Cardiac Nuclear Medicine

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This term paper will highlight the following aspects:

- Abstract
- Introduction

Some common uses of procedures
- Diagnosis, Imaging and Instrumentation
- Radio-pharmaceuticals
- Coronary heart disease
- Artificial Neural Network
- 1st Case study
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Abstract

Nuclear Medicine is a diagnostic method that is multidisciplinary in nature. Coronary artery disease and cardiomyopathy are diagnosed via cardiac nuclear medicine imaging. It can also be used to see if chemotherapy or radiotherapy has caused damage to the heart. Nuclear medicine involves the inhalation, swallowing, or injection of trace amounts of radioactive compounds known as radio-tracers or radio medicines into the bloodstream. These radio-tracers move through the area under investigation and emit energy in the form of gamma rays, which are detected by a gamma camera and a computer, resulting in images of the inside of the body based on Artificial Neural Network. While a radio tracer travels around the body, ANN (Artificial Intelligence technology) functions as a tool for detecting and localising disorders. The information contained in myocardial perfusion scintigrams is used to diagnose cardiac problems. Founder or merging of images is a technique that uses CT or MRI to create unique views. Nowadays, we have a single SPECT/CT and PET/CT device that can perform both imaging exams simultaneously. Artificial intelligence is used to detect and localise coronary artery disease, typically by analysing data from myocardial perfusion scintigrams. To reduce the amount of variables and extract relevant features from the myocardial perfusion images, they were preprocessed. A 2-D Fourier transformation was used to perform the preprocessing, which included both rest and stress images. Nuclear medicine imaging gives information that is often not available through standard imaging methods[10].

Keywords - Coronary artery disease;radioactive;gamma rays;artificial intelligence technology;scintigrams;SPECT;PET

1 Introduction

Nuclear medicine is the branch of medicine that deals with the use of radioactive diagnosis and treatment. It is a branch of medical imaging that uses trace amount of radioactive to diagnose and determine the severity and treatment for many types of disease as in cancers, heart disease, gastro-intestinal, endocrine, neurological disorders other abnormalities inside the body.

Radionuclide are radioactive compounds that are given to patients physically, ingested, or inhaled. These radio detectors pass through the area being explored and emit gamma rays as energy. A specific camera called a gamma camera detects these gamma rays.

When a radionuclide is injected into the body, it is frequently chemically attached to a complex that acts as a carrier molecule. This allows us to track molecular activity throughout the body. This has the ability to detect disease early on as well as a patient's rapid reaction to therapeutic interventions. Coronary artery disease and cardiomyopathy are assessed by cardiac nuclear medicine imaging[17]. It can also be used to detect whether chemo or radiotherapy has caused harm to the heart. Small doses of radioactive elements called radio-tracers are injected into the circulation, breathed, or taken in nuclear medicine[5]. The radio-tracer passes through the area being examined and emits energy in the form of gamma rays, which are detected by a gamma camera and a computer, resulting in images of the inside of your body. Nuclear medicine imaging gives information that is often not available through other imaging techniques.

1.1 Some common uses of procedures[9]

• Nuclear medicine imaging of the cardiac is also done.
• A myocardial perfusion scan is being used to visualise circulatory patterns to the cardiac walls.
• To determine whether or not coronary artery disease is present and how serious it is.
• To detect the extent of heart damage after a heart attack, also known as a myocardial infarction.
• To analyze the effects of bypass surgery or other revascularization operations re - establishing the heart's blood circulation.
• A technique known as cardiac gating is used in connection with an electrocardiogram (ECG) to evaluate cardiac movement and overall heart function.

2 Diagnosis, Imaging and Instrumentation

Cardiac single photon emission computed tomography (SPECT) and positron emission tomography (PET) are increasingly being utilised to detect myocardial viability and perfusion in patients with suspected or known coronary artery disease, giving useful diagnostic and prognostic information. These myocardial perfusion imaging techniques are superior to existing approaches for the diagnosis of multi-vessel coronary artery disease and potentially for risk assessment and prediction of cardiac events since they can evaluate left ventricular function as well as coronary flow reserve. Flow-limiting coronary lesions can be identified using hybrid SPECT/CT and PET/CT scanners, which has enormous potential for both diagnosis and management. Advances in cardiovascular molecular biology have aided in the development of molecular imaging, which may be beneficial in the future for evaluating specific molecular and cellular disorders[7]. Planar perfusion imaging has been replaced by SPECT imaging. By spinning detector heads around the patient, multiple planar images of the heart using photons (gamma rays) generated by radiopharmaceuticals are recorded, and myocardial perfusion images are reconstructed using concepts similar to CT imaging. It's widely available and used to check myocardial perfusion and ventricular function in those who have been diagnosed with IHD. The idea has remained the same since its inception in the late 1980s for everyday clinical practise; nevertheless, there have been some substantial adjustments for improved and optimal imaging of the heart,180° acquisitions, for example, have nearly completely supplanted 360° acquisitions. Faster acquisition times have resulted as a result of this, particularly when using two-headed cameras at a 90° angle. Iterative reconstruction has mostly superseded back-projection reconstruction of pictures. Because it is a calculation-intensive technique, it necessitates a lot of computing power[2]. Although it has been frequently available in nuclear medicine since the 1990s, it has only recently become widely used. Due to the increased computational power necessary for higher quality CT pictures, this technology is currently being used in CT imaging. The first-pass extraction of 13NH3 is 80%, and myocardial absorption demands energy. Uptake is linear throughout a large range of cardiac blood flow rates, except at very high flow rates, as with SPECT myocardial perfusion agents. An on-site cyclotron or proximity to a regional positron radiopharmaceutical source facility are required for imaging with 13NH3. 82RbCl is a potassium analogue that requires energy for myocardial absorption and has a first-pass extraction of 65 percent. Because of its short half-life, it is possible to repeat investigations. 82RbCl has an advantage over 13NH3 in that it can be generated without a cyclotron using a strontium-82/82Rb generator[12].

FDG is utilised to assess glucose utilisation in ischemic myocardium with impaired mitochondrial fatty acid oxidation. Insulin infusion in the fasted state reduced myocardial extraction of free fatty acids by 85% and accelerated myocardial absorption of both FDG and glucose, according to Ng et al. In diabetic individuals as well as those with normal glucose tolerance, FDG absorption is diverse in normal myocardium in the fasting state. Ischemic tissue has increased FDG uptake, whereas scar tissue has significantly reduced or nonexistent uptake[3]. To increase myocardial FDG uptake, researchers used oral glucose loading and continuous insulin, potassium, and glucose infusions. Images produced in non-diabetic patients following insulin infusion were of higher quality than those obtained after oral glucose loading, according to Knuuti et al. Similar findings were found by Ohtake et al in patients with non-insulin-dependent diabetes. Insulin infusion has been considered by several researchers as inconvenient for routine clinical use. Alternatives such as oral glucose loading and insulin bolus injections have been recommended[18].

Carbon-11 acetate, C-11 palmitate, and oxygen-15 water are less widely used PET radiotracers for monitoring regional myocardial oxygen consumption, fatty acid metabolism, and myocardial blood flow[6].

3 Radio-pharmaceuticals

Myocardial perfusion: Thallium-201 chloride was the first pharmaceutical commonly utilised in clinical cardiac perfusion imaging. It's a good agent for imaging perfusion, and many centres still employ it to image the heart. It is not the best agent for imaging because of its extended half-life and low energy X-ray emission, resulting in a higher radiation dosage and inferior image quality than technetium agents. It functions similarly to the K+ ion (through Na/KATPase) and is rapidly redistributed, beginning 20 minutes after injection[22]. Ischemic heart disease: Nuclear medicine plays a significant role in the identification of ischemic heart disease (IHD), which can be reversible or irreversible, by employing a particular radiopharmaceutical. The most often utilised radiopharmaceuticals in clinical practise are 99mTc-Sestamibi, 99m Tc-Tetrofosmin, and 201Tl. This research looked at the usage of counts/second /pixel(c/s/p), reversibility percent among arteries (LAD, LCX, and RCA) in assessing 99mTc-MIBI and 201TL bio-distribution in both stress and rest, as well as factors impacting reversibility including age, gender, and obesity.

4 Coronary heart disease

Radionuclide stress testing is injecting a radioactive isotopein into a patient's vein, following which a special camera captures an image of the patient's heart. The normal heart muscle absorbs the radioactive isotopes. Nuclear pictures are taken while the subject is at rest and soon after exercise. After that, the two sets of photos are compared. If a blockage in a coronary artery causes reduced blood flow to a portion of the cardiac muscle during exercise, this area of the heart will appear as a "cold spot" on a nuclear scan. On photos taken while the patient is at rest, this cold patch is not evident (when coronary flow is adequate). While more time-consuming and expensive than a standard ECST, radionuclide stress testing considerably improves the accuracy of identifying coronary heart disease[15].

5 Artificial Neural Network

Artificial neural networks are used to detect and localise coronary artery disease, typically by analysing from myocardial perfusion scintigrams. In a group of individuals ranging in age from 74 to 410, a neural network was used to diagnose coronary artery disease. Artificial neural networks diagnosed cases of coronary artery disease that were comparable to a gold standard, which included a coronary angiography, two human experts analysing myocardial perfusion studies, or all clinical patient data, including ECG analysis, results of a physical exercise test, and the patient's history. All of the artificial neural network models that were used had a three-layer structure and a feed-forward information flow. There were three layers in each neural network: an input layer, a hidden layer, and an output layer. The number of neurons in an input layer ranged from 11 to 256, depending on the scintigram matrix and other data utilized, whereas the number of neurons in a hidden layer varied from 3 to 140[14]. One, two, or eight units made up an output layer. All of the clinical data was used in the input signals of an artificial neural network that detected coronary artery disease. To reduce the amount of variables and extract essential features from the images, the myocardial perfusion images were pre-processed. A two-dimensional Fourier transformation was employed to perform the preprocessing, which included both rest and stress images. After this modification, the input neurons were given 30 values that represent the real and imaginary parts of the Fourier coefficients. Other studies included male or female individuals, an exercise test, a resting ECG, heart rate, and workload. The features of the artificial neural network's (ANN) input signals were designed so that each neuron represented pixels from bull's eye images. The results were binary values such as 0 or 1 when the output layer included one neuron that recorded whether coronary artery disease was present or not. Another study used eight output neurons to encode coronary artery disease severity, which was obtained by dividing the disease into seven faulty categories and one normal case. The back propagation algorithm was used to train artificial neural networks in the development of studies. The number of neurons, each layer of artificial neural networks (input, hidden, and output), the learning method (BP, Bayes), and the number of patients are all included in the list. It's based on research that shows artificial neural networks can detect coronary artery disease better than humans[1].

6 1st Case study[21]

A 58-year-old man comes to the ER with chest pain.

6.1 Past medical history

- Coronary disease
- Cocaine abuse
- Questionable history of emphysema
- The patient has chronic joint pain problems

6.2 Family history

Positive for hypertension. His brother died of a heart attack at age 45.

6.3 Social history

A 58-year-oldAfrican-American gentleman with history of emphysema was transferred from another hospital with dynamic EKG changes and chest pain. The patient admitted cocaine use five days prior to presentation. Beta blocker was held due to cocaine use. Amlodipine was added in an effort to decrease coronary spasm. Decadron was continued post procedure for 18 hours.

Echo was done to reevaluate bilateral function, showing an EF of 30%. The patient had smoked crack cocaine the day before presentation and had experienced substernal chest pain with typical angina symptoms the afternoon and evening before the morning of presentation. He was admitted to the ER and was given nitroglycerine with some relief of pain. Urine drug screen was positive for cocaine. The cardiology service recommended coronary angiogram the following day. The patient however did not want to have an invasive test.

6.4 Lab values- cardiac injury level

Patient had history of problems with affording medications and illicit drug use. Patient refused invasive testing, but did consent to a nuclear medicine stress test. Patient complained of shortness of breath, but denied any chest pain. SPECT images of the myocardium were obtained at approximately one hour delay. 39 mg of IV Persantine were infused over four minutes for pharmacy logical stressing.

7 Impression

Large fixed perfusion defect in ferolateral walls including the lateral, inferior, and apex. To test for hibernating myocardium, a thallium viability scan is indicated. This information was given to the patient's doctor. Quantitative gated SPECT: During the stress acquisition, a quantitative gated SPECT examination was done. The diastolic volume at the end of the diastole was calculated to be 180cc. The 148cc end systolic volume was determined. The ejection fraction of the left ventricle was calculated to be 18 percent. On the CINE images, there is dyskinesis involving the apex [16].

8 Impression

With an ejection fraction of 18 percent, the left ventricle is dilated, with major worldwide hypokinesis and apical dyskinesis. After three days, the patient was discharged with no chronic pain or other angina-like symptoms. For the next month, the patient was discharged in stable condition with a cardiac diet and instructions to limit activity to non-stressful activities. He was also strongly encouraged to avoid abusing drugs and to engage in a drug rehabilitation programme[8].

9 Medications on discharge

1. Zocor 20 mg
2. Lisinopril 10 mg
3. Aspirin 325 mg
4. Plavix 75 mg
5. Spironolactone 25 mg
6. Nitroglycerin

He went to the ER four days after being discharged because he was having trouble breathing and swallowing, and he was diagnosed with angioedema of the uvula and bottom lip. He came in with a one-day history of lip swelling. He claims he has neither chest pain or diaphoresis. On the day before his admittance, he had a little amount of cocaine in his system. He was brought to the hospital for observation and given IV Benadryl and H2 Cimetidine. He was started on hydrocortisone and received one epinephrine injection. His difficulties swallowing and shortness of breath vanished. He was thought to have had an allergic response to the Lisinopril. After an internal medicine evaluation, the patient was discharged the next day. Patient was uncomplaining, and he was told not to take the ace inhibitor at this time, and he was reminded of the significance of quitting cocaine. The patient was readmitted only four days after his previous stay. The patient had elapsed and was unconscious on the day of admission. MEMS were dispatched, and the patient was shocked with an EED. After six electric shocks, the patient was given Lidocaine 100mg IV. On arrival, he was drugged and intubated. Aspiration pneumon was suspected, thus Clindamycin and Cefepime were given to the patient. A chest x-ray later revealed an infiltrate in the left lower lobe. The patient's temperature continued to rise, and his whiteness increased. The patient was given aspirin, Plavix, and heparin, as well as IV Amiodarone. The patient improved and became afebrile while on IV antibiotics. The number of white people began to decline. He had low haemoglobin and hematocrit, but they were steady. The patient's plans to move to a rehab unit were reviewed with social work. However, the patient grew evasive and refused to be admitted to a rehabilitation facility. The patient also refused an IV line, necessitating the discontinuation of IV antibiotics. As a result, he was put on 400 mg of gatifloxacin for another seven days. Following contacting his family, the patient was released 14 days after his stay. Two follow-up appointments were scheduled for the patient, as well as instructions on how to take his meds. The patient was also warned about the dangers of drinking alcohol or using cocaine again, as well as the potential of sudden cardiac death[19].

10 2nd Case study[23]

A 48-year-old black woman with hypertension and chest problems was admitted to the hospital.

10.1 ECG Results

- Normal Sinus Rhythm
- Nonspecific T-wave abnormality

- Otherwise normal ECG
- Ventricular Rate 64 bpm

10.2 Nuclear Medicine

She was sent to the nuclear medicine department for diagnostics to see whether she had any cardiac ischemia.

IV Persantine Stress - The patient was given 0.56 mg per kg of IV Persantine (47 mg total) over 4 minutes while resting. The blood pressure was 99/56 and the resting heart rate was 59 beats per minute. The EKG revealed a typical sinus rhythm with no sudden changes. The heart rate was 75 beats per minute after the Persantine infusion, and the blood pressure was 110/74. There were no systemic symptoms mentioned by the patient.

10.3 Impression

There was no Ischemic variation in the physiologic response to IV Persantine.

10.4 Myocardial Perfusion Study with SPECT[4]

The patient was given an IV infusion of Tc-99m Sestamibi at rest. After a one-hour delay, SPECT pictures of the myocardium were acquired. The patient was given an additional 32 mCi of Tc-99m Sestamibi seven minutes into the Persantine infusion, and the imaging protocol was repeated.

A perfusion deficit involving the front wall of the left ventricle can be seen on post-stress imaging.

10.4.1 Impression

A reversible abnormality involving the left ventricle's front wall. A lad distribution lesion is the most likely explanation for the findings.

10.5 Quantitative Gated SPECT[11]

During the stress acquisition, gated SPECT imaging was used. The end diastolic volume of the left ventricle was calculated to be 79 cc, the end systolic volume to be 32 cc, and the left ventricular ejection percentage to be 62%.

10.5.1 Impression

SPECT with a normal quantitative gate. The results were communicated to the referring physician in the family medicine service.

After the procedure, the patient was discharged from the hospital. Her doctor called her at home and told her she needed to go to the ER since she had a positive stress test that morning. She had severe exertional chest pain but no nausea, diaphoresis, dizziness, or dyspnea, according to the patient. The patient stated that she was experiencing chest pain and that her heart was racing. She also stated that she was not feeling well. She stated that she will go to the emergency room tonight.

11 Conclusion

Many heart illnesses, including CAD, necessitate both anatomical and functional data to be fully assessed. This can be done in a variety of methods, and the capabilities of typical imaging modalities overlap, especially when it comes to assessing myocardial viability, function, and coronary morphology. The accuracy and cost of the procedures are similar, according to NICE recommendations in the UK on the assessment of patients initially presenting with suspected angina, and the decision between them can be dependent on local availability and expertise[20]. While their accuracy may be comparable in ideal hands, it is unknown whether the newer perfusion procedures function as well in the real world, and no robust cost-effectiveness studies have been conducted. Each approach is backed by suitability criteria that overlap in the group of patients who have a moderate risk of coronary artery disease (CAD). The fact that echocardiography, nuclear cardiology, cardiovascular MRI, and CT were developed by separate specialties, such as cardiology, nuclear medicine, and radiology, is a significant difference. When a procedure is in the hands of the referring physician, it is more likely to be employed for professional and financial reasons. As a result, in certain circumstances, the decision is made in the doctor's best interests rather than the patient's. In this aspect, there are significant variances between countries. The imaging industry's interests have influenced the development of technology in several circumstances. A scenario like this should not be allowed to continue[13]. The panel believed that the best way to achieve a balanced use of cardiac imaging is through education of consumers and providers of imaging services, which should be independent as much as possible of the specialist's past expertise, whether in cardiology, nuclear medicine, or radiology. The committee was also optimistic that increased collaboration between experts and subspecialists would allow the best interests of the patient to prevail, as well as the significant advances in cardiac imaging for patients in all regions.

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