150 (100.0%)		
Functional impairment category	Normal	109 (76.2%)	6 (4.2%)	17 (11.9%)	11 (7.7%)	143 (100.0%)	4.703	0.195
	Abnormal	4 (50.0%)	0 (0.0%)	2 (25.0%)	2 (25.0%)	8 (100.0%)		
	Total	113 (74.8%)	6 (4.0%)	19 (12.6%)	13 (8.6%)	151 (100.0%)		

Discussion

Selection for angiography:

In 2019, it was declared that 2D-echocardiography remained one of the most useful imaging methods because it is easily available, easy to use, inexpensive, and could serve repeatedly at the bedside. It is therefore one of the most employed cardiovascular imaging modalities to assess CAD [2], despite more advanced options that may exist. Patients in our study were screened suspected CAD patients with 2D-echocardiography to identify high-risk patients who require diagnostic testing with angiography. According to the results, patients selected for angiography had higher GAES and functional impairment categories. On the contrary however, LVEF% was lower in the selected group and the global LV function categories had no significance.

Relationship between basic 2D-echocardiography and coronary angiography:

On review of the patients' angiography, a similar conformation was noted to selection group. The intermediate-high risk angiogram tended to be positively correlated with higher GAES, but negatively correlated with LVEF% and FS. Abnormal angiograms had higher GAES, abnormal functional impairment categories and lower LVEF% than normal angiograms. The

angiographic LVF measured on ventriculography correlated negatively with the LVEF% (on 2D-echocardiography) but tended to correspond with the global systolic LVF category.

Global LV function versus regional function:

A key finding noted in the patients selected for angiography and the patients with coronary artery disease on angiography was the higher GAES and abnormal functional impairment category, coupled with the lower LVEF% and the normal global LV category. The GAES and functional impairment category are measures of regional wall motion abnormality, whereas the LVEF% and global LV category reflect the general function of the LV. This may be explained by the underlying diagnosis that is under investigation.

Atherosclerotic coronary artery disease:

In the presence of atherosclerotic coronary artery disease, there is inadequate myocardial perfusion. Myocardial ischemia results in a regional transient imbalance between myocardial oxygen supply and demand. Hypo-perfusion to the affected area initiates an ischemic cascade of intracellular changes, shifting cellular metabolism from glucose to fatty acids. Decreased oxygen supply required for aerobic metabolism results in decreased adenosine triphosphate (ATP) production and failure of calcium reuptake into the sarcoplasmic reticulum. This results in diastolic dysfunction initially. Systolic dysfunction follows. Repolarization abnormalities (seen as ST-segment deviation on ECG) and angina occur later. The severity of LV dysfunction, ECG changes, and angina all depend on the extent and severity of the underlying hypo-perfusion. Echocardiography provides important information on myocardial hypo-perfusion prior to ECG changes or clinical symptoms [4].

The distinctive consequence of ischemia on the echocardiogram is the impairment of regional systolic contractility. If severe ischemia persists or myocardial infarction occurs, scarring follows, and the regional function is permanently impaired. The regional myocardial function is assessed visually by evaluating endocardial thickening and motion of myocardial segments. The individual myocardial movements may be caused by adjacent segment tethering or overall LV displacement, allowing subtle regional wall motion abnormalities to be missed when global LV function is assessed. Hypo-perfusion from CAD is therefore best assessed by wall motion abnormality [2,7].

LV systolic performance has long been known to indicate severity of heart disease and to predict cardiovascular morbidity and mortality. Using the findings on angiography (both results and quantitative scoring systems), our study has demonstrated that assessment of the LV in CAD is best performed through measurement of the GAES and functional impairment category. This allows the proper assessment of regional wall motion abnormalities, as LVEF% and global systolic LVF category may not reflect the subtle changes that occur along the coronary artery distributions. This may be achieved through the use of basic 2D-echocardiography.

Limitations

While basic 2D-echocardiography is rivalled by newer technology, its only real restrictions are limited echogenicity of many patients and its undeniable operator dependence [2].

This study only evaluates TTE and not transoesophageal echocardiography.

The investigator must always consider that although in most cases regional wall motion abnormalities are ascribed to underlying ischaemia, this may not be exclusive. Regional wall motion abnormalities may sometimes be encountered in other clinical conditions, such as conduction system (e.g., left bundle branch block), abnormal ventricular interaction (e.g., right sided heart disease, valvular heart disease), and other causes (congenital abnormalities, pregnancy, myocarditis, hypertrophic obstructive cardiomyopathy) [20]. The investigator should always consider and exclude other possibilities.

Patients selected for angiography were inherently at higher risk of CAD through the selection process. Therefore, the results and scores on angiography may also indicate the underlying homogeneity of the selected group.

Conclusions

Patients in our study were evaluated with 2D-echocardiography to identify those at high risk for CAD requiring angiography. After selection of the high-risk group, angiography was performed to diagnose CAD.

The patients who were diagnosed with CAD had a higher GAES and abnormal functional impairment category, coupled with the lower LVEF% and normal global systolic LVF category. The LVEF% and global LV category reflect the general function of the LV and therefore was not sensitive enough to detect underlying hypo-perfusion and ischaemia that was revealed on angiography. This is an accepted constraint of the LVEF% and global LV category in assessment of CAD on echocardiography.

The GAES and functional impairment category, however, measured subtle regional wall abnormality accurately because the underlying distribution of atherosclerotic vessels has been marked. We conclude that despite advanced technology, when applied with correct understanding, basic 2D-echocardiography is still useful in the assessment of CAD [2].

Declarations

Ethics approval and consent to participate:

1. This study was approved by the University of Kwa-Zulu Natal Biomedical Research and Ethics Committee (approval number BE 513/17).
2. The study is observational, and patients had provided informed consent for all investigations and procedures that were performed.
3. The Health and Research Knowledge Management for the Department of Health in Kwa-Zulu Natal has provided approval to conduct this research (approval number HRKM 19/10).
4. The medical manager at Inkosi Albert Luthuli Hospital has provided site approval to conduct the study at the hospital, and to and store the data for the required period of time.
5. This research complies with the Declaration of Helsinki.

Consent for publication:

This paper has not been published before and is not under consideration for publication anywhere else. The authors of this paper hereby consent to its publication.

Availability of data and materials:

Data is stored according to Good Clinical Practice standards. The hardcopy stored in a locked, fireproof and waterproof cupboard. The soft copy is stored online with password security. Data may be presented upon request.

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Table

Table 1 is available in the Supplemental Files section.

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