Sudan University of Science and Technology

College of Graduate Studies

Evaluation of Heart Stroke Volume Using single Photon Emission Computed Tomography

تقويم حجم كمية الدم المدفوق من القلب باستخدام جهاز الاشعة المقطعية

A Thesis Submitted, For a Partial Fulfillment of Aware of Master Degree in Nuclear Medicine Technology

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بسم الله الرحمن الرحيم

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Dedication

To my father who always supported me in every endeavor. To my mother who is the reason I am here at all, and made me who I am today. If I donated to you everything in this world, it is not enough to give you your right.

Acknowledgement

My deep thanks to my supervisor Dr. Mohammed Omar for his contact supervision, inexhaustible patience& unlimited help I would like to thanks also radiology department staff in Elnilein medical center and peripheral centers for their cooperation. Finally I would like to thanks my friends, teachers and colleges.

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List of abbreviations

abbreviations	Fullname
CVDs	CardioVascular Diseases
ACS	Acute Coronary Syndrome
MI	Myocardial Infarctions
CAD	coronary artery disease
AV	AtrioVentricular
SVC	Superior Vena Cava
IVC	Inferior Vena Cava
RCA	Right Coronary Artery
LCA	Left Coronary Artery
LAD	Left Anterior Descending
SA	SinoAtrial
AMI	Acute Myocardial Infarction
spect	Single photon emation tomography

Abstract

Recently measuring of stroke volume by scintigraphy has been used as indicator of heart muscle ability to contract. This study aimed to identify and evaluate the stroke volume. Accordingly the data was collected from 50 patients at Elnilein medical center, department of nuclear medicine, during the period from 4/4/2011 to 24/8/2011. The patients were injected with a 99mTc-sestamibi (hexakis [2-methoxyisobutylisonitril]) and 99mTc-tetrofosmin (1, 2-bis [bis (2-ethoxyethyl)-phosphino] ethane) then gamma camera was used to detect the count rate and hence stroke volume was calculated. The data were analyzed by using statistical packages for social studies (SPSS) under windows using linear association between age, body mass index, stroke volume, cardiac output and ejection fraction. Consequently the results revealed that the stroke volume increased as the cardiac output and ejection fraction increased with direct liner relationship by a coefficient factor equal to 0.58% per L / min, and 0.55 % per ejection fraction units. Also the age and body mass index showed a invers linear relationship with the stroke volume. The stroke volume decresed by 0.9 % per years of age and by 1.3 % per body mass index units.

ملخص الدراسه

في وقتنا الحالي يتم قياس حجم ضربة القلب باستخدام جهاز الماسح الذريذ ويستخدم حجم ضربة القلب كالمقياس لمدى قدرة عضلة القلب على الانقباض.اجريت دراسة الهدف منها تقيم حجم ضربة القلب

باستخدام الماسح الذري.اجريت هذه الدراسة على خمسون حالة في مركز النيلين التشخيصي قسم الطب النووي في الفترة من الثاني من اغسطس 2014 الى الرابع عشر من نفس الشهرحيث يتم حقن المريض بالمادة المشعة. ويتم استخدام جهاز الماسح الذري لحساب حجم ضربة القلب.نتائج الدراسة تم تحليلهاباستخدام برنامج تحليلي احصائي متخصص.يتم فيه استخدام معامل الارتباط الخطي بين حجم ضربة القلب وسعة القلب وخرج القلب وعمر الحالة ومعامل كتلة الجسم. ومن خلال الدراسة وجدا ان حجم ضربة القلب يزيد بمعدل 0,58 لتر لكل دقيقة كلما زاد سعة القلب وبمعدل 0,55 وحدة خرج القلب. ووجد ان حجم ضربة القلب يقل بمعدل 0,9 لكل عام كلما زاد عمر الحالة وبمعدل 1,3 وحدة معامل كتلة الجسم في كل زيادة.

(Introduction)

Chapter one

1.1 Introduction:

Stroke volume is the amount of blood that leaves a ventricle, depends on the strength of contraction (Mader 2004).

1.1.2 Factors affect in stroke volume:

Left ventricle performance can be measured by: stroke volume, cardiac output, cardiac index and ejection fraction. Stroke voulme can be controlled by four major factors: preloaded, after loaded, heart rate and contractility (Patton et al 2003).

1.1.2.1 Preloaded:

Stroke volume is intrinsically controlled by preload is the degree to which the ventricles are stretchedpriorto contracting(Sukkar et al, 2000). An increase in the volume or speed of venous return will increase preload and, through the Franky

Starling law of the heart, will increase stroke volume. Decreased venous return has the opposite effect, causing a reduction in stroke volume (Patton et al 2003).

1.1.2.2 After loaded:

Elevated after load (commonly measured as the aortic pressure and pulmonary pressure during systole). Decreas stoke volume. Increased\ after load will hinder the ventricles in ejecting blood, causing reduced stroke volume. Increased after load may be found in aortic stenosis and arterial hypertension (Patton et al 2003).

1.1.2.3 Heart rate:

The heart rate (number of beats per minutes) affects the force of contraction. As the heart rate increases. The duration of diastole becomes shorter and the end diastolic volume becomes smaller. Thus the stroke volume according the starling law should be decreases (Patton et al 2003).

1.1.2.4 Contractility:

Contractility is the ability of the heart muscle to convert chemical energy to mechanical work (Sukkar et al, 2000). The heart acts as muscular pump and the strength of contractility determines its pumping power. That means the stroke volume affected by the power of contraction when the force of contraction increases the blood which ejected from the ventricles increases too (Patton et al 2003).

1.1.2.5 Exercise:

Prolonged aerobic exercise training may also increase stroke volume, which frequently results in a lower (resting) heart rate. Reduced heart rate prolongs ventricular diastole (filling), increasing end-diastolic volume, and ultimately allowing more blood to be ejected thus increases stroke volume (sukkar et al 2000).

1.1.2.6 Gender and heart size:

Men, on average, have higher stroke volume than women due to the larger size of their hearts because the end diastolic volume increases due to starling law of heart. The length tension increases and that lead to increases the force of contraction (sukkar et al 2000).

1.1.2.7Age:

As we age, our heart compensates for clogged arteries by working harder and raising blood pressure. These changes put the heart at risk and impact our quality of life (Davies 2006-2007) The effect of the aging heart on the cardiovascular system: Aging Arteries: Arteries take oxygen-rich blood away from the heart and deliver it to the body. As we age, our arteries become stiffer and less flexible. This causes our blood pressure to increase. The heart has to adjust to the increase in blood pressure by increasing heart rate as the heart rate increases, the duration of the diastole become shorter and the end diastolic volume become smaller. Thus, the stroke volume according to starling's law should be decreased (Davies 2006-2007).

1.1.2.8TheHeartCan'tSqueezeasTightly:

Because of the increase in diastolic blood pressure, the heart also stretches larger each beat, giving a stronger pump in order to have a stronger contraction to pump the excess blood volume (called the Frank-Starling mechanism). But because of the greater diastolic pressure, the heart can't squeeze as tightly. Therefore the stroke volume reduced the reason is; the stroke voume depend on the power of contractility when the ability to contraction going down the stroke volume also going down (Davies 2006-2007).

1.1.2.9Bodymassindex:

Body mass index is defined as the individual's body weight divided by the square of his or her height (Guyton and hall 2006). Body mass index = (Guyton and hall 2006).

1.1.2.9.1Body mass index category:

A frequent use of the body mass index is to assess how much an individual's body weight departs from what is normal or desirable for a person of his or her height. The weight excess or deficiency may, in part, be accounted for by body fat (adipose tissue) although other factors such as muscularity also affect body mass index significantly. The world health organization regard a body mass index of less than 18.5 as underweight and may indicate malnutrition, an eating disorder, or other health problems, while a body mass index greater than 25 is considered overweight and above 30 is considered obese. These ranges of body mass index values are valid only as statistical categories(Guyton and hall 2006).

Table (1-1): illustrate body mass index category according to WHO health organization:

Gategory	Body mass index rang (kg/m2)
Severly underweight	Less than 16
Underweight	16 – 18.5
Normal	18.5 – 25
Overweight	25 -30
Obesity class one	30 -35
Obesity class two	35 -40
Obesity class three	Over 40

1.1.2.9.2 Obesity:

Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health, leading to reduced life expectancy and/or increased health problems(Guyton and hall2006). The effect of obesity on the cardiovascular system:

Abnormal cholesterol levels:

The obese people tend to have more chances of high total cholesterol or high levels of triglycerides (called Dyslipidemia) than healthy people. Due to accumulate fats and lipids in the large and medium arteries. Leading to deposition of fat in the blood vessel the affected arteries become narrowing. Narrowing of coronary arteries causing myocardial infarction. Myocardial infarction decreasing strength of contraction. Because of strokke volume affected by power of contraction. This cause decrease in stroke volume (Guyton and hall 2006).

High blood pressure:

Another obesity effect is being high blood pressure or hypertension. The obese person is more likely to have higher level of blood pressure twice than the normal one. The mechanism of elevating the arterial blood pressure is unknown. High blood pressure in the aorta and pulmonary arteries causes the contractile force to drop down because the ventricles have to contract against increased resistance therefore the stroke volume is decreased (Guyton and hall 2006).

1.2 Problem of the study:

figure out the relation of the stroke volume with ejection fraction, cardiac output, age and body mass index.

1.3 Objective:

1.3.1 The general objective:

of this study was to evaluate heart stroke volume by nuclear medicine technology

1.3.2 Specific objectives:

To find out the coefficient factor between the stroke volume, cardiac output, age of patient, weight of patient and ejection fraction.

To find out the association between the ejection fraction, cardiac output, stroke volume, age and body mass index.

1.4 Overview of the study:

This study will be consisted of five chapters, with chapter one is an introduction which, includes; objectives, problem of the study and importance of the study. While chapter two will includes a comprehensive literature review, and chapter three will describe the material and method. Chapter four will include result presentation; finally chapter five will include the discussion and conclusion.

(Literature Review)

Chapter two

Literature review

2.1 Anatomy:

The heart is located in the thoracic cavity between the lungs. This area is called the mediastinum. The base of the cone-shaped heart is uppermost, behind the sternum, and the great vessels enter or leave here. The apex (tip) of the heart points downward and is just above the diaphragm to the left of the midline. This is why we may think of the heart as being on the left side because the strongest beat can be heard or felt here (Scanlon 2007).

2.1.1 Chamber vessels and valves:

The walls of the four chambers of the heart are made of cardiac muscle called the myocardium. The chambers are lined with endocardium, simple squamous Epithelium that also covers the valves of the heart and continues into the vessels as their lining (endothelium). The important physical characteristic of the endocardium is not its thinness, but rather its smoothness (Scanlon 2007).

The upper chambers of the heart are the right and left atria (singular: atrium), which have relatively thin walls and are separated by a common wall of myocardium called the interatrial septum. The lower chambers are the right and left ventricles, which have thicker walls and are separated by the interventricular septum. As you will see the atria Receive blood, either from the body or the lungs, and the ventricles pump blood to either the lungs or the body (Scanlon 2007).

2.1.1.1 Right atrium:

The two large caval veins return blood from the body to the right atrium. The superior vena cava carries blood from the upper body, and the inferior vena cava carries blood from the lower body. From the right atrium, blood will flow through the right atrioventricular (AV) valve, or tricuspid valve, into the right ventricle. The tricuspid valve is made of three flaps (or cusps) of endocardium reinforced with connective tissue. The general purpose of all valves in the circulatory system is to prevent backflow of blood. The specific purpose of the tricuspid valve is to prevent backflow of blood from the right ventricle to the right atrium when the right ventricle contracts. As the ventricle contracts blood is forced behind the three valve flaps, forcing them upward and together to close the valve (Scanlon 2007).

2.1.1.2 Lift atrium:

The left atrium receives blood from the lungs, by way of four pulmonary veins. This blood will then flow into the left ventricle through the left atrioventricular (AV) valve, also called the mitral valve or bicuspid (two flaps) valve. The mitral valve prevents backflow of blood from the left ventricle to the left atrium when the left ventricle contracts (Scanlon 2007).

2.1.1.3 Right ventricle:

When the right ventricle contracts, the tricuspid valve closes and the blood is pumped to the lungs through the pulmonary artery (or trunk). At the junction of this large artery and the right ventricle is the pulmonary semilunar valve (or more simply, pulmonary valve). Its three flaps are forced open when the right ventricle contracts and pumps blood into the pulmonary artery. When the right ventricle relaxes, blood tends to come back, but this fills the valve flaps and closes the pulmonary valve to prevent backflow of blood into the right ventricle (Scanlon 2007).

Projecting into the lower part of the right ventricle are columns of myocardium called papillary muscles. Strands of fibrous connective tissue, the chordate tendineae, extend from the papillary muscles to the flaps of the tricuspid valve. When the right ventricle contracts, the papillary muscles also contract and pull on the chordate tendineae to prevent inversion of the tricuspid valve (Scanlon 2007).

2.1.1.4 Left ventricle:

The walls of the left ventricle are thicker than those of he right ventricle, which enables the left ventricle to contract more forcefully. The left ventricle pumps blood to the body through the aorta, the largest artery of the body. At the junction of the aorta and the left ventricle is the aortic semilunar valve (or aortic valve). This valve is opened by the force of contraction of the left ventricle, which also closes the mitral valve. The aortic valve closes when the left ventricle relaxes, to prevent backflow of blood from the aorta to the left ventricle. When the mitral (left AV) valve closes, it prevents backflow of blood to the left atrium; the flaps of the mitral valve are also anchored by chordate tendineae and papillary muscles (Scanlon 2007).

The fibrous skeleton of the heart is fibrous connective tissue that anchors the outer edges of the valve flaps and keeps the valve openings from stretching. It also separates the myocardium of the atria and ventricles and prevents the contraction of the atria from reaching the ventricles except by way of the normal conduction pathway (Scanlon 2007).

As you can see from this description of the chambers and their vessels, the heart is really a double, or two-sided, pump. The right side of the heart receives deoxygenated blood from the body and pumps it to the lungs to pick up oxygen and release carbon dioxide the left side of the heart receives oxygenated blood from the lungs and pumps it to the body. Both pumps work simultaneously; that is, both atria contract together, followed by the contraction of both ventricles (Scanlon 2007).

2.1.2 Coronary vessels:

The right and left coronary arteries are the first branches of the ascending aorta, just beyond the aortic semilunar valve. The two arteries branch into smaller arteries and arterioles, then to capillaries. The coronary capillaries merge to form coronary veins, which empty blood into a large coronary sinus that returns blood to the right atrium.

The purpose of coronary vessels is to supply blood to the myocardium itself, because oxygen is essential for normal myocardial contraction. If a coronary artery becomes obstructed, by a blood clot for example, part of the myocardium becomes ischemic, that is, deprived of its blood supply. Prolonged ischemia will create an infarct, an area of necrotic (dead) tissue. This is a myocardial infarction, commonly called a heart attack (Scanlon 2007).

2.2 Physiology:

The basic function of the heart is pump blood into systemic circulation and pulmonary vessels

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2.2.1 Cardiac cycle and heart sound:

The cardiac cycle is the sequence of events in one heartbeat the heart as a pump goes through phases of contraction (systole) and relaxation (diastole). The cardiac cycle can be divided into three main parts: atrial systole, ventricle systole and diastole of atrium and ventricle (Scanlon 2007).

2.2.1.1 Atrial systole:

The contraction of the atria starts towards the end of atria and ventricle diastole and helps to complete the filing of the ventricle (Scanlon 2007).

2.2.1.2 Ventricle systole:

The contraction of the ventricle starts towards the end of atria systole and helps to pump blood into pulmonary artery and aorta (Scanlon 2007).

2.2.1.3 Diastole of atrium and ventricle:

The relaxation of the atria and ventricle after the end of ventricle systole and helps to receives blood.

The heart sound is the vibrations generated by the closure of the valves (sukkar et al 2000).

The cardiac cycle also creates the heart sounds: Each heartbeat produces two sounds, often called lub-dup that can be heard with a stethoscope.

The first sound, the loudest and longest, is caused by ventricular systole closing the AV valves. The second sound is caused by ventricle diastole the closing the aortic and pulmonary semilunar valves.

2.2.2 Cardiac conduction pathway:

The conduction is the ability of the cardiac muscle fibers to conduct the cardiac impulse (sukkar et al 2000) through cardiac conduction system.

The cardiac conduction system composed of: sinoatrium node (SA), intermodal pathways, atrioventricle (AV), bundle of his, purkinje system.

Conduction tissue of the heart consists of specialized myocardial cells. The peace maker cells are found in the sinoatrium node in the right atrium near the junction with the superior vein cava. The atrioventricular node lies above the fibers ring and represents the only myocardial connection between the atria and ventricle. The bundle of his start in the atrioventricle node and give the rise of two brunches (right and lift), with descend into the interventricular septum. The terminal brunch of the conducting tissue end in the subindocardial muscle of the ventricle (sukkar et al 2000).

From the sinoatrium node the impulse are conducted to the atrioventricle node through atrial musculature and intermodal pathways to bring atrium systole, which are three in number. They connect the sinoatrium node to the atrioventricle node. From the atrioventricle node the impulse pass to the bundle of his, which divided into two brunch, right and lift, and transmit the impulses to the ventricle. From the apex of the heart the impulse are conducted to the base of the heart through the purkinje fibers to bring ventricle systole (sukkar et al 2000).

2.2.3 Stroke volume:

Stroke volume, which is the amount of blood that leaves a ventricle, depends on the strength of contraction (Mader 2004). Stroke volume is calculated using measurements of ventricle volumes from an echocardiogram and nuclear medicine techology then subtracting the volume of the blood in the ventricle at the end of a beat (called end-systolic volume) from the volume of blood just prior to the beat (called end-diastolic volume).

(Pete Shackett 2009).

Stroke volume normal range is 55 – 100 ml and the typical value is 70 ml (Sylvia S. Mader, 2004).

2.2.4 Cardiac output:

Cardiac output is the amount of blood pumped by a ventricle in 1 minute (Scanlon 2007). The cardiac output varies with the size of individual. Women have smaller cardiac output than men, and children have smaller cardiac output than adolescent or adults (sukkar et al 2000).

To calculate cardiac output, we must know the pulse rate and how much blood is pumped per beat. Stroke volume is the term for the amount of blood pumped by a ventricle per beat. The formula to calculate cardiac output is

Cardiac output = stroke volume x heart rate

(Scanlon 2007).

Cardiac output normal range between 4 – 8 L / minutes and the typical value is 4.9 (Scanlon 2007).

Cardiac output measuring by Echocardiography, Transcutaneous Doppler (Ultrasonic Cardiac Output Monitor), Transoesophageal Doppler.

2.2.5 Ejection fraction study:

Ejection fraction is the percent of the blood in a ventricle that is pumped during systole (Scanlon 2007).

By definition, the volume of blood within a ventricle immediately before a contraction is known as the end-diastolic volume. Similarly, the volume of blood left in a ventricle at the end of contraction is end-systolic volume. The difference between end-diastolic volume (EDV) and end-systolic volumes (ESV) is the stroke volume, the volume of blood ejected with each beat. Ejection fraction (Ef) is the fraction of the end-diastolic volume that is ejected with each beat; that is, it is stroke volume (SV) divided by end-diastolic volume (EDV):

$$\text{Ejection fraction} = \frac{stroke\,volume\,(ml)}{end\,diastolic\,volume\,(ml)} \text{ x } 100$$

(Pete Shackett 2009).

Ejection fraction % normal range is between 60 – 70% (Scanlon 2007).

Ejection fraction commonly measured by echocardiography. Other methods of measuring ejection fraction include cardiac MRI, fast scan cardiac computed axial tomography (CT) imaging, ventriculography, Gated SPECT and the MUGA scan(nuclear medicine technology). A MUGA scan involves the injection of a radioisotope into the blood and detecting its flow through the left ventricle. The historical gold standard for the measurement of ejection fraction is ventriculography.

2.3 The electrocardiogram (ECG):

Electrocardiography is a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. The recording produced by this noninvasive procedure is termed an electrocardiogram (also ECG or EKG) (sukkar et al 2000).

2.3.1 Function:

The ECG device detects and amplifies the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a charge across its outer wall, or cell membrane. Reducing this charge towards zero is called depolarization, which activates the mechanisms in the cell that cause it to contract. During each heartbeat a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrium node, spreads out through the atrium, passes through "intrinsic conduction pathways" and then spreads all over the ventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart which is displayed as a wavy line either on a screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle (sukkar et al 2000).

Usually more than 2 electrodes are used and they can be combined into a number of pairs (For example: Left arm (LA), right arm (RA) and left leg (LL) electrodes form the three pairs LA+RA, LA+LL, and RA+LL). The output from each pair is known as a lead. Each lead is said to look at the heart from a different angle. Different types of ECGs can be referred to by the number of leads that are recorded, for example 3-lead, 5-lead or 12-lead ECGs (sometimes simply "a 12-lead"). A 12-lead ECG is one in which 12 different electrical signals are recorded at approximately the same time and will often be used as a one-off recording of an ECG, traditionally printed out as a paper copy. 3- and 5-lead ECGs tend to be monitored continuously and viewed only on the screen of an appropriate monitoring device, for example during an operation or whilst being transported in an ambulance. There may or may not be any permanent record of a 3- or 5-lead ECG, depending on the equipment used (sukkar et al 2000).

2.4 Dose calibrator:

An ionization chamber is an instrument constructed to measure the number of ions within a medium. It usually consists of a gas filled enclosure between two conducting electrodes (the anode and cathode). When gas between the electrodes is ionized by any means, such as by gamma rays or other radioactive emission, the ions and dissociated electrons move to the electrodes of the opposite polarity, thus creating an ionization current which may be measured. Each ion essentially deposits or removes a small electric charge to or from an electrode, such that the accumulated charge is proportional to the number of like-charged ions. A voltage potential that can have a wide range from a few volts to many kilovolts can be applied between the electrodes; depending on the application. Ionization chambers are widely used in the nuclear industry as they provide an output that is proportional to radiation dose.

Ionization chambers are used in nuclear medicine to determine the exact activity of radioactive dose administered to the patients. Such devices are called 'radioisotope dose calibrators'(Patton et al 2003).

2.5 SPECT:

Single-photon emission computed tomography (SPECT, or less commonly, SPET) is a nuclear medicine topographic imaging technique using gamma rays. It is very similar to conventional nuclear medicine planar imaging using a gamma camera. However, it is able to provide true 3D information. This information is typically presented as cross-sectional slices through the patient, but can be freely reformatted or manipulated as required (Patton et al 2003).

The basic technique requires injection of a gamma-emitting radioisotope (called radionuclide) into the bloodstream of the patient. On occasion, the radioisotope is a simple soluble dissolved ion, such as a radioisotope of gallium(III), which happens to also have chemical properties that allow it to be concentrated in ways of medical interest for disease detection. However, most of the time in SPECT, a marker radioisotope, which is of interest only for its radioactive properties, has been attached to a special radioligand, which is of interest for its chemical binding properties to certain types of tissues. This marriage allows the combination of ligand and radioisotope (the radiopharmaceutical) to be carried and bound to a place of interest in the body, which then (due to the gamma-emission of the isotope) allows the ligand concentration to be seen by a gamma-camera (Patton et al 2003).

2.5.1 Principles:

In the same way that a plain X-ray is a 2-dimensional (2-D) view of a 3-dimensional structure, the image obtained by a gamma camera is a 2-D view of 3-D distribution of a radionuclide (Patton et al 2003).

SPECT imaging is performed by using a gamma camera to acquire multiple 2-D images (also called projections), from multiple angles. A computer is then used to apply a tomography reconstruction algorithm to the multiple projections, yielding a 3-D dataset. This dataset may then be manipulated to show thin slices along any chosen axis of the body, similar to those obtained from other tomography techniques, such as MRI, CT, and PET (Patton et al 2003).

SPECT is similar to PET in its use of radioactive tracer material and detection of gamma rays. In contrast with PET, however, the tracer used in SPECT emits gamma radiation that is measured directly, whereas PET tracer emits positrons that annihilate with electrons up to a few millimeters away, causing two gamma photons to be emitted in opposite directions. A PET scanner detects these emissions "coincident" in

Because SPECT acquisition is very similar to planar gamma camera imaging, the same radiopharmaceuticals may be used. If time, which provides more radiation event localization information and, thus, higher resolution images than SPECT (which has about 1 cm resolution). SPECT scans, however, are significantly less expensive than PET scans, in part because they are able to use longer-lived more easily-obtained radioisotopes than PET (Patton et al 2003).

a patient is examined in another type of nuclear medicine scan but the images are non-diagnostic, it may be possible to proceed straight to SPECT by moving the patient to a SPECT instrument, or even by simply reconfiguring the camera for SPECT image acquisition while the patient remains on the table (Patton et al 2003).

To acquire SPECT images, the gamma camera is rotated around the patient. Projections are acquired at defined points during the rotation, typically every 3–6 degrees. In most cases, a full 360-degree rotation is used to obtain an optimal reconstruction. The time taken to obtain each projection is also variable, but 15–20 seconds is typical. This gives a total scan time of 15–20 minutes (Patton et al 2003).

Multi-headed gamma cameras can provide accelerated acquisition. For example, a dual-headed camera can be used with heads spaced 180 degrees apart, allowing 2 projections to be acquired simultaneously, with each head requiring 180 degrees of rotation. Triple-head cameras with 120-degree spacing are also used (Patton et al 2003).

Cardiac gated acquisitions are possible with SPECT, just as with planar imaging techniques such as MUGA. Triggered by Electrocardiogram (EKG) to obtain differential information about the heart in various parts of its cycle, gated myocardial SPECT can be used to obtain quantitative information about myocardial perfusion, thickness, and contractility of the myocardium during various parts of the cardiac cycle, and also to allow calculation of left ventricular ejection fraction, stroke volume, and cardiac output (Patton et al 2003).

2.5.2 Application:

SPECT can be used to complement any gamma imaging study, where a true 3D representation can be helpful, e.g., tumor imaging, infection (leukocyte) imaging, thyroid imaging or bone imaging (Patton et al 2003).

Because SPECT permits accurate localization in 3D space, it can be used to provide information about localized function in internal organs, such as functional cardiac or brain imaging (Patton et al 2003).

2.5.3 Myocardial perfusion imaging:

Myocardial perfusion imaging (MPI) is a form of functional cardiac imaging, used for the diagnosis of ischemic heart disease. The underlying principle is that under conditions of stress, diseased myocardium receives less blood flow than normal myocardium. MPI is one of several types of cardiac stress test (Patton et al 2003).

A cardiac specific radiopharmaceutical is administered, e.g., 99mTc-tetrofosmin (Myoview, GE healthcare), 99mTc-sestamibi (Card iolite, Bristol-Myers Squibb). Following this, the heart rate is raised to induce myocardial stress, either by exercise or pharmacologically with adenosine, dobutamine, or dipyridamole (aminophylline can be used to reverse the effects of dipyridamole) (Patton et al 2003).

SPECT imaging performed after stress reveals the distribution of the radiopharmaceutical, and therefore the relative blood flow to the different regions of the myocardium. Diagnosis is made by comparing stress images to a further set of images obtained at rest. As the radionuclide redistributes slowly, it is not usually possible to perform both sets of images on the same day, hence a second attendance is required 1–7 days later (although, with a Tl-201 myocardial perfusion study with dipyridamole, rest images can be acquired as little as two hours post-stress). However, if stress imaging is normal, it is unnecessary to perform rest imaging, as it too will be normal; thus, stress imaging is normally performed first (Patton et al 2003).

MPI has been demonstrated to have an overall accuracy of about 83% (sensitivity: 85%; specificity: 72%), (Elhendy a et al, 2002) and is comparable with (or better than) other non-invasive tests for ischemic heart disease (Patton et al 2003).

2.5.4 Reconstruction:

Reconstructed images typically have resolutions of 64×64 or 128×128 pixels, with the pixel sizes ranging from 3–6 mm. The number of projections acquired is chosen to be approximately equal to the width of the resulting images. In general, the resulting reconstructed images will be of lower resolution, have increased noise than planar images, and be susceptible to artifacts (Patton et al 2003).

Scanning is time consuming, and it is essential that there is no patient movement during the scan time. Movement can cause significant degradation of the reconstructed images, although movement compensation reconstruction techniques can help with this. A highly uneven distribution of radiopharmaceutical also has the potential to cause artifacts. A very intense area of activity (e.g., the bladder) can cause extensive streaking of the images and obscure neighboring areas of activity. (This is a limitation of the filtered back projection reconstruction algorithm. Iterative reconstruction is an alternative algorithm that is growing in importance, as it is less sensitive to artifacts and can also correct for attenuation and depth dependent blurring) (Patton et al 2003).

Attenuation of the gamma rays within the patient can lead to significant underestimation of activity in deep tissues, compared to superficial tissues. Approximate correction is possible, based on relative position of the activity. However, optimal correction is obtained with measured attenuation values. Modern SPECT equipment is available with an integrated X-ray CT scanner. As X-ray CT images are an attenuation map of the tissues, this data can be incorporated into the SPECT reconstruction to correct for attenuation. It also provides a precisely registered CT image, which can provide additional anatomical information (Patton et al 2003).

2.6 Previous study:

2.6.1 Arterial vasodilatory and ventricular diastolic reserves determine the stroke volume response to exercise in elderly female hypertensive patients: (Anders Sahlén etal.2011).

Elderly female hypertensives with arterial stiffening constitute a majority of patients with heart failure with preserved ejection fraction (HFpEF), a condition characterized by inability to increase cardiac stroke volume (SV) with physical exercise. As SV is determined by the interaction between the left ventricle (LV) and its load, we wished to study the role of arterial hemodynamics for exertional SV reserve in patients at high risk of HFpEF. Twenty-one elderly (67 ± 9 yr) female hypertensive patients were studied at rest and during supine bicycle stress using echocardiography including pulsed-wave Doppler to record flow in the LV outflow tract and arterial tonometry for central arterial pressure waveforms. Arterial compliance was estimated based on an exponential relationship between pressure and volume. The ratio of aortic pressure-to-flow in early systole was used to derive characteristic impedance, which was subsequently subtracted from total resistance (mean arterial pressure/cardiac output) to yield systemic vascular resistance (SVR). It was found that patients with depressed SV reserve (NoRes; reserve <15%; n = 10) showed decreased arterial compliance during exercise, while patients with SV reserve ≥15% (Res; n = 11) showed increased compliance. Exercise produced parallel increases in LV end-diastolic volume and arterial volume in Res patients while NoRes patients exhibited a lesser decrease in SVR and a drop in effective arterial volume. Poor SV reserve in elderly female hypertensives is due to simultaneous failure of LV preload and arterial vasodilatory reserves. Abnormal arterial function contributes to a high risk of HFpEF in these patients.

2.6.2 Cardiac function following prolonged exercise: influence of age (Laura Banks et al, 2011).

This study sought to determine the influence of age on the left ventricular (LV) response to prolonged exercise (PE; 150 min). LV systolic and diastolic performance was assessed using echocardiography (ECHO) before (pre) and 60 min following (post) exercise performed at 80% maximal aerobic power in young (28 ± 4.5 years; *n* = 18; mean ± SD) and middle-aged (52 ± 3.9 years; *n* = 18) participants. LV performance was assessed using two-dimensional ECHO, including speckle-tracking imaging, to determine LV strain (LV S) and LV S rate

(LV SR), in addition to Doppler measures of diastolic function. We observed a postexercise elevation in LV S (young: −19.5 ± 2.1% vs. −21.6 ± 2.1%; middle-aged: −19.9 ± 2.3% vs. −20.8 ± 2.1%; $P < 0.05$) and LV SR (young: −1.19 ± 0.1 vs. −1.37 ± 0.2; middle-aged: −1.20 ± 0.2 vs. −1.38 ± 0.2; $P < 0.05$) during recovery in both group+s. Diastolic function was reduced during recovery, including the LV SR ratio of early-to-late atrial diastolic filling ($SR_{e/a}$), in young (2.35 ± 0.7 vs. 1.89 ± 0.5; $P < 0.01$) and middle-aged (1.51 ± 0.5 vs. 1.05 ± 0.2; $P < 0.01$) participants, as were conventional indices including the E/A ratio. Dobutamine stress ECHO revealed a postexercise depression in LV S in response to increasing dobutamine dose, which was similar in both young (pre-exercise dobutamine 0 vs. 20 $\mu g \cdot kg^{-1} \cdot min^{-1}$: −19.5 ± 2.1 vs. −27.2 ± 2.2%; postexercise dobutamine 0 vs. 20 $\mu g \cdot kg^{-1} \cdot min^{-1}$: −21.6 ± 2.1 vs. −23.7 ± 2.2%; $P < 0.05$) and middle-aged participants (pre: −19.9 ± 2.3 vs. −25.3 ± 2.7%; post: −20.8 ± 2.1 vs. −23.5 ± 2.7; $P < 0.05$). This was despite higher noradrenaline concentrations immediately postexercise in the middle-aged participants compared with young (4.26 ± 2.7 nmol/L vs. 3.00 ± 1.4 nmol/L; $P = 0.12$). These data indicate that LV dysfunction is observed following PE and that advancing age does not increase the magnitude of this response.

2.6.3 Exercise cardiac output is maintained with advancing age in healthy human subjects: cardiac dilatation and increased stroke volume compensate for a diminished heart rate: (R J Rodeheffer, et al,2011).

To assess the effect of age on cardiac volumes and function in the absence of overt or occult coronary disease, we performed serial gated blood pool scans at rest and during progressive upright bicycle exercise to exhaustion in 61 participants in the Baltimore Longitudinal Study of Aging. The subjects ranged in age from 25 to 79 years and were free of cardiac disease according to their histories and results of physical, resting and stress electrocardiographic, and stress thallium scintigraphic examinations. Absolute left ventricular volumes were obtained at each workload. There were no age-related changes in cardiac output, end-diastolic or end-systolic volumes, or ejection fraction at rest. During vigorous exercise (125 W), cardiac output was not related to age (cardiac output [1/min] = 16.02 + 0.03 [age]; r = .12, p = .46). However, there was an age-related increase in end-diastolic volume (end-diastolic volume [ml] = 86.30 + 1.48 [age]; r = .47, p = .003) and stroke volume (stroke volume [ml] = 85.52 + 0.80 [age]; r = .37, p = .02), and an age-related decrease in heart rate (heart rate [beats/min] = 184.66 - 0.70 [age]; r = -.50, p = .002). The dependence of the age-related increase in stroke volume on diastolic filling was emphasized by the fact that at this high workload end-systolic volume was higher (end-systolic volume [ml] = 3.09 + 0.65 [age]; $r = .45$, $p = .003$) and ejection fraction lower (ejection fraction = 88.48 - 0.18 [age]; $r = -.33$, $p = .04$) with increasing age. These findings indicate that although aging does not limit cardiac output per se in healthy community-dwelling subjects, the hemodynamic profile accompanying exercise is altered by age and can be explained by an age-related diminution in the cardiovascular response to beta-adrenergic stimulation.

2.6.4 Heart failure with preserved ejection fraction: pathophysiology, diagnosis, and treatment (Barry A. Borlaug , Walter J. Paulus 2010).

Half of patients with heart failure (HF) have a preserved left ventricular ejection fraction (HFpEF). Morbidity and mortality in HFpEF are similar to values observed in patients with HF and reduced EF, yet no effective treatment has been identified. While early research focused on the importance of diastolic dysfunction in the pathophysiology of HFpEF, recent studies have revealed that multiple non-diastolic abnormalities in cardiovascular function also contribute. Diagnosis of HFpEF is frequently challenging and relies upon careful clinical evaluation, echo-Doppler cardiography, and invasive haemodynamic assessment. In this review, the principal mechanisms, diagnostic approaches, and clinical trials are reviewed, along with a discussion of novel treatment strategies that are currently under investigation or hold promise for the future.

(Materials and Methods)

Chapter three

Materials and methods

This study was done at Sudan University of science and technology college of Medical Radiologic Sciences-Khartoum Sudan, during the period from 2014to 2015.

3.1 The Sample

patients with suspected or known heart diseases examined by SPECT

A total of fifty patients (34 males and 16 females) were enrolled in this study at Elnilen diagnostic center-nuclear medicine department. All cases underwent MPI. The exclusion criteria whereas follows: frequent premature beat, contraindications for iodinated contrast agent, serious coronary calcification and motion artifacts affecting measures of stenosis. All patients gave formal written consent approved by our Institution Ethics Committee.

3.2 Equipment used

3.2 .1SPECT Machine:

3.2 .1.1 Gamma camera:

(Siemens, MIE, Sntrom) accessory for the model of Gamma camera, the specifications of which as follows:

3.2 .1.2 -Detector:

All MIE Gamma Camera Systems consist of the same detector unit that is in use in the Siemens- or GE Gamma Camera System, and we claim substantial equivalence, The detector is consists of NaI(Tl) scintillation crystal with size of Large Field of View: 390 mm Narrow detector flange for close positioning Counterbalanced stand offers limitless positioning capabilities with wheelchairs, stress tables or gurneys.

3.2 .1.3 -Gantry:

The Orbiter coupled with the Scintron IV computer is virtually a new system. All camera functions are controlled by a single workstation. This gantry optimizes space and minimizes service problems. Options include: A wide variety of collimators (any two are included), Whole body, and film formatter. An EPSON printer is standard.

3.2 .1.4 -Collimators:

The above model of Gamma camera, has the ability to apply these types of collimators as follows: LEGP, LEHR, LEUHR, HEGP

3.2 .1.5 -99Mo-99mTc Generator:

(MONROL\A\TR\G41476EBZE-KOCAZL\ Turky with initial activity 354 mci and 15gBq volume) used at the EL-Niline nuclear center

Figure 3.1 shows the Gamma camera

3.3 Study protocols methods (techniques)

3.3.1 MPI Protocol

3.3.1.1. Imaging Acquisition:

All patients underwent electrocardiography-gated MPI protocol. Exercise stress/rest gated MPIs were performed on a SPECT scanner (Siemens).

Each patient underwent Tc^{99m} Sestamibi stress and rest studies. Tc^{99m} Sestamibi study was performed according to protocol which is as follows. The acquisition for stress gated-SPECT study was performed about 1 hour after injection. Rest studies started acquisition about 1.5 hour after injection by using the same amount of doses. The acquisition parameters were listed as follows: a low-energy, high-resolution collimator; a 20% symmetric window at 140 keV; a 64 × 64 matrix; an elliptic orbit with step-and-shoot acquisition at 6◦ intervals over 180◦ from the right anterior oblique 45◦ to left posterior oblique 45◦; 25sdwell time per stop. Acquisitions were gated as the follows:

Sequence of serially acquired images typically consists of 12 frames of 10 seconds each, followed by 2 frames of 30 seconds each, followed by 1 frame of 60 seconds, and, finally, by 1 frame of 900 seconds, amounting to a total acquisition time of 19 minutes.1–3 The final, 900-second transaxial image data set is reoriented into short and long axis slices of the left ventricular myocardium Images will be obtained over a 180° orbit from the right anterior oblique 45° view to the left posterior oblique 45° view, using a dual-head, variable-angle gamma camera equipped with ultra-high-resolution collimators

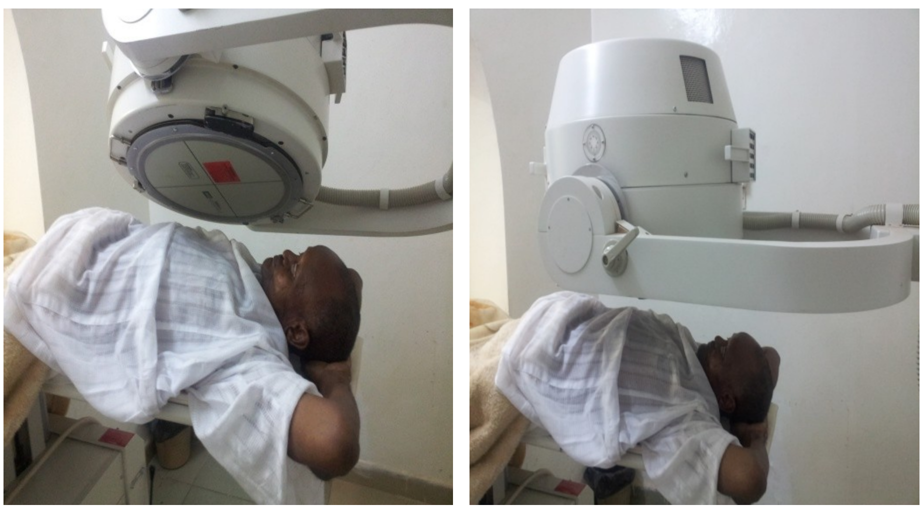

Figure 3.2 A male patient while taking the MPI Scan

3.3.1.2. Image Reconstruction and Interpretation:

All data were transferred to workstation and reconstructed using an iterative reconstruction algorithm. Images were reconstructed into short axial, horizontal axial, and vertical long axial sections. At the same time, polar maps, wall motion, and wall thickening were obtained using a special software package. The left ventricular myocardium was divided into segments. The results of MPIs were divided into two categories: negative MPI, defined as having homogenous radioactive distributions in myocardium and no defective segments noticed for both stress and rest scans; positive MPI.

3.3.1.3 Left ventricular function :

A number of studies have demonstrated that gated SPECT evaluation of ejection fraction (EF), regional wall motion and wall thickening was accurate, and gated SPECT could be considered as an effective substitute modality of radionuclide ventriculography for the assessment of left ventricular function.

3. 4. Statistical analysis

Continuous data are presented as mean ± standard deviation (SD) and compared using the t test. Categorical data were expressed as percent frequencies, and differences between proportions were compared using the chi square test. Statistical correlation between continuous variables was tested using the Pearson's product-moment coefficient of correlation (r). All tests of significance were two tailed and a p-value < 0.05 was considered statistically significant.All analyses were performed using SPSS version12. statistical software (SPSS Inc., Chicago, Illinois).

(Results)

Chapter four
Results

Table (4-1) show the average of stroke volume between male and female according the data been collected:

Male	**30**
Female	**20**

Figure (4-1) show the relation between the stroke volume and cardiac output.

Figure (4-2) represent the relation between stroke volume and ejection fraction.

Figure(4-3) show the relation of stroke volume and patint age.

Figure (4-4) show the relation between stroke volume and body mass index

(Discussion, Conclusion and Recommendations)

Chapter five

Discussion,conclusion and recommendations

5-1 Discussion:

Chapters five explains and clarify the results in chapter four and give us the finale conclusion and recommendation for the study.

The relation between stroke volume and ejection fraction is proportional When the stroke volume increase the ejection fraction increase too because from the definitions the stroke volume is the amount of the blood leave the ventricle depend on the amount of contractility strength and the ejection fraction is the percentage of the blood get out from the left ventricle.

the association between the stroke volume and cardiac out put is proportional. due to increasing in stroke volume the cardiac out put increase the reason is the stroke volume is parameter of the amount of blood pumped out the left ventricle and the cardiac out put is the amount of blood pumped by ventricles in one minute.

decreasing in the paragraph curve of the age and stroke volum according to when the patient get aging the stroke volume going down because of the heart muscle lose the ability of stratching and contraction tightly with age due to starling low so the volum of the ventrivle is decreasing and the amount of the blood puomped out from the ventricle decresing as well and the second reson is arteial blood pressure with aging increase and couse Decreasing stoke volume. Increased\ after load will hinder the ventricles in ejecting blood, causing reduced stroke volume. Increased after load may be found in aortic stenosis and arterial hypertension (Patton et al 2003).

Increasing in body mass index come with decreasing in stroke volume increasing in body mass index lead to obesity. Obesity couse increasing in blood pressure and cholesterol levels. The obese people tend to have more chances of high total cholesterol or high levels of triglycerides (called Dyslipidemia) than healthy people. Due to accumulate fats and lipids in the large and medium arteries. Leading to deposition of fat in the blood vessel the affected arteries become narrowing. Narrowing of coronary arteries causing myocardial infarction. Myocardial infarction decreasing strength of contraction. Because of strokke volume affected by power of contraction. This cause decrease in stroke volume (Guyton and hall 2006). Another obesity effect is being high blood pressure or hypertension. The obese person is more likely to have higher level of blood pressure twice than the normal one. The mechanism of elevating the arterial blood pressure is unknown. High blood pressure in the aorta and pulmonary arteries causes the

contractile force to drop down because the ventricles have to contract against increased resistance therefore the stroke volume is decreased (Guyton and hall 2006).

5-2 Conclusion:

The study conclude that Stroke volume increase with ejection fraction by 0.555%..the stroke volum increase proportionly with cardiac out put by 0.585

l/m.stroke volume has invers proportion with age by 0.975 years and with body mass index with 1.345.

5-3 Recommendation:

Calculation of stoke volume should be used more efficiently as indicator of heart health in medical field with other heart parameter performance as ejection fraction and cardiac out put.

Age of patient and body mass index must be put in consideration in diagnose the heart performance with stroke volume.

Stroke volume need more study and research especially with low and high stroke volume and the relation with cardiac defect.

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AppendicesA

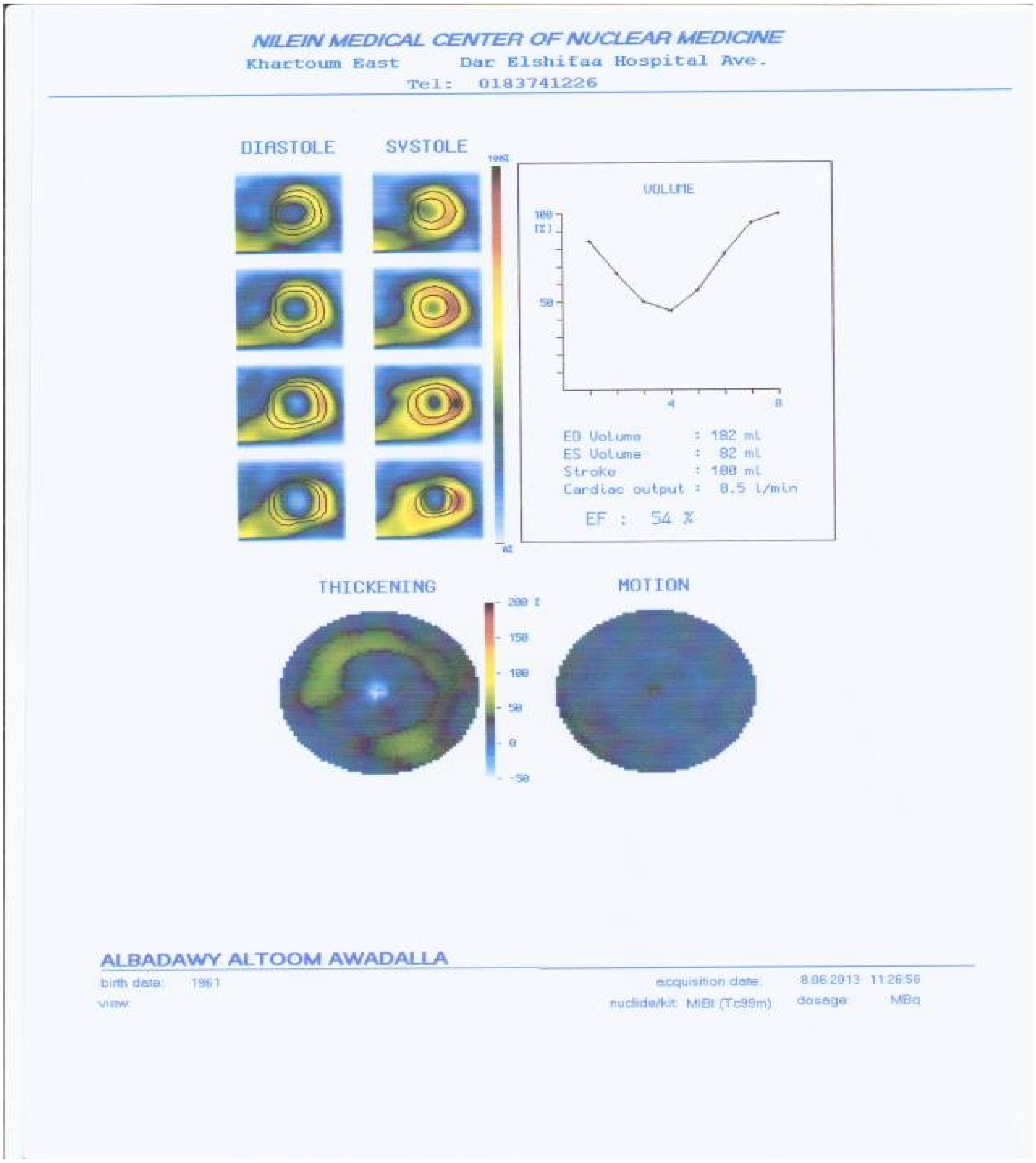

Image (1) SPECTMPI study at rest showed markedly reduced uptake at the apex, mid anterior wall, mid anterior septum, Quantification of EF, regional myocardial wall motion, and thickening from gated myocardial perfusion.) Myocardial contours displaying endocardial and epicardial surfaces overlying end-diastolic (ED) and end-systolic (ES) frames display short-axis images

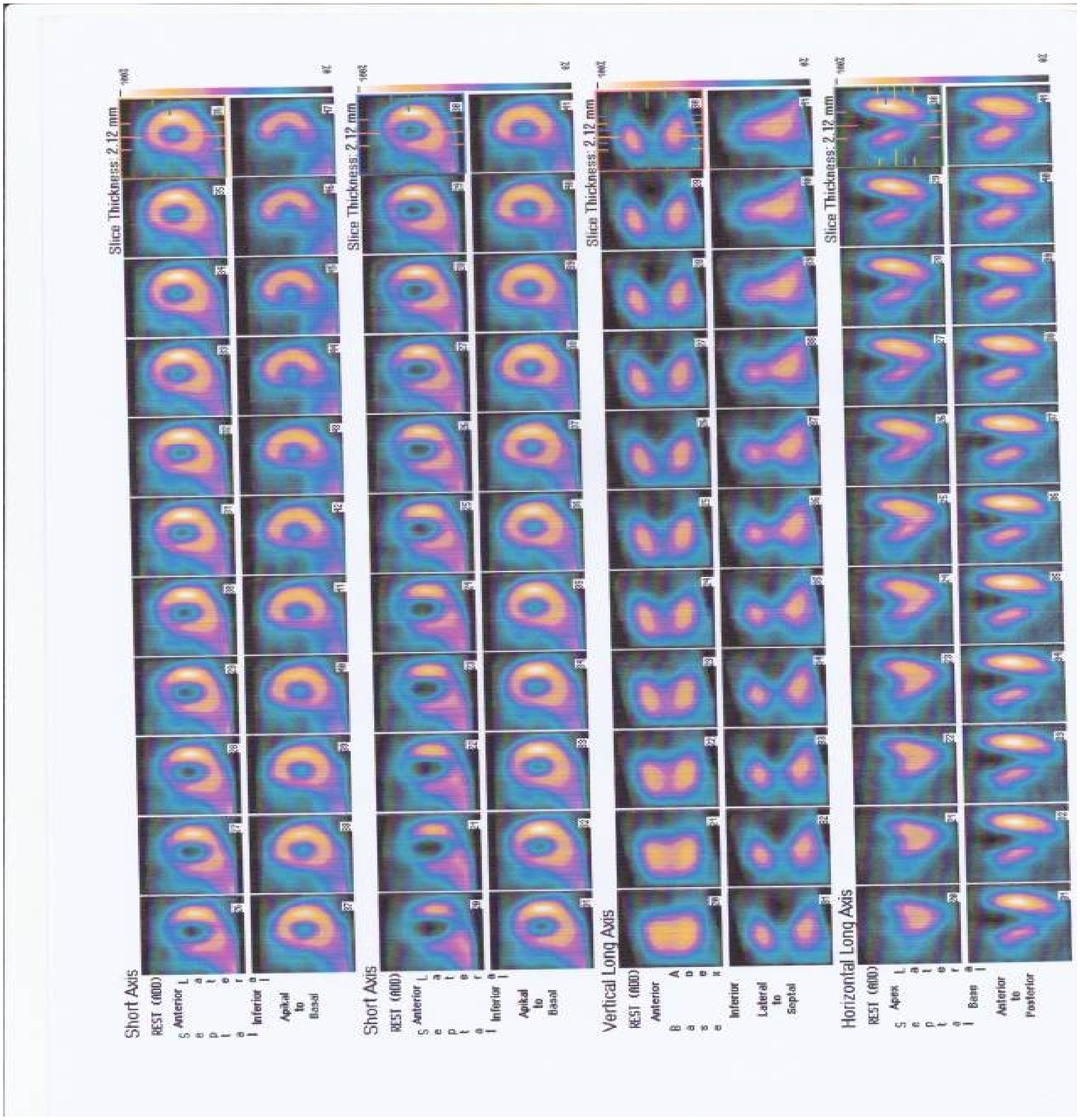

Image (2) Left ventricular wall motion and systolic function can be analyzed with an ECG-gated study. EDV, ESV and EF are calculated and displayed (circled)

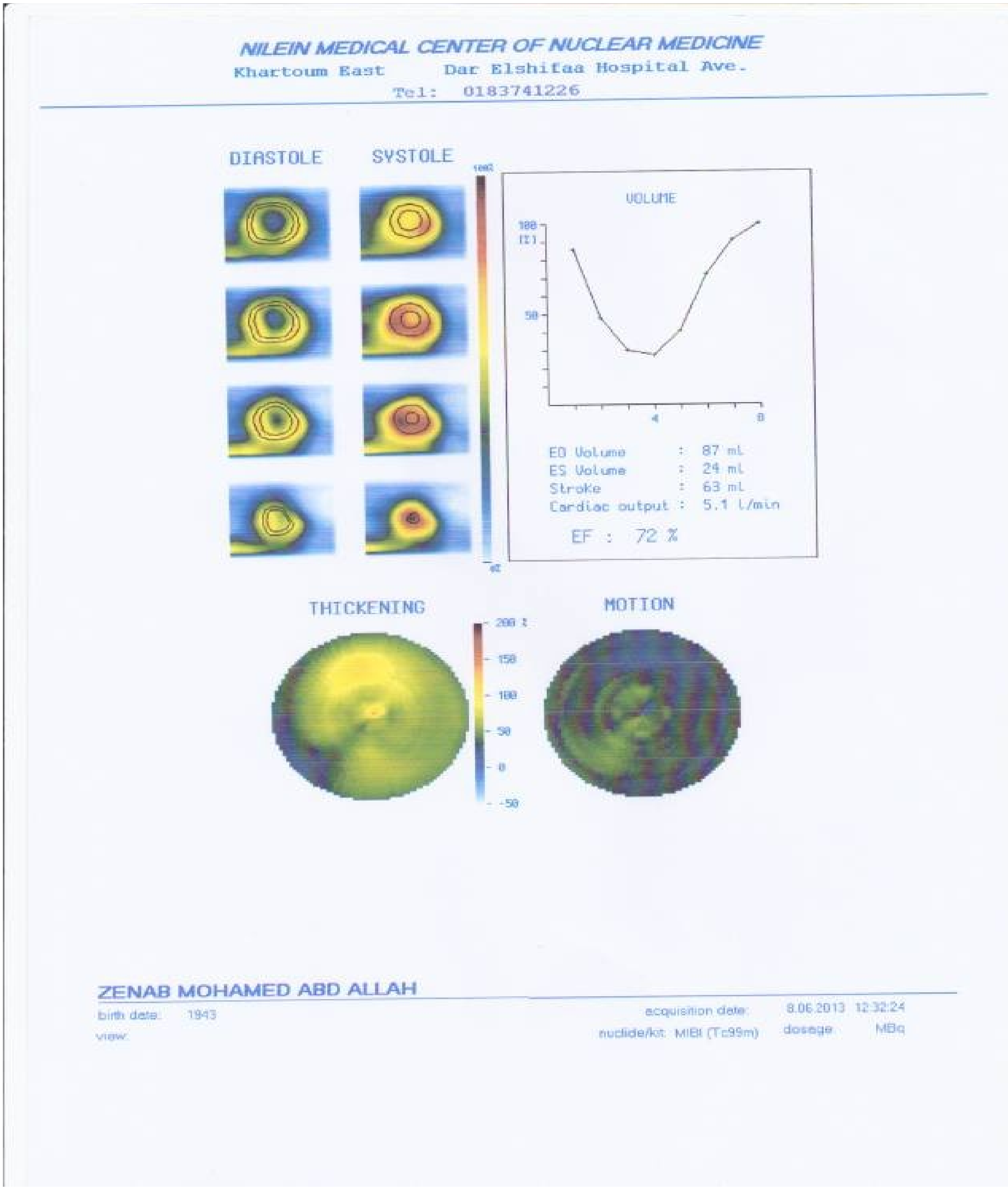

Image (3) SPECT MPI study at stress showed no significant reduction in tracer uptake at maximum hyperemia.

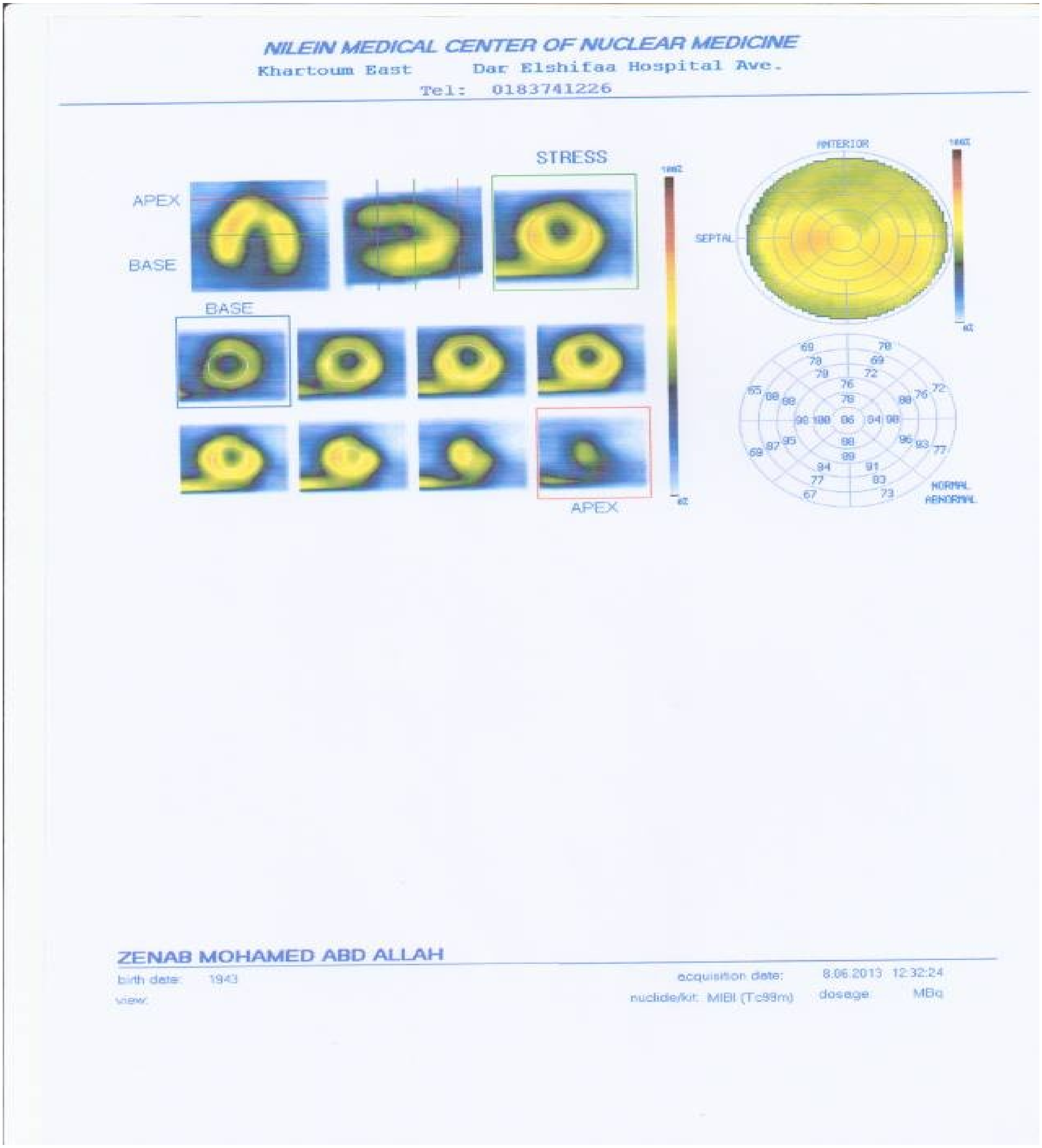

Image (4) Gated SPECT shows good contractility at all segments

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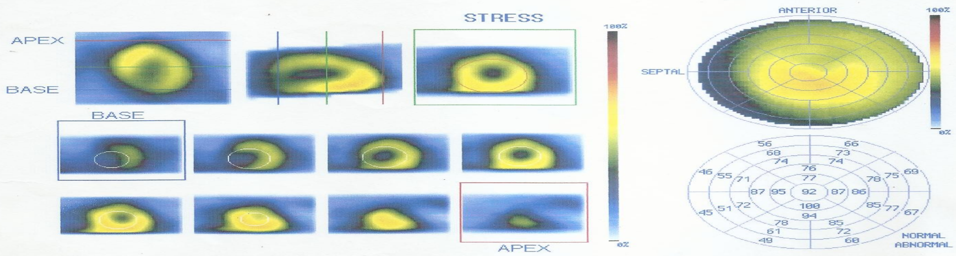
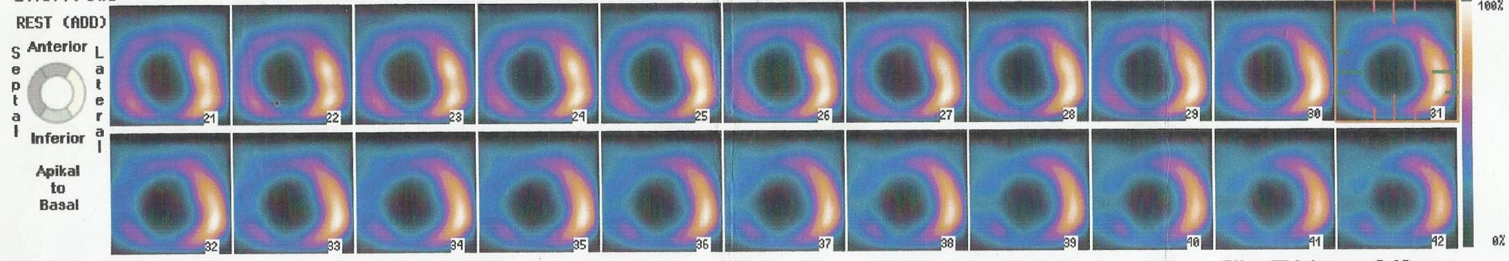
Kartoum East   Dar Elshifaa Hospital Ave.
Tel:



FATIMA SULIMAN RABIH
birth date: 1945 — acquisition date: 12.02.2011 16:45:44
view: — nuclide/kit: MIBI (Tc99m) — dosage: MBq

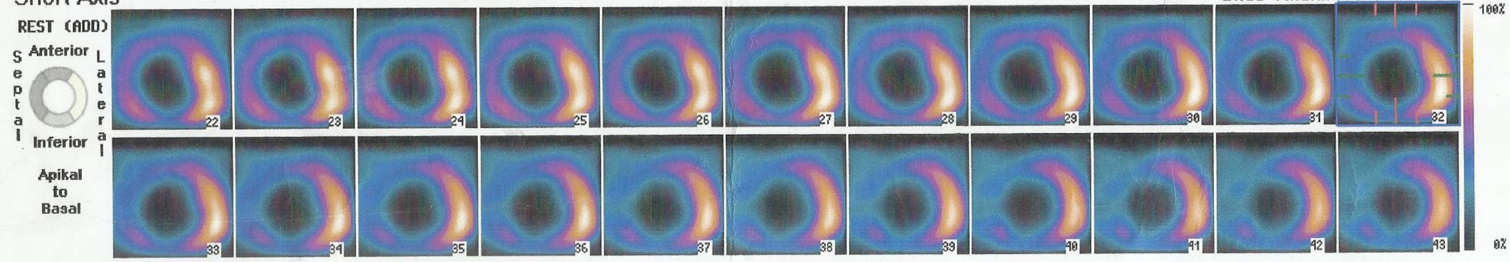
Short Axis

Slice Thickness: 2.12 mm



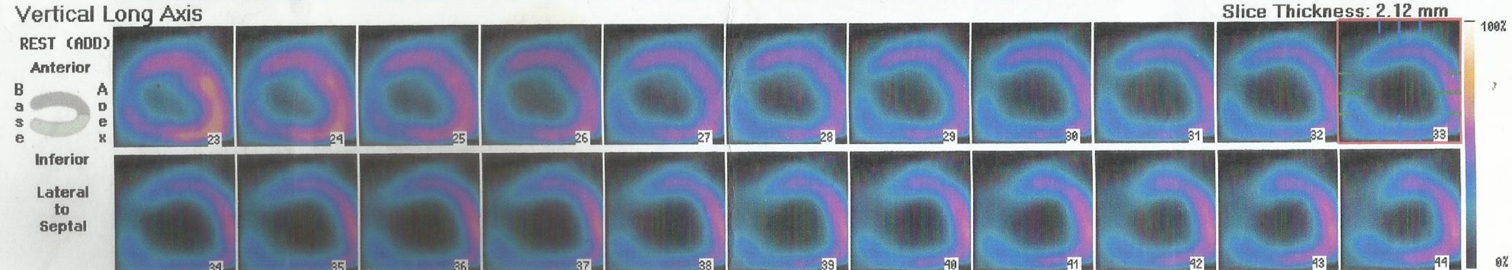
Short Axis

Slice Thickness: 2.12 mm



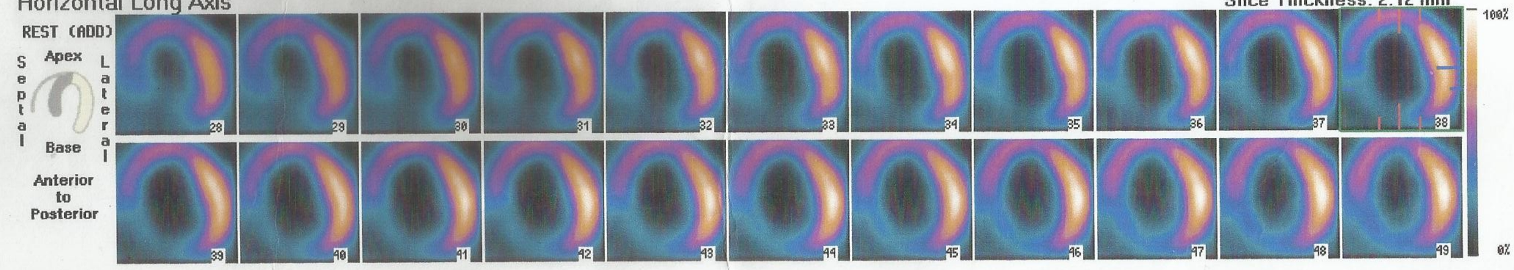
Vertical Long Axis

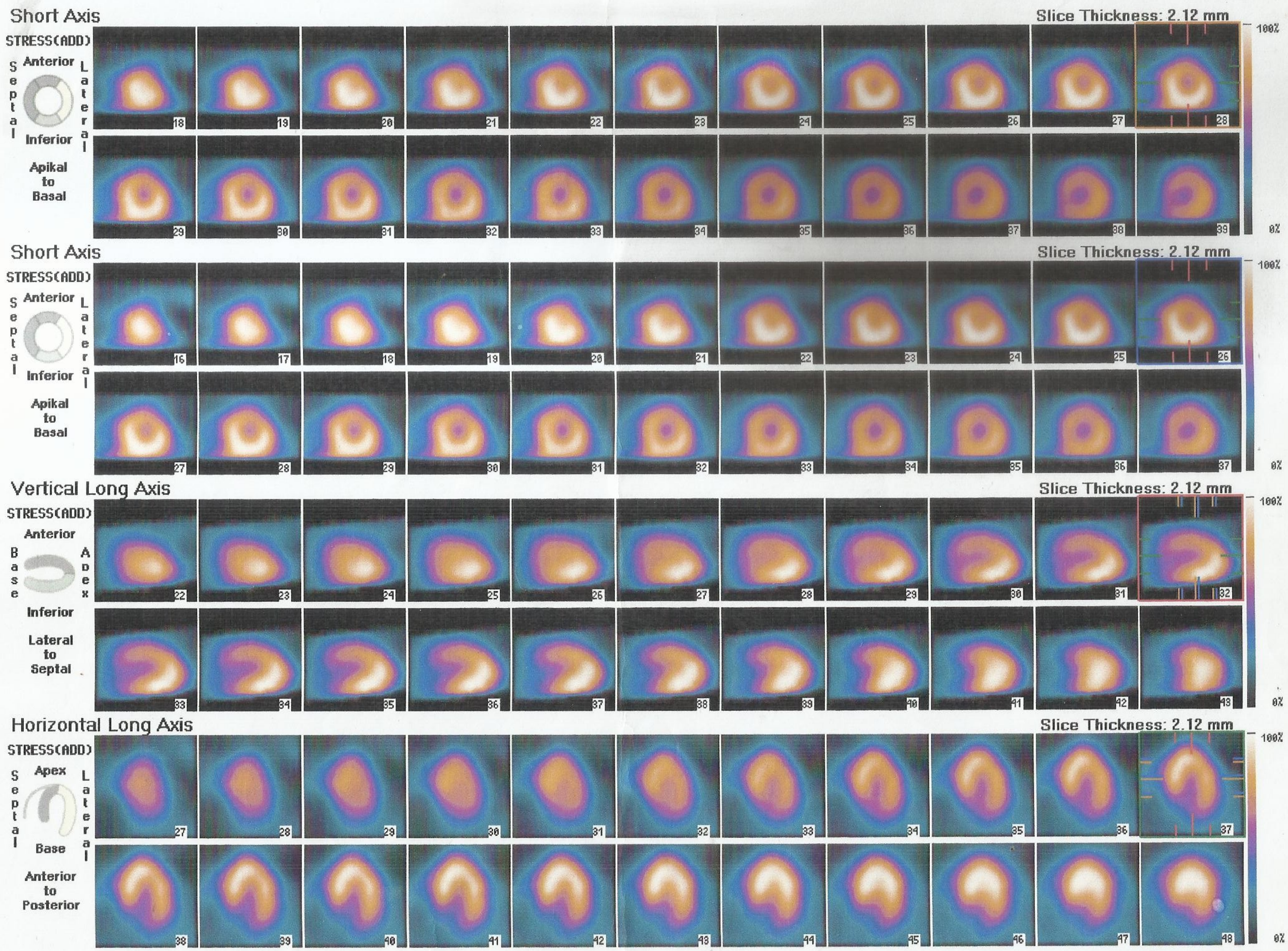
Slice Thickness: 2.12 mm



Horizontal Long Axis

Slice Thickness: 2.12 mm




Short Axis
Slice Thickness: 2.12 mm
STRESS(ADD)
Anterior
Septal
Lateral
Inferior
Apikal to Basal
100%
0%
Short Axis
Slice Thickness: 2.12 mm
STRESS(ADD)
Anterior
Septal
Lateral
Inferior
Apikal to Basal
100%
0%
Vertical Long Axis
Slice Thickness: 2.12 mm
STRESS(ADD)
Anterior
Base
Apex
Inferior
Lateral to Septal
100%
0%
Horizontal Long Axis
Slice Thickness: 2.12 mm
STRESS(ADD)
Apex
Septal
Lateral
Base
Anterior to Posterior
100%
0%

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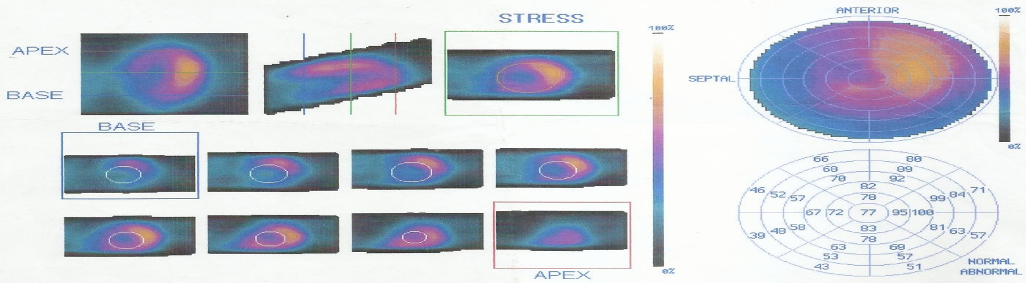
Tel:



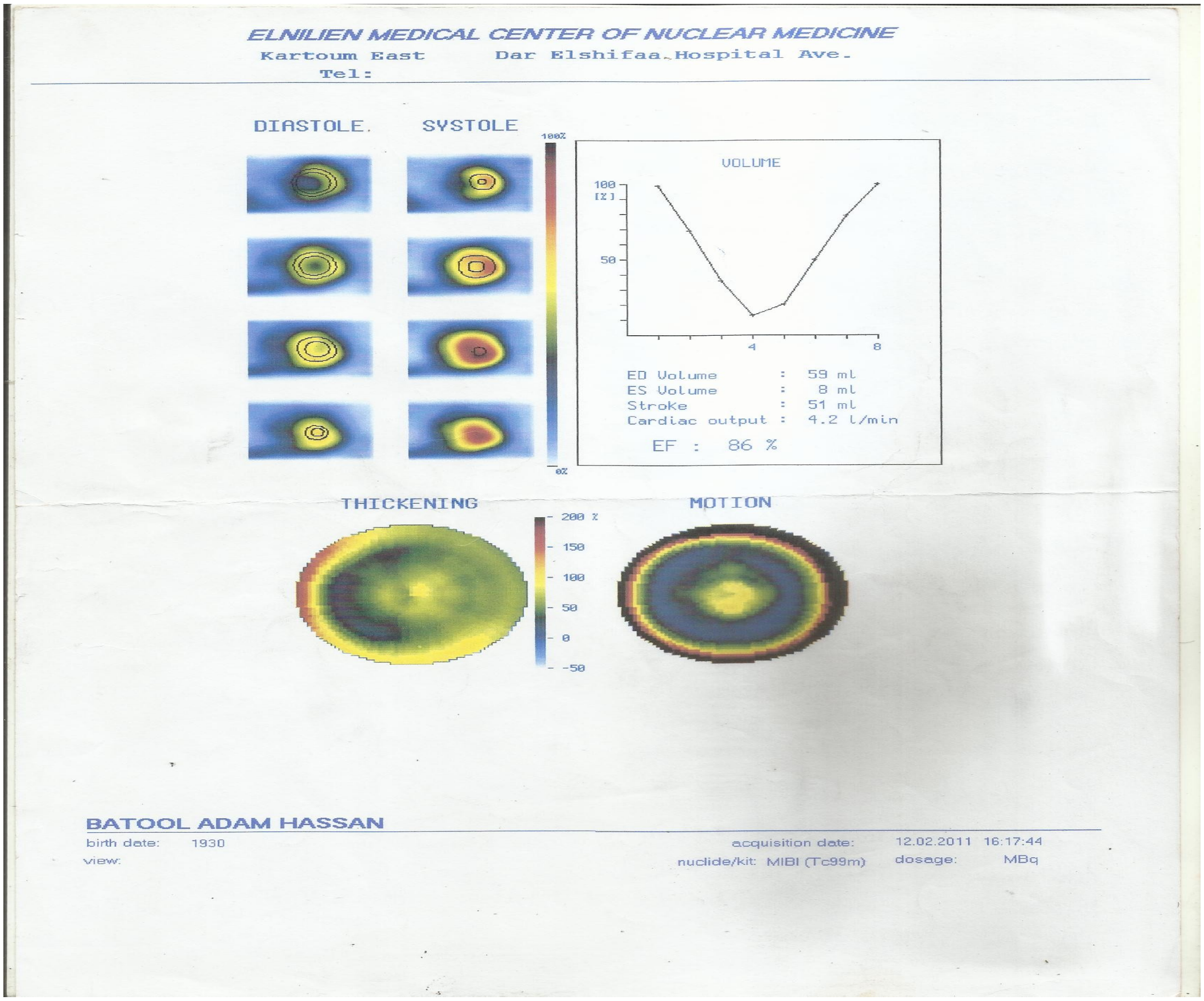
SALAH KHEIR ALSEID

birth date: 1948

view:

acquisition date: 6.11.2010 13:47:14

nuclide/kit: MIBI (Tc99m) dosage: MBq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Kartoum East Dar Elshifaa Hospital Ave.
Tel:
DIASTOLE.
SYSTOLE
VOLUME
ED Volume : 59 ml
ES Volume : 8 ml
Stroke : 51 ml
Cardiac output : 4.2 l/min
EF : 86 %
THICKENING
MOTION
BATOOL ADAM HASSAN
birth date: 1930
view:
acquisition date: 12.02.2011 16:17:44
nuclide/kit: MIBI (Tc99m)
dosage: MBq

Appendix B:

Age	Body mass index	Gender	Cardiac out put	Stroke	Ejection fraction
years			L/min	volume(ml)	%
51	27	Female	4.5	57	52
61	22	Female	6.6	65	55
70	24	Male	6	55	50
66	18	Female	4.3	64	60
61	20	Female	5.7	63	53
65	19	Female	5	60	56
54	14	Female	6.7	69	61
61	17	Female	7.1	72	60
63	20	Female	5.3	70	63
57	19	male	4.9	75	75
68	22	Male	5.2	79	67
49	24	Female	7.2	77	61
59	25	Female	5,8	81	65
55	18	male	7.7	74	78
41	21	Male	6.8	84	74
46	23	Female	4	78	57
68	29	male	4.4	62	62
43	26	Male	5.6	66	68
53	19	Female	4.8	78	55
45	28	Female	5.2	67	56
58	23	male	6.4	73	80
66	16	Male	7.8	85	61
43	25	Male	5.7	71	73
45	15	Female	7.7	88	66
42	26	Female	7.3	82	55
67	27	Female	5.5	86	70
66	17	Male	6.6	92	78
55	14	Female	7.6	83	59
60	30	Male	4.9	96	68
56	21	Male	6.4	93	74
68	19	Female	7.2	87	65
67	24	Male	7.1	84	72
58	27	male	8	99	76
47	20	Male	7.4	85	68
50	23	Female	6.2	84	62
49	23	Male	6.3	100	70
61	16	Male	7.8	91	76
46	19	Male	7.5	90	73
66	25	Male	5.7	98	73
49	29	Female	4.8	86	63
53	30	Male	7.7	94	70
62	24	Male	4.7	90	79
42	17	Male	7.4	75	77

56	18	Male	7.4	89	73
63	21	Male	6.1	83	65
46	29	Male	5.8	95	73
50	22	Male	6.6	77	78
64	17	Male	6.9	96	75
58	25	Female	6.5	71	80
60	15	Male	7.6	82	64