VOL. 3 (6). ISSN 2424-5755

RADIOLOGY UPDATE

JOURNAL available at radiologyupdate.org

Online Journal

Lithuanian Association of Radiologists

This page is intentionally left blank

Editorial board

This page is intentionally left blank

Contents

Comparison of Echocardiography, Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography/Computed Tomography (PET/CT) and Cardiac Magnetic Resonance Imaging (MRI) diagnostic value while choosing treatment strategies after acute myocardial infarction (AMI)

Povilas Žudys, Eglė Kazakauskaitė, prof. habil. dr. Renaldas Jurkevičius

Lithuanian University of Health Sciences, Department of Cardiology

ABSTRACT

Background and aim. The adrenal tumors are a reasonably common pathology. Radiologic imaging detects an adrenal Aim. Evaluate myocardial viability, volumes of heart chambers and systolic function with different modalities: echocardiography, SPECT, PET/CT, and MRI.

Objectives. 1) Assess and compare myocardium movement, perfusion, and viability with echocardiography, SPECT, PET/CT, and MRI.
2) Compare ejection fraction (EF), end-diastolic volume (EDV), and end-systolic volume (ESV) results between different modalities.
3) Establish which diagnostic method is similar to PET/CT („gold standard“) the most.
4) Compare MRI („gold standard“) EF, EST, EDT results with results of other modalities.

Methods. Prospective trial. The statistical analysis was performed by SPSS software.

Study participants. Thirty patients who were treated in the Department of Cardiology, Hospital of Lithuanian University of Health Sciences Kaunas Clinics in 2012-2016. They have significantly lowered EF (EF ≤40%), severely damaged coronary arteries after acute myocardial infarction, that is why the benefit of revascularization for these patients is questionable because myocardium could have scars.

Results. Average patient age was 67,8 (interval 43–84 year), there was 25 (83,3%) men and 5 (16,6%) women. All patients had risk factors. Between echocardiography and PET/CT paired t test results of EF (OR 0,73 [95% CI -2,04-3,51], p=0,59), EDV (OR 13,36 [95% CI -10,18-36,92], p=0,25), ESV (OR 0,76[95% CI -16,93-18,46], p=0,93) were not significantly different (p>0,05). Although SPECT compared with PET/CT (paired t test) between EF (OR 2,76 [95% CI 0,88-4,64], p<0,05), EDV (OR 37,7 [95% CI 20,08-55,39], p<0,05), ESV (OR 23,26 [95% CI 11,34-35,19], p<0,05) and paired t test results between CMR and PET/CT (OR 3,43 [95% CI -5,68-(-1,18)], p<0,05), GDT (OR -43,23 [95% CI -66,82 (-19,64)], p<0,05) ir GST (OR -23,13 [95% CI -40,35-(-5,90)], p<0,05), it is clear that difference is significant. While evaluating miocard segment with Spearman corelation coeficient (r>0,05) and tested with McNemar test (p>0,05) it is clear, that in thirteen from sixteen miocardium segments there was found no significant difference between different modalities. Calculated Kappa coeficient shows agreement from fair to great. On the other hand, three of rest segments (lateral basal (18), lateral middle (12) and upper anterior(1)) statisticaly significantly were different (r<0.05, κ<0.20), McNemar test was negative with only few PET/CT with ultrasound and PET/CT with SPECT (p<0.05).

Conclusion. 1) Non-invasive cardiovascular imaging modalities (echocardiography, (99mTc)-MIBI SPECT, (18F)-FDG PET/CT and MRI) correlate well because 13 of 16 segment parameters match between types of examination. Spearman correlation coefficient (r>0,05) and Kappa value (κ>0,05) was counted, McNemar test was performed (p>0,05).
2) The agreement is seen between ultrasound and PET/CT when EF, ESV, and EDV is compared. Agreement between MRI and SPECT is seen too. Only EF (without EDV and ESV) agreement is seen between echocardiography and MRI. A paired t-test was performed (p>0,05).
3) PET/CT ("gold standard") and CMR damage of segments (viability) correlate best of all because most of the segments (10 of 16) Spearman coefficients and 11 of 16 segments Kappa values are close to one.
4) Comparing MRI ("gold standard") EF, EDV, ESV with other modalities, significantly similar data could be obtained only with MRI and SPECT. EF (without EDT and ESV) agreement is seen between echocardiography and MRI alone (p>0,05).

Keywords: PET/CT, MRI, SPECT, myocardial infarction

INTRODUCTION

The number of people who are prevalent to have ischemic heart disease (IHD), angina pectoris (AP), or myocardium infarction (MI) is increasing, and this trend is growing worldwide [33, 38]. Ischemic heart disease is a dysfunction of myocardium because of the decreased flow of oxygen to heart contractile cells. The cause of the disease is atherosclerotic coronary artery stenosis or spasms, which causes various length or localization myocardium ischemia [15]. IHD can expose as the sudden death of heart muscle, myocardium infarction, angina pectoris, heart rhythm, and conduction disorders or heart failure [33, 34]. According to the Lithuanian Institute of Hygiene, coronary artery disease-related deaths comprise more than half cases of death in Lithuania [33]. This is one of the biggest social, economic, and health issues not only in Lithuania but in the world as well [34]. In Europe, 4,25 million people die because of coronary artery disease annually [32]. More women die (55% of all deaths) than men (43%), the condition is more prevalent between the lower-income population, because people and society health depend on finance and budget [32, 33].

Left ventricle (LV) ejection fraction (EF), end-diastolic volume (EDV), and end-systolic volume (ESV) are used to diagnose and evaluate heart and coronary artery disease [35]. Moreover, these parameters provide useful diagnostic information during heart failure or when heart valves are damaged [36].

Various diagnostic modalities are used to evaluate EF, EDV, ESV, and condition of heart muscle segments: echocardiography, Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET/CT), heart Magnetic Resonance Imaging (MRI) [37]. Those modalities should give the same results with comparable errors [38, 39]. Diagnostic methods are convenient because all necessary information can be acquired in a single procedure.

SPECT shows LV function and myocardial perfusion [41], PET/CT – LV function, and viability (evaluation of functional parameters), although MRI with late gadolinium enhancement precisely shows EF, EDV, ESV and myocardial viability (anatomical parameter (scar) evaluation) [42]. With echoscope LV function, volumes and movement could be easily evaluated [40]. Previous studies show that there is a good correlation of LV parameters between those four methods, although there are some problems while myocardium perfusion defects, hibernating myocardium, or scars are found [43]. Moreover, there are specific problems with patients who have a small heart or because of poor video resolution and decreased quality of LV endocardium view because of image fusion at the end of systole [44, 45 46].

Firstly, if doctors want to increase patient prognosis, and outcomes of the disease, the precision of radiologic modalities should be evaluated. Looking at the world literature, only two modalities are being analyzed. Moreover, this is the first time in Lithuania when all four modalities are compared together.

In this article, main LV parameters (EF, ESV, EDV) and function of damaged heart segments (contraction, perfusion, and viability) are compared using echocardiography, SPECT, PET/CT, and heart MRI. PET/CT is a "gold standard" evaluating myocardial viability [13] while MRI – LV volumes and function [3]. It is essential to compare the match level between all four modalities (echocardiography, SPECT, PET/CT, and MRI). Differences between results can occur because of the type of myocardial damage or the size of the heart [39]. The reason why big errors were seen while evaluating LV viability, function, and volumes was because of doctor's subjectivity and time between examination (procedures took place not the same day). All different diagnostic modalities are used to evaluate anatomical heart structure, although PET/CT (being expensive) is partly harmful to the patient because of exposure to radiation, shows myocyte morphology what helps to determine myocardial viability more precisely. Four chosen modalities are discussed not only that it shows myocardial damage precisely but is increasingly being used in clinical practice (PET/CT and MRI first were introduced in LUHS KC in autumn of 2012).

It is expected that this article will help to answer the question of which modality is the best to evaluate different parameters of the heart, but will help to choose which one to use (most precise, fastest and cheapest, less harmful) to examine patient. According to all mentioned reasons, the aim of this article is clear – to evaluate myocardium viability, heart volumes, systolic LV function using different modalities: echocardiography, SPECT, PET/CT, and heart MRI.

POSITRON EMISSION TOMOGRAPHY

PET scanners were introduced in 1970 and were used only for scientific purposes. After 1990 all body PET scans were started to be used in clinical practice. Firstly, it was used only for neoplastic processes, later for cardiologic patients. There was a problem related to the lack and availability of radionuclide material. Lack of computer software was an issue, too, so PET examinations were not performed daily.

PET is a radionuclide related examination method in which detectors are used to discern positron-emitting particles. This allows scientists and doctors to observe various biological events. There is no stable matter in nature which emits positrons, that is the reason why radionuclides must be produced in a particle accelerator – cyclotron (for example 18 F-fluor-2-deoxyglucose, which has a half-life of 110 seconds). PET scanners just visualize radionuclide existence in tissue, and physiologic signal depends on radioactive substance characteristics. The main disadvantage is that the half-life of a substance is low, which leads to high procedure costs [1, 2].

When positron leaves the atom's nucleus, it travels few millimeters and meets an electron, collides with it, and emits two photons, who travel in two opposite directions and are seen in circular detectors. Trail of two photons draws a line between two detectors and is called response line (sinogram). With the help of a computer, all response lines are combined, and a three-dimensional image is made dependent on radioactive material presence in tissue [3, 4].

Radiotracers attenuation correction is produced using computed tomography, which leads to lesser artifacts, and it leads to less negatively positive perfusion defects, which result in higher specificity. High PET resolution allows us to evaluate small perfusion defects and lowers false-negative results. Moreover, short radiotracer half-life reduces radiation dose and enables to produce tension and relaxation phases with the same scan.

PET compared to SPECT has more advantages because it has higher spatial resolution and attenuates correction more precisely, which leads to lesser numbers of tissue artifacts. Many studies proved that PET specificity and sensitivity is more than 90% [50, 51, 52].

Using outer detectors and PET radiotracking technique, it is possible to get in vivo radiotracer dispersion views. Just as the same as in CT scans, cross-sectional views are produced. View quality and type depend on radiotracer. PET allows evaluating blood flow, heart function, and metabolism using biological substrates not invasively with radionuclides such as carbon, oxygen, nitrogen, or fluoride. These radionuclides have a shorter half-life than those used in SPECT. Moreover, fluoro-deoxy-glucose (FDG) metabolizes fast, which means that stress test with adenosine or dobutamine could be proceded quite fast [24].

PET radiotracers acquire a stable stance when they emit positron, which is electron antimatter. Positrons have the same resting mass as electrons but are charged positively. When positron collides with an electron, they annihilate each other and emits 511-keV gamma radiation. Gamma radiation is colinear and flies in the opposite direction, so PET scanner could be programmed to detect only that kind of rays. This method allows us to reach higher spatial resolution than SPECT. Also, PET is stationary, while SPECT rotates [5, 7]. PET allows for correcting attenuation too [6].

Myocardium blood flow speed evaluation provides diagnostic and prognostic value sooner than it could be evaluated with SPECT, that is the main disadvantage of SPECT. Also, perfusion, substrate metabolism, and heart innervation in vivo can be monitored with PET noninvasively. That allows scientists to examine heart physiology and pathophysiology. FDG is the most common radiotracer used in examining myocardium viability [5].

HYBRID PET/CT

Ability to evaluate CAD, myocardium perfusion, metabolic activity, and function of the ventricle with hybrid PET/CT makes it inextinguishable

in clinical practice [8]. Heart PET/CT is quite a new modality for patients with CAD. The myocardium is evaluated coronary anatomy and function with a single scan; that is the reason why it has huge potential for cardiac patients. Hybrid PET/CT allows evaluating the location of the stenosis, level, and functional myocardium damage [10]. Moreover, the calcium index could be computed to patients with CAD and to proceed noninvasive angiography with contrast [9].
Production of PET/CT scanners starts with adding a CT system (which can produce 64 or more sections) to the PET scanner. These integrated systems work together to help the patient. All software is combined into a mechanical part of the PET device. One universal gantry is used with integrated software with PET/CT interface. CT portal is used in front of the device or back of it. Originally CT component in PET/CT device was used to correct attenuation and to see the patient's anatomy more precisely. Other more modern tomographs are able not only to correct attenuation but evaluate coronary calcium index and make CT angiography. All information about CT could be found in SNMMI/ASNC/SCCT guidelines [11].
Multiple layer CT angiography improved fast and became the most promising noninvasive heart artery examination method. Because of PET/CT scanners and improved software, multidisciplinary methods came to life with whom coronary arteries can be evaluated thoroughly using coronary artery calcium index and coronary angiography [12]. Moreover, PET/CT allows evaluating myocardium viability and metabolism [13].
Hybrid PET/CT helps to evaluate risk level and helps to make a decision about which CAD treatment strategy to choose. Compared studies showed that half of angiographically significant stenoses are not related to perfusion defects and are not hemodynamically significant. In contrast, coronary anomalies are found to patients with normal perfusion; First clinical trials were presented by Namdar et al., using PET with [13N]NH3 and four-layer CT angiography for 25 patients with CAD. Sensitivity, specificity, positive and negative, and predictive values foreseeing significant stenoses were 90%, 98%, 82%, and 99% respectively compared to golden standard – PET and angiography. This research shows that hybrid heart examination is crucial non-invasive for CAD and choice of treatment strategy [14, 15, 16].
Previous studies show that if perfusion defects are not found with PET/CT, then the probability for a patient (who has a moderate or high risk for CAD) to die is very low (1%). Also, patients who have less recurrent ischemia are treated with medication more effectively than a revascularization procedure. Although patients with large ischemia regions treated with invasive procedures receive better outcomes. Discussed methods allow specialists to decide which treatment strategy to use [2].
Diagnostic PET accuracy for CAD is high (sensitivity and specificity are more top than 90%). It is unique that with the help of PET, scientists can measure blood flow mL/min/g in the active and resting phase. Studies show that blood flow analysis with PET significantly reveals CAD incidence. Moreover, hybrid PET/CT is developing fast and can examine patients in the 45-minute interval in one session [2, 18].

GLUCOSE METABOLISM IN MYOCYTE

In specific surroundings, myocyte uses glucose for proper function for energy production and survival. In the aerobic environment, myocyte uses long-chain fatty acids, and this provides 70% of all energy demand. About 20% is received from glucose. Postprandial glucose rise is used for energy production firstly; this fast adaptation is crucial for normal heart function and is independent of lack of substrate, hormone imbalances, heart work, or other factors.
Chronic adaptation for substrate metabolism is seen after abnormal stimuli are observed. For example, if there is a chronic insufficiency of myocardial blood flow when the myocardium is hybernated leads to excessive dependability from plasma glucose. That is the mechanism of protection against hypoxia. On the other hand, if diabetes mellitus is present, then fatty acids are used more, and glucose is becoming not that necessary. This way of receiving energy is harmful to heart cells, which lead to heart dysfunction [19].

FDG is used for the detection of viable myocardium because glucose metabolism is a sign of biological activity. Also, FDG is used to diagnose patients with heart sarcoidosis, moderate or intense vasculitis, and heart implant infection where inflammation is the primary pathogenetic process.
Myocardial glucose intake depends on serum glucose and insulin level. Patient preparation also plays a crucial role in the need of getting an accurate view of myocardial viability. There are specific protocols that advises how to cope with a patient who has diabetes and those who do not [5, 20].
PET/CT is an essential procedure for diagnosing CAD because it allows detecting atherosclerotic damage (CT) and its‘ effect on blood flow (PET) in a single scan. It provides essential CAD diagnostic value and has a considerable advantage compared to CT or PET separately [18].

ECHOCARDIOGRAPHY

Echocardiography is cheap, convenient, and is easy to do. This diagnostic method can show heart function and hemodynamics. It is the most common diagnostic modality after cardiography and chest x-ray. For patients with acute heart pain, transthoracic echocardiography is made to evaluate myocardial movement and to diagnose acute coronary events. It is easy to find some dyspnea reasons such as dissection of the aorta or heart tamponade [47].

CARDIAC MAGNETIC RESONANCE IMAGING

Magnetic Resonance Imaging procedure in cardiology is making progress significantly fast, especially when there is a possibility to combine and synchronize it with electrocardiography. Using intravenous contrast agents, it is possible to evaluate myocardial structure changes. MRI is a noninvasive diagnostic method that allows examining a patient while he is laying on his back. MRI has better soft tissue differentiation ability than CT even without contrast agent.
MRI similarities compared to other radiologic methods – there is no radiation, the procedure is noninvasive, and there is no known negative effect to the human body, only that tissue collects radio waves, and body temperature may increase to around 1 degree Celsius during the procedure. To have quality images, 1,5 T MRI is required. 3 T MRI machines are better only at evaluating myocardial perfusion. While diagnostics with MRI is evolving and progressing, ventricle general and segmental functions could be evaluated easily (resolution is better than CT). Valve and vessel blood flow analysis could be performed because of great video resolution, and MRI is the easiest method to evaluate right ventricle function compared to other modalities. MRI disadvantages are excessive patient cooperation during the long phase of the examination, which takes 1,5 hours, is expensive, and requires a long time to proceed [21].
Heart muscle evaluation for patients with CAD and left ventricle insufficiency is crucial. Many methods are being used in clinical practice to evaluate heart morphology, function, and metabolism. Every method and procedure has its‘ own diagnostic advantage for measuring myocardial viability, although no one of each can show heart wall damage. MRI with contrast was presented as an alternative for evaluating heart damage. Few experimental studies show a comparison of histologic and contrast MRI views of muscle necrosis, moreover, contrast MRI allows to detect reversible and permanent myocardium defects with the help of contrast agent, which accumulates transmurally. Depending on the radiotracer’s presence in heart muscle contractile function, prognosis can be predicted after revascularization of infarcted myocardium in the presence of CAD [22, 23].
Late gadolinium enhancement (LGE) is a unique feature of MRI and is related to different gadolinium contrast agent presence in normal and damaged myocardium. When a marked gadolinium agent is introduced into the bloodstream, it moves to expanded intracellular space of infarcted heart cells and shows scientists which parts are affected by necrosis. Maximal signal strength is received 10-20 minutes after contrast agent introduction [23]. Late gadolinium enhancement test has a high sensitivity level and can detect

CAD caused scars. Using the late gadolinium enhancement technique, small scars that were not identified with cine MRI were found [24]. It is calculated that the scar area must cover more than 50% of muscle for wall movement anomaly to occur. Also, using late gadolinium enhancement technique, infarctions can be found, which were not seen with SPECT. Surprisingly, microinfarctions are found created with percutaneous angiography and a slight increase of creatine kinase [25].

LGE MRI correlates well with PET/CT findings of myocardium blood flow and metabolism and is more sensitive to endocardial infarctions. Studies also show importance in examining myocardium after revascularization [26]. Moreover, there is a vast amount of information showing MRI benefits, that is the reason why many think MRI with LGE is the golden standard in examining myocardial viability better than PET/CT [23, 27].

Using MRI high-resolution myocardium images is received, and the high contrast between tissue and blood allows doctors to evaluate heart chambers more precisely. CAD is usually diagnosed when abnormal heart movement is observed using an echoscope with dobutamine or myocardium perfusion method after injection of gadolinium radiotracer. Detecting scars or necrosis with the LGE technique is a unique MRI ability [14]. On the other hand, chronic ventricle insufficiency with altered blood flow and metabolism can be evaluated using PET/CT, though tissue composition (a scar or normal tissue) with MRI [28]. MRI is much better for evaluating subendocardial or transmural damage because of its high image resolution. In addition, it is used to evaluate wall scaling during ventricular contraction. When a viable myocardium shows a distortion of the marked magnetic lines through the systole, the myocardial scar will not show such differences [29]. In one study, scientists compared MRI and PET with FDG. He discovered that MRI with late gadolinium enhancement closely agrees with PET/CT data as a myocardial scar marker. However, MRI has more often identified a scar than PET/CT, with a higher resolution [29].

Single Photon Emission Radionuclide Computed Tomography (SPECT)

SPECT is a radionuclide test where gamma rays are used to obtain an object's two-dimensional image. The SPECT machine consists of a gamma camera, a bed for the patient, a computer that produces tomographic reconstruction, software, and interface.

Various radiotracers (usually (99m Tc) -MIBI) are used for examination. Unlike PET, gamma photons are released directly from the radioactive material. PET radiotracers annihilate positrons to electrons a few millimeters away and emit two gamma photons that are thrown in the opposite direction.

Radiated photons are "captured" by the collimators, which leave scintillation (glow) in scintillation crystal. The photoelectric multiplier is sensitive to that glare, which is captured and processed by the computer. From 1 to 3, gamma chambers are used in SPECT. You need to scan at a 360° angle to get more accurate images.

SPECT is about three times cheaper than PET/CT, and one of the most sensitive cardiac perfusion modality (83% accuracy - 85%, sensitivity, 72% specificity). Disadvantages of SPECT: inadequate image due to scattered gamma rays compared to PET/CT, last long, the image quality decreases if the patient moves and artifacts are possible due to the random distribution of radiotracer. The sensitivity of the SPECT to detect angiographically proven CAD is high (87-89%), and specificity is 89%. SPECT not only identifies a lesion but shows where and what size it is [48]. Also, patients with less reversible ischemia have been shown to have a greater chance of survival while receiving medication than a revascularization procedure, whereas, in patients with high ischemic zone, invasive revascularization procedures are more necessary [49]. These SPECT properties are useful for selecting patients for percutaneous coronary intervention and possible revascularization.

Myocardial perfusion reserve data obtained with MRI and PET/CT correlate well in the evaluation of myocardial blood flow. Both methods show myocardial damage accurately and similarly [30]. Volumes of the heart were measured by PET/CT, left ventricle EF and wall movement corresponds well to the parameters determined by MRI [3]. In addition. Higher resolution images are obtained with MRI compared to PET/CT. MRI should be an alternative method for the assessment of patients with CAD in centers where it is not possible to study myocardial viability with PET/CT, or it is just too expensive [31]. Similar results are observed when comparing PET/CT with SPECT and PET/CT with echocardiography [23, 45, 47, 48].

RESEARCH OBJECT

Patients who are examined and treated in Lithuanian University of Health Sciences Kaunas Clinics Department of Cardiology after acute myocardial infarction with significantly decreased left ventricular ejection fraction (LV EF ≤40%) and serious coronary artery damage which revascularization is compromised because of myocardial scarring.

SELECTION OF SUBJECTS

Participant selection was performed according to disease (CAD, MI), present heart insufficiency, and examination technique (echocardiography, SPECT, PET/CT, and MRI). There were 30 participants who were examined in Lithuanian University of Health Sciences Kaunas Clinics from 2012 to 2016.

RESEARCH ORGANIZATION AND METHODS

There is not a daily routine to perform all mentioned radiologic examination procedures to patients after acute myocardial infarction even in specialized Lithuanian hospitals. This was the reason for choosing a prospective trial. Patient information was examined (case histories and records). Some patients decided not to participate in the trial or had contraindications for MRI.

Left ventricle EF, EDV, ESV, and sixteen heart segment damage was evaluated with four different modalities:

1) Echocardiography
2) Single Photon Emission Computed Tomography (SPECT) using (99mTc)-MIBI radiotracer.
3) Positron Emission Tomography/Computed Tomography (PET/CT) using (18F)-FDG radiotracer.
4) Heart Magnetic Resonance Imaging (MRI) using late gadolinium enhancement with Gd-DO3A-butrol radiotracer.

Heart segments were numbered from heart apex to base. Sixteen segments are: basal anteroseptal (14) basal anterior (13), basal lateral (18), basal posterior (17), basal inferior (16), basal inferioseptal (15), mid anteroseptal (8), mid anterior (7), mid lateral (12), mid posterior (11), mid inferior (10), mid inferoseptal (9), apical anterior (1), apical lateral (5,6), apical inferior (4), apical septal (2,3).

Using echoscope, myocardium segments were marked by doctor and movement evaluated in scale by a number. If the segment value is three or more, that means that the segment is not functioning well and has akinetic zones. Examining with SPECT significant perfusion defect was considered if the index value is 3,5 or more. Segment examined using PET had little viability if glucose accumulation in heart muscle was lower than 50%, and segments that were examined with MRI and had transmural scar were considered to be not viable at all.

METHODS OF DATA ANALYSIS

Statistical data analysis was performed using SPSS (Statistical Package for the Social Sciences) program („IBM," Armonk, New York, USA). Data belonging to the normal distribution was checked by Kolmogorov-Smirnov and Shapiro-Wilk criteria. Distributed values are given as averages with standard deviation (SD) in brackets. Data is given in absolute value.

While analyzing the relationship between different cardiac testing methods chi-square, ($\chi 2$) probability criterion was performed. Myocardial segment damage was checked by the McNemar test and a paired t-test was performed for EF, EDV, and EST. The results were considered statistically significant when p is lower than 0.05.

GENERAL DATA OF THE SUBJECTS

The mean age of subjects (n=30) during the study was 67.8 years (range 43-84 years). Distribution by sex - 25 males (83.3 %) and five females (16.6 %). Patients had risk factors: six (20 %) were obese (BMI ≥30 kg/m2), ten (33 %) had overweight (BMI 25-29,99 kg/m2), presence of dyslipidemia – twenty-five (83.3 %), twenty-one patient (70 %) had arterial hypertension, seven patients (23.3%) were smoking, two (6.6%) had diabetes, and fourteen had a family history of CAD (46.6%).

Table 1. Risk factors

Risk factor	N	%	Risk factor	N	%
BMI ≥30 kg/m2	6	20	Smoking	7	23,3
BMI 25–29,99 kg/m2	10	33.3	Diabetes	2	6,6
Dislipidemia	25	83.3	Family history	14	46,6
Arterial hypertension	21	70	Age >45 male, >55 female	29	96,6
Male	25	83,3			

According to anamnesis, atrial fibrillation was diagnosed in five (16.6%) patients and atrial flutter in one (3.3%). Ventricular extrasystoles were found in five (16.6%) and ventricular tachycardia to four (13.3%) patients — the weakness of the sinoatrial node diagnosed to (3.3%) patient. According to NYHA (New York Heart Association) heart failure criteria, two subjects (6.6%) had class II heart failure, nineteen (63.3%) had grade III, and nine (30%) had grade IV. Six patients (20%) had a stroke. The oncologic process has been previously recorded for one patient (3.3%). One (3.3%) patient had the chronic obstructive pulmonary disease (COPD), and two (6.6%) were diagnosed with anemia. The first stage of chronic kidney disease (CKD calculated by glomerular filtration rate) was diagnosed to one (3.3%), the second stage CKD to four (13.3%), the third stage - to three (10%). Coronary artery bypass graft (CABG) operation was conducted on six (20%) subjects.

It was evaluated how many drugs were used. The most common drug was adrenal blockers, 28 patients used it (93.3%), no one used calcium channel blockers, ACE inhibitors was prevalent to 21 (70%) patients, Aldosterone receptor blockers - 5 (16.6%), ivabradine - 8 (26.6 %), digoxin - 3 (10%), torazemide - 20 (66.6%), spironolactone - 20 (66.6%), aspirin - 27 (90%), clopidogrel - 10 (30%), vitamin K antagonists - 9 (30 %), nitrates - 17 (56.6%), statins - 28 (93.3%), one patient (3.3%) treated with oral drugs and another one (3.3%) with insulin. Allopurinol was taken by 6 (20%) patients.

Almost all patients were treated with the best possible treatment because they were treated with beta-adrenergic blockers (93.3%), ACE inhibitors, or aldosterone receptor inhibitors (70 + 16.6 = 86.6%). These three drugs are adequate treatment for patients with CAD and heart insufficiency. Statins (93.3%) are also used to achieve the optimum treatment result, while aspirin is always given after an acute myocardial infarction, although two patients (6.6%), aspirin was contraindicated because of a high risk of bleeding from the gastrointestinal tract. Despite the best available treatment, symptoms continued, and patients still contacted doctors. After advanced radiological examinations, the treatment regimen for CAD and heart failure was chosen: to continue medication, to prescribe interventional, or to treat surgically.

Table 2. Anamnesis

Anamnesis		N	%	Anamnesis		N	%
Atrial fibrillation		5	16.6	CKD	I	1	3.3
Atrial flutter		1	3.3		II	4	13.3
Ventricular extrasystoles		5	16.6		III	3	10
Ventricular tachycardia		4	13.3	Anemia		2	6.6
The weakness of the sinoatrial node		1	3.3	Stroke		6	20
HF, NYHA	I	0	0	Cancer		1	3.3
	II	2	6.6	COPD		1	3.3
	III	19	63.3	Heart bypass surgery		6	20
	IV	9	30				

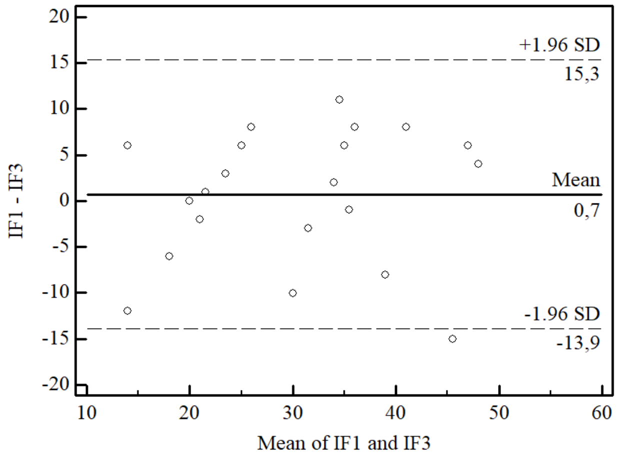
Table 3. Drug use among patients

Medication	N	%	Medication	N	%
Beta adreno blocker	28	93.3	Alopurinol	6	20
Calcium channel blocker	0	0	Aspirin	28	93.3
ACE inhibitor	21	70	Clopidogrel	10	30
Aldosterone receptor blocker	5	16.6	Vit. K antagonist	9	30
Ivabradine	8	26.6	Nitrates	17	56.6
Digoxin	3	10	Statins	28	93.3
Torazemide	20	66.6	Injections of insulin	1	3.3
Spironolactone	20	66.6	Metformin	1	3.3

While assessing the history of past or existing arrhythmias, it was observed that the left bundle branch block occurred in most cases - 14 patients (46.6%), while other arrhythmia monitored less often: sinus rhythm - 4 (13.3%), atrioventricular block - 4 (13.3%), premature complexes - 1 (3.3%), while the right bundle branch block have occurred to nobody (0%). Resynchronization therapy has not been applied to anyone. Moreover, patients with intracardiac defibrillators are not included in the study because MRI is contraindicated for them. Coronary angiography was performed to all 30 (100%) patients. Right coronary artery stenosis was found to (RCA> 75%) 21 (70 %) patients, anterior interventricular branch (AIB> 75%) to 28 (93.3 %), circumflex branch (Cx> 75%) to 23 (76.6 %).

Pair Differences Of Ejection Fractions (EF) Between Test Methods

Paired t-test checks whether test value t is close to zero. If so, the difference between results of the two modalities EF, EDV, and ESV values is negligible. It was found that only paired difference between echocardiography and PET/CT in EF, EDV and ESV was negligible. However, comparing the SPECT with PET/CT, and MRI with PET/CT differences between the EF, EDV, and ESV is significant. If 95% of normal distribution includes a zero value, the differences between the methods are considered to be statistically insignificant.



The paired difference between echocardiography (EF1) and PET/CT (EF3).

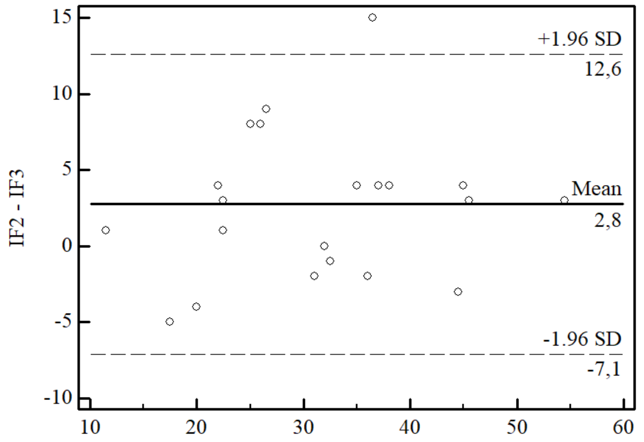
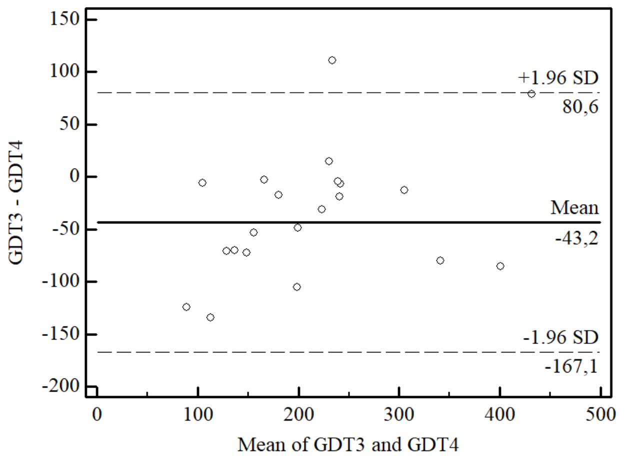


Fig. 2. Paired EF difference of SPECT (EF2) and PET/CT (EF3).

PAIRED END-DIASTOLIC VOLUME (EDV) DIFFERENCES BETWEEN TEST METHODS



4 Fig. The paired difference between echocardiography and PET/CT (EDV3).

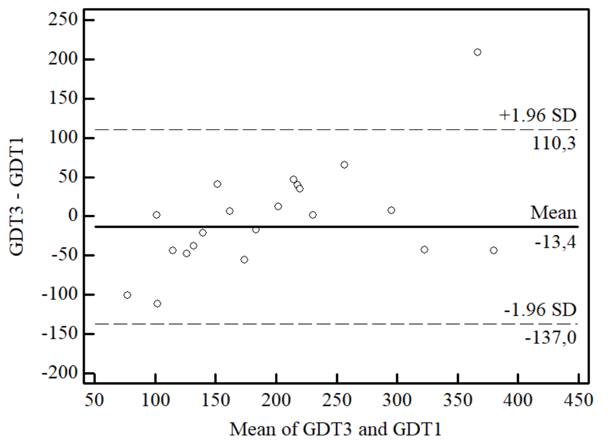


Fig.5. Paired GDT difference of SPECT (EDV1) and PET/CT (EDV3)

EDV difference between echocardiography and PET/CT was not significant (OR 13.36 [95% CI -10,18-36,92], p=0.25), but paired GDT difference between SPECT and PET/CT study techniques - significant (OR 37.7 [95% CI 20.08-55.39], p <0.05), same result with MRI and PET/CT modalities (OR 43.23 [95% CI -66.82-(-19.63)], p <0.05).

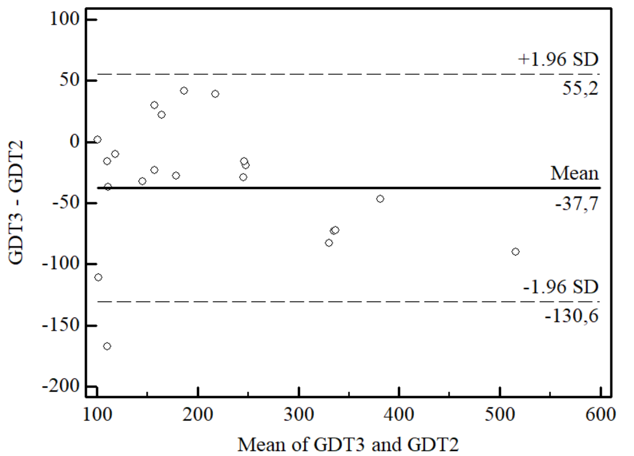
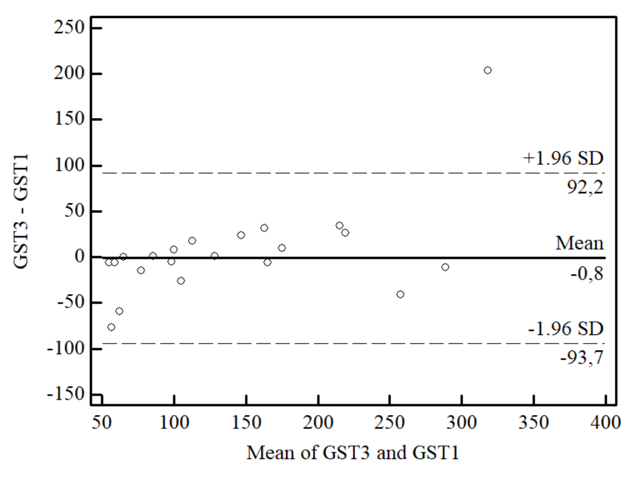
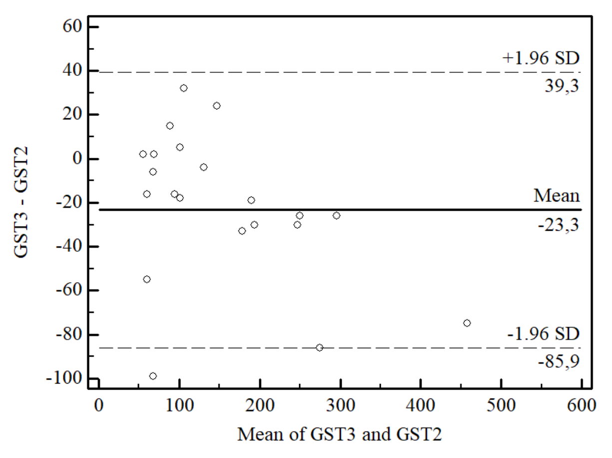


Fig. 6. Paired EDV difference between MRI (EDV2) and PET/CT (EDV3)

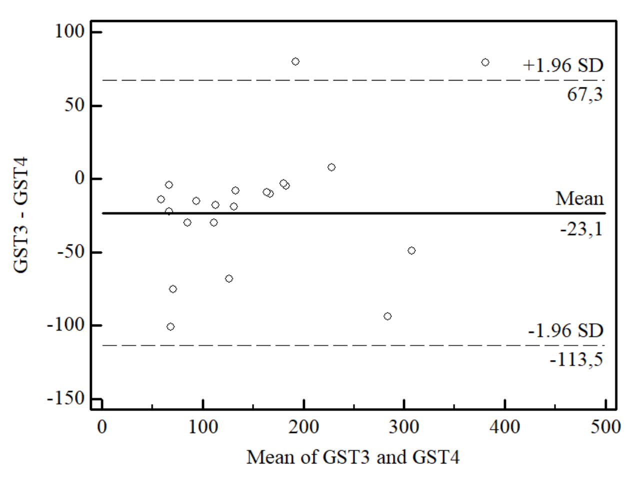


7. Paired ESV Difference of Echoscope (ESV1) and PET/CT (ESV3)



8. Paired ESV difference between SPECT (ESV2) and PET/CT (ESV3)

PAIRED END-SYSTOLIC VOLUME (ESV) DIFFERENCES BETWEEN TEST METHODS



9 Fig . Paired ESV difference between MRI (ESV4) and PET/CT (ESV3).

Pair ESV difference between echocardiography and PET/CT modalities was not significant (odds ratio 0.76 [95% CI -16,93-18,46], p=0.93), but paired ESV difference between SPECT and PET/CT was significant (odds ratio 23.267 [95% CI, 11.34-35.19], p<0.05) together with ESV difference between MRI and PET/CT (odds ratio - 23.13 [95% CI-4 0.35-(-5.90)], p<0.05).

STATISTICAL ANALYSIS OF DAMAGED SEGMENTS

Four hundred eighty myocardium segments were analyzed with four different methods in total. Hibernating myocardium areas larger than 10% was found in a combination of SPECT and PET/CT for eight (26.6%) patients.

It was calculated after examination with each diagnostic method of how many damaged segments were detected. Independent data was examined, results were reported, and the Pearson Chi-square criterion checked their significance.

Most of the damaged myocardial segments showed the statistically insignificant difference (p> 0.05), a significant difference was observed only between lower apex (4), and lateral apex (5, 6) segments (p<0.05). That is the reason why we can say that segment damage is detected similarly with different methods.

While comparing the studies, the values of apical lateral (5, 6) and apical septal (2,3) segment lesion detection difference was statistically significant between echocardiography, SPECT, PET/CT and MRI (p <0.05). There is no complete correlation between echocardiography, SPECT, PET/CT, and MRI in evaluating myocardial damage.

TABLE 4. NUMBER OF DAMAGED MYOCARDIAL SEGMENTS

Segment	Number of damaged myocardial segments (out of 30 patients)				P-value
	Echoscopy	GNP	PET / CT	IHR	
14	12	10	9	10	0.88
13	10	6	5	7	0.46
18	4	1	2	2	0.52
17	4	6	5	7	0.78
16	9	7	4	7	0.48
15	3	4	6	9	0.2
8	22	16	15	18	0.26
7	19	17	15	16	0.76
12	4	3	2	3	0.86
11	7	8	4	5	0.56
10	11	11	7	9	0.64
9	9	6	5	7	0.64
1	20	22	17	17	0.43
5.6	20	16	9	13	<0.05
4	20	15	9	12	<0.05
2.3	20	13	14	18	0.22

STATISTICAL ANALYSIS OF DEPENDENT DATA

Dependent data analysis was performed, and Spearman correlation coefficients (r) and kappa value (κ) were determined, data were checked with the McNemar test.
The greater the Spearman correlation factor is, the greater the segment damage correlation is, using different diagnostic methods.
When Spearman correlation coefficients were identified (r> 0.05), and values of McNemar test checked (p <0.05), It was found that there is a correlation in the detection of thirteen (from sixteen) myocardial segments damage with all four different modalities. Kappa (κ) value indicates a higher or lower coincidence level.

5 table. Interpretation of Kappa value

Kappa (κ) value	Compliance
<0.20	Bad
0.21-0.40	Enough
0.41-0.60	Average
0.61-0.80	Good
0.81-1.00	Very good

Table 6. Myocardial segments coincidence analysis

Segment of myocardium		Modality	Spearman correlation rate (r)	Kappa (κ) value	McNemar test value
basal anteroseptal (14)	PET/CT	Echocardiography	0,65	0,64	0,38
		PET/CT	0,72	0,77	1,00
		MRI	0,93	0,92	1,00
basal anterior (13)	PET/CT	Echocardiography	0,44	0,40	0,13
		SPECT	0,89	0,89	1,00
		PET/CT	0,81	0,79	0,50
basal lateral (18)	PET/CT	Echocardiography	-0,06	-0,05	0,63
		SPECT	-0,13	-0,13	1,00
		MRI	0,80	0,78	1,00
basal posterior (17)	PET/CT	Echocardiography	0,38	0,38	1,00
		SPECT	0,45	0,44	0,69
		MRI	0,58	0,58	1,00
basal inferior (16)	PET/CT	Echocardiography	0,76	0,74	0,25
		PET/CT	0,91	0,90	1,00
		MRI	0,91	0,90	1,00
basal inferoseptal (15)	PET/CT	Echocardiography	0,44	0,40	0,13
		SPECT	0,53	0,50	0,22
		PET/CT	0,37	0,37	0,73
mid anteroseptal (8)	PET/CT	Echocardiography	0,34	0,31	0,11
		SPECT	0,33	0,33	1,00
		MRI	0,60	0,6	0,69
mid anterior (7)	PET/CT	Echocardiography	0,42	0,40	0,18
		SPECT	0,94	0,93	1,00
		MRI	0,94	0,93	1,00
mid-lateral (12)	PET/CT	Echocardiography	-	-	0,25
		PET/CT	-	-	0,25
		MRI	-	-	0,25
mid posterior (11)	PET/CT	Echocardiography	0,35	0,35	1,00
		SPECT	0,71	0,67	0,25
		MRI	0,88	0,87	1,00
mid inferior (10)	PET/CT	Echocardiography	0,68	0,63	0,06
		SPECT	0,61	0,6	0,38
		MRI	0,92	0,91	1,00
mid inferoseptal (9)	PET/CT	Echocardiography	0,38	0,38	1,00
		SPECT	0,51	0,51	1,00
		MRI	0,32	0,31	1,00
apical anterior (1)	PET/CT	Echocardiography	-	0,35	<0,05
		SPECT	-	0,05	0,12
		MRI	-	0,54	0,13

apical lateral (5,6)	PET/CT	Echocardiography	0,34	0,21	<0,05
		SPECT	0,48	0,38	<0,05
		MRI	0,35	0,29	0,07
apical inferior (4)	PET/CT	Echocardiography	0,4	0,27	<0,05
		SPECT	0,39	0,36	0,18
		MRI	0,59	0,59	1,00
apical septal (2,3)	PET/CT	Echocardiography	0,76	0,74	0,13
		SPECT	0,73	0,73	1,00
		MRI	0,46	0,46	1,00

While comparing echocardiography with PET/CT, and SPECT with PET/CT basal lateral (18) segment results completely divides, as Spearman coefficient, Kappa value is negative (ultrasonographically observed only one lesion, with PET/CT – 3 and with SPECT - 4). The coincidence level is very low. A similar trend has been observed, and with mid-lateral (12) segment, as with PET/CT procedure, any mid-lateral (12) segment lesion was observed. Spearman correlation coefficient and Kappa value cannot be calculated because some PET/CT test result is constant (not any specific myocardial zone lesion was found). It is also impossible to count the Spearman correlation coefficient of the apical frontal segment (1), as neither one patient examined with PET/CT had myocardial damage. This data can be considered as completely unfamiliar.

It seems that the segments of PET/CT and MRI have the most significant similarities, as the majority (10 out of 16) segments Spearman ratio and 11 out of 16 segments Kappa values are closest to one.

If the McNemar test value is > 0.05, then we can reject the hypothesis that the results of the different test methods are significantly different when evaluating segment damage. All damaged myocardium segments examined with PET/CT coincided with echocardiography, SPECT and MRI tests, except apical frontal segment (1) of the PET/CT and echocardiography (McNemar - <0.05) and PET/CT with echocardiography (McNemar - <0.05) and PET/CT with MRI (McNemar <0.05) for apical lateral (5, 6) segment. Also, a value that not passed McNemar test was calculated by examining the apical inferior (4) segment with PET/CT and echocardiography.

In conclusion, it could be said that if we get McNemar test value is <0.05, then there is no coincidence between the test methods. While investigating patients, only two segments lesion diagnosis mismatched between methods.

Analysis of heart EF, EDV, and ESV

A comparison of PET/CT with echocardiography, SPECT, and MRI revealed that there is no statistical reliability of significant errors in EF, EDV, and ESV between the same methods (p>0.05).

Using echocardiography, it was found the most damaged segments compared with PET/CT, SPECT, and MRI - the biggest mismatch result. The biggest viable myocardial area was calculated using PET/CT.

While examining EF, EDV, and ESV detected with MRI and comparing it with other modalities; it was clear that significantly similar data was received only using MRI and SPECT (p>0.05). The difference is insignificant if using a paired Student t-test for dependent samples change close to 0, and 95% CI includes 0.

Table 10. MRI EF , EDV and ESV P values for comparison

Couple of modalities (EF)		**P value (EF)**	**P value (EDV)**	**P value (ESV)**
MRI	Echocardiography	0.77	<0.05	<0.05
	SPECT	0.57	0.69	0.99
	PET/CT	<0.05	<0.05	<0.05

MRI is a 'golden standard' for cardiac volume and function. This study found that using MRI and SPECT EF, EDV, and ESV coincide well ($p>0.05$). EF also coincides with echocardiography ($p=0.77$). MRI and PET/CT EF, EDV, and ESV were compared, and results do not match ($p<0.05$).

Patients who have more than 10% of hibernated myocardium found with SPECT perfusion and PET/CT metabolism tests coronary artery bypass grafting (CABG) would be useful because revascularized hibernated myocardium recovers to the previous stage. However, if the scar is already formed and the hibernating myocardial area is less than 5%, the CABG would not be beneficial to the patient. While comparing SPECT and PET/CT images, the hibernating left ventricular zone was found to be more than 10% in 8 (26.6%) patients, CABG is recommended for them.

DISCUSSION

In this study, heart muscle motility, perfusion, and metabolism were evaluated by various modalities in patients after acute myocardial infarction (MI). The most important results were found by comparing the levels of segment damage. It has been observed that segmental damage is well seen by methods of echocardiography, SPECT, PET/CT, and MRI.

In one study, after PET/CT and MRI evaluation of left ventricle EF, EDV and ESV were found a good correlation between function parameters, but some variation was seen, so these two studies cannot be used as a replacement for each other [59]. Although after the assessment of echocardiography and MRI results, there was found proper matching in EF [57]. Other studies showed similarities between methods for evaluating EF, cardiac volumes, and vitality [53, 54, 55, 56, 57, 58].

In another study, 289 segments were evaluated with PET/CT, and 82% of the segments were identified as damaged while with MRI, only 72.6%. Both methods correlated with 75% precision [60]. Similar situations observed with echocardiography and MRI modalities [61]. Another study showed that PET/CT and MRI correlate carefully evaluating left ventricular volumes and EF [58], although this article shows discrepancies in EDV and ESV between the two methods of examination.

Transmural heart defects closely correlate between MRI and PET/CT. Due to the high image resolution, MRI identifies even subendocardial scars. However, more research is required to find out whether MRI is more useful than PET/CT in assessing myocardial recovery after revascularization because there is still not enough data if MRI could replace PET/CT as a starting point in the investigation of myocardial viability [62].

PET/CT research is getting more available, and its accuracy is higher than SPECT. PET/CT sensitivity and specificity for CAD diagnosis are 89 % and 90%, respectively [4, 63]. PET/CT accuracy is achieved through improved video resolution, overlay matching, and attenuation correction. This gives an advantage to studying obese patients, who are particularly prone to increasing the chance of artifacts. Echocardiography is also not the best study for patients who have a BMI of more than 30. Scientists have researched and found that PET/CT is very similar but slightly more accurate than SPECT (89% and 79%) in myocardial injury determination, including obese patients. Also, researchers have shown that the quality of the images was better with PET/CT (78%) than with SPECT (62%) [51]. Accurate diagnosis and prognosis for the patient are important, and various heart examination techniques accurately detect cardiac lesions. That helps to determine the appropriate treatment for the patient. Moreover, the probability of another cardiovascular event must be evaluated for each patient [66]. The PET/CT study is not an extremely frequent study, as it is costly for the healthcare system [64].

The accuracy of echocardiography is heavily dependent on investigating physicians because it is difficult to assess wall movements without a large margin of error objectively. Besides this, the patient's physique and the acoustic window have influence [65]. Due to examined reasons, echocardiography correlates not so well with PET/CT while assessing myocardial segments,

but EF, EDV, and ESV results correlate well with those from PET/CT study. As echocardiography develops, it is assumed that in the future, the echocardiographic examination will be used to evaluate myocardial movements more precisely.
To asses ideally, echocardiography, SPECT, PET/CT, and MRI should be proceeded in a period of a few days, because over time, myocardial structure changes, which may change cardiac parameters. The data compared in this study may also have been different because echocardiography, SPECT, PET/CT, and MRI were not performed on the same day.
Coronary artery bypass graft may be needed for those with more than 10% of hibernating myocardium in the left ventricle, believing that post-operative heart muscle viability, movement, and function will be restored. Although further research is needed to optimize this procedure [67].

CONCLUSIONS

1) Non-invasive cardiovascular imaging modalities (echocardiography, (99mTc)-MIBI SPECT, (18F)-FDG PET/CT and MRI) correlate well because 13 of 16 segment parameters match between types of examination. Spearman correlation coefficient ($r>0,05$) and Kappa value ($\kappa>0,05$) was counted, McNemar test was performed ($p>0,05$).
2) The agreement is seen between ultrasound and PET/CT when compared to EF, ESV, and EDV. Agreement between MRI and SPECT is seen too. Only EF (without EDV and ESV) agreement is seen between echocardiography and MRI. The paired t-test was performed ($p>0,05$).
3) PET/CT ("gold standard") and CMR damage of segments (viability) correlate best of all because most of the segments (10 of 16) Spearman coefficients and 11 of 16 segments Kappa values are close to one.
4) Comparing MRI ("gold standard") EF, EDV, ESV with other modalities, significantly similar data could be obtained only with MRI and SPECT. EF (without EDT and ESV) agreement is seen between echocardiography and MRI alone ($p>0,05$).

REFERENCES

1. Knuuti, J., & Bengel, F. M. (2008). Positron emission tomography and molecular imaging. Heart (British Cardiac Society), 94(3), 360-367.

2. Saraste, A., & Knuuti, J. (2012). Cardiac PET, CT, and MR: What are the advantages of hybrid imaging? Current Cardiology Reports, 14(1), 24-31.

3. Schaefer, W. M., Lipke, C. S., Nowak, B., Kaiser, H. J., Buecker, A., Krombach, G. A., et al. (2003). Validation of an evaluation routine for left ventricular volumes, ejection fraction and wall motion from gated cardiac FDG PET: A comparison with cardiac magnetic resonance imaging. European Journal of Nuclear Medicine and Molecular Imaging, 30(4), 545-553.

4. Al Moudi, M., & Sun, Z. H. (2014). Diagnostic value of (18) F-FDG PET in the assessment of myocardial viability in coronary artery disease: A comparative study with (99m)tc SPECT and echocardiography. Journal of Geriatric Cardiology : JGC, 11(3), 229-236.

5. Dilsizian, V., Bacharach, S. L., Beanlands, R. S., Bergmann, S. R., Delbeke, D., Dorbala, S., et al. (2016). ASNC imaging guidelines/SNMMI procedure standard for positron emission tomography (PET) nuclear cardiology procedures. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 23(5), 1187-1226.

6. Al-Mallah, M. H., Sitek, A., Moore, S. C., Di Carli, M., & Dorbala, S. (2010). Assessment of myocardial perfusion and function with PET and PET/CT. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 17(3), 498-513.

7. Ghesani, M., Depuey, E. G., & Rozanski, A. (2005). Role of F-18 FDG positron emission tomography (PET) in the assessment of myocardial viability. Echocardiography (Mount Kisco, N.Y.), 22(2), 165-177.

8. Fihn, S. D., Gardin, J. M., Abrams, J., Berra, K., Blankenship, J. C., Dallas, A. P., et al. (2012). 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS guideline for the diagnosis and management of patients with stable ischemic heart disease: Executive summary: A report of the American college of Cardiology Foundation/American heart association task force on practice guidelines, and the American college of physicians, American Association for thoracic surgery, preventive cardiovascular nurses association, society for cardiovascular angiography and interventions, and society of thoracic surgeons. Circulation, 126(25), 3097-3137.

9. Schroeder, S., Achenbach, S., Bengel, F., Burgstahler, C., Cademartiri, F., de Feyter, P., et al. (2008). Cardiac computed tomography: Indications, applications, limitations, and training requirements: Report of a writing group deployed by the working group nuclear cardiology and cardiac CT of the European society of cardiology and the European Council of nuclear cardiology. European Heart Journal, 29(4), 531-556.

10. Knaapen, P., de Haan, S., Hoekstra, O. S., Halbmeijer, R., Appelman, Y. E., Groothuis, J. G., et al. (2010). Cardiac PET-CT: Advanced hybrid imaging for the detection of coronary artery disease. Netherlands Heart Journal: Monthly Journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation, 18(2), 90-98.

11. Dorbala, S., Di Carli, M. F., Delbeke, D., Abbara, S., DePuey, E. G., Dilsizian, V., et al. (2013). SNMMI/ASNC/SCCT guideline for cardiac SPECT/CT and PET/CT 1.0. Journal of Nuclear Medicine: Official Publication, Society of Nuclear Medicine, 54(8), 1485-1507.

12. Task Force Members, Montalescot, G., Sechtem, U., Achenbach, S., Andreotti, F., Arden, C., et al. (2013). 2013 ESC guidelines on the management of stable coronary artery disease: The task force on the management of stable coronary artery disease of the European society of cardiology. European Heart Journal, 34(38), 2949-3003.

13. Gaemperli, O., & Kaufmann, P. A. (2011). PET and PET/CT in cardiovascular disease. Annals of the New York Academy of Sciences, 1228, 109-136.

14. Gaemperli, O., Saraste, A., & Knuuti, J. (2012). Cardiac hybrid imaging. European Heart Journal Cardiovascular Imaging, 13(1), 51-60.

15. Timmer, S. A., Teunissen, P. F., Danad, I., Robbers, L. F., Raijmakers, P. G., Nijveldt, R., et al. (2016). In vivo assessment of myocardial viability after acute myocardial infarction: A head-to-head comparison of the perfusable tissue index by PET and delayed contrast-enhanced CMR. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology.

16. Vontobel, J., Liga, R., Possner, M., Clerc, O. F., Mikulicic, F., Veit-Haibach, P., et al. (2015). MR-based attenuation correction for cardiac FDG PET on a hybrid PET/MRI scanner: Comparison with standard CT attenuation correction. European Journal of Nuclear Medicine and Molecular Imaging, 42(10), 1574-1580.

17. Novack, V., Pencina, M., Cohen, D. J., Kleiman, N. S., Yen, C. H., Saucedo, J. F., et al. (2012). Troponin criteria for myocardial infarction after percutaneous coronary intervention. Archives of Internal Medicine, 172(6), 502-508.

18. Kajander, S., Joutsiniemi, E., Saraste, M., Pietila, M., Ukkonen, H., Saraste, A., et al. (2010). Cardiac positron emission tomography/computed tomography imaging accurately detects anatomically and functionally significant coronary artery disease. Circulation, 122(6), 603-613.

19. Knuuti, M. J., Nuutila, P., Ruotsalainen, U., Saraste, M., Harkonen, R., Ahonen, A., et al. (1992). Euglycemic hyperinsulinemic clamp and oral glucose load in stimulating myocardial glucose utilization during positron emission tomography. Journal of Nuclear Medicine: Official Publication, Society of Nuclear Medicine, 33(7), 1255-1262.

20. Juneau, D., Erthal, F., Chow, B. J., Redpath, C., Ruddy, T. D., Knuuti, J., et al. (2016). The role of nuclear cardiac imaging in risk stratification of sudden cardiac death. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 23(6), 1380-1398.

21. Valevičienė N., Palionis, D., Glaveckaitė, S., Matačiūnas, M., Petrulionienė, Ž., Tamošiūnas, A., Laucevičius, A. (2010). Pagrindinės širdies magnetinio rezonanso tyrimo indikacijos, praktiniai pavyzdžiai. Medicinos teorija ir praktika, 15(3), 266-275.

22. Achenbach, S., Friedrich, M. G., Nagel, E., Kramer, C. M., Kaufmann, P. A., Farkhooy, A., et al. (2013). CV imaging: What was new in 2012? JACC.Cardiovascular Imaging, 6(6), 714-734.

23. Wu, H. D., & Kwong, R. Y. (2008). Cardiac magnetic resonance imaging in patients with coronary disease. Current Treatment Options in Cardiovascular Medicine, 10(1), 83-92.

24. Underwood, S. R., Bax, J. J., vom Dahl, J., Henein, M. Y., Knuuti, J., van Rossum, A. C., et al. (2004). Imaging techniques for the assessment of myocardial hibernation. Report of a study group of the European society of cardiology. European Heart Journal, 25(10), 815-836.

25. Jaarsma, C., Schalla, S., Cheriex, E. C., Smulders, M. W., van

Dongen, I., Nelemans, P. J., et al. (2013). Incremental value of cardiovascular magnetic resonance over echocardiography in the detection of acute and chronic myocardial infarction. Journal of Cardiovascular Magnetic Resonance: Official Journal of the Society for Cardiovascular Magnetic Resonance, 15, 5-429X-15-5.

26. Kim, R. J., Wu, E., Rafael, A., Chen, E. L., Parker, M. A., Simonetti, O., et al. (2000). The use of contrast-enhanced magnetic resonance imaging to identify reversible myocardial dysfunction. The New England Journal of Medicine, 343(20), 1445-1453.

27. Schwitter, J., Nanz, D., Kneifel, S., Bertschinger, K., Buchi, M., Knusel, P. R., et al. (2001). Assessment of myocardial perfusion in coronary artery disease by magnetic resonance: A comparison with positron emission tomography and coronary angiography. Circulation, 103(18), 2230-2235.

28. Knuesel, P. R., Nanz, D., Wyss, C., Buechi, M., Kaufmann, P. A., von Schulthess, G. K., et al. (2003). Characterization of dysfunctional myocardium by positron emission tomography and magnetic resonance: Relation to functional outcome after revascularization. Circulation, 108(9), 1095-1100.

29. Ponikowski, P., Voors, A. A., Anker, S. D., Bueno, H., Cleland, J. G., Coats, A. J., et al. (2016). 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. Revista Espanola De Cardiologia (English Ed.), 69(12), 1167.

30. Morton, G., Chiribiri, A., Ishida, M., Hussain, S. T., Schuster, A., Indermuehle, A., et al. (2012). Quantification of absolute myocardial perfusion in patients with coronary artery disease: Comparison between cardiovascular magnetic resonance and positron emission tomography. Journal of the American College of Cardiology, 60(16), 1546-1555.

31. Kuhl, H. P., Beek, A. M., van der Weerdt, A. P., Hofman, M. B., Visser, C. A., Lammertsma, A. A., et al. (2003). Myocardial viability in chronic ischemic heart disease: Comparison of contrast-enhanced magnetic resonance imaging with (18)F-fluorodeoxyglucose positron emission tomography. Journal of the American College of Cardiology, 41(8), 1341-1348.

32. F Piepoli, M. (2017). 2016 European guidelines on cardiovascular disease prevention in clinical practice: The sixth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of 10 societies and by invited experts). International Journal of Behavioral Medicine.

33. Mirties priežasčių registras. Mirties priežastys 2016. Higienos instituto Sveikatos informacijos centras. ISSN 1392–9186. Link: http://www.hi.lt/uploads/pdf/leidiniai/Statistikos/Isankstiniai%20duomenys_2016.pdf

34. Boerma, T., Eozenou, P., Evans, D., Evans, T., Kieny, M. P., & Wagstaff, A. (2014). Monitoring progress towards universal health coverage at country and global levels. PLoS Medicine, 11(9), e1001731.

35. San Roman JA, Candel Riera J, Arnold J. Quantitative analysis of left ventricular function as a tool in clinical research, theoretical barrier of methodology. Rev Esp Cardiol 2009; 62: 535–551

36. Achenbach, S., Friedrich, M. G., Nagel, E., Kramer, C. M., Kaufmann, P. A., Farkhooy, A., et al. (2013). CV imaging: What was new in 2012? JACC.Cardiovascular Imaging, 6(6), 714-734.

37. Yang, Y., Yam, Y., Chen, L., Aljizeeri, A., Aliyary Ghraboghly, S., Al-Harbi, I., et al. (2016). Erratum to: Assessment of left ventricular ejection fraction using low radiation dose computed tomography. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 23(3), 422.

38. Demir H, Tan YZ, Kozdag G et al. Comparison of gated SPECT, echocardiography and cardiac magnetic resonance imaging for the assessment of left ventricular ejection fraction and volumes. Ann Saudi Med 2007; 27: 415–420

39. Danesh-Sani, S. H., Zakavi, S. R., Oskoueian, L., & Kakhki, V. R. (2014). Comparison between 99mTc-sestamibi gated myocardial perfusion SPECT and echocardiography in assessment of left ventricular volumes and ejection fraction--effect of perfusion defect and small heart. Nuclear Medicine Review.Central & Eastern Europe, 17(2), 70-74.

40. Shapiro, E. (1983). The first textbook of electrocardiography. Thomas Lewis: Clinical electrocardiography. Journal of the American College of Cardiology, 1(4), 1160-1161.

41. Srivatsava, M. K., Indirani, M., Sathyamurthy, I., Sengottuvelu, G., Jain, A. S., & Shelley, S. (2016). Role of PET-CT in the assessment of myocardial viability in patients with left ventricular dysfunction. Indian Heart Journal, 68(5), 693-699.

42. Qayyum, A. A., Qayyum, F., Larsson, H. B., Kjaer, A., Hasbak, P., Vejlstrup, N. G., et al. (2017). Comparison of rest and adenosine stress quantitative and semi-quantitative myocardial perfusion using magnetic resonance in patients with ischemic heart disease. Clinical Imaging, 41, 149-156.

43. Chua T, Yin LC, Thiang TH, Choo TB, Ping DZ, Leng LY. Accuracy of the automated assessment of left ventricular function with gated perfusion SPECT in the presence of perfusion defects and left ventricular dysfunction: correlation with equilibrium radionuclide ventriculography and echocardiography. J Nucl Cardiol 2000; 7: 301–311

44. Kakhki VR, Zakavi SR, Sadeghi R. Comparison of two software in gated myocardial perfusion single photon emission tomography, for the measurement of left ventricular volumes and ejection fraction, in patients with and without perfusion defects. Hell J Nucl Med 2007; 10: 19–23

45. Kakhki VR, Sadeghi R. Gated myocardial perfusion SPECT in patients with a small heart: effect of zooming and filtering. Clin Nucl Med 2007; 32: 404–406 11.

46. Kakhki VRD, Zakavi SR, Sadeghi R, Emadzadeh MR, Vejdani A. Normal values of left ventricular functional indices in gated 99mTc-MIBI myocardial perfusion SPECT. Iran J Nucl Med 2008; 16: 14–19.

47. Esmaeilzadeh, M., Parsaee, M., & Maleki, M. (2013). The role of echocardiography in coronary artery disease and acute myocardial infarction. The Journal of Tehran Heart Center, 8(1), 1-13.

48. Angelidis, G., Giamouzis, G., Karagiannis, G., Butler, J., Tsougos, I., Valotassiou, V., et al. (2017). SPECT and PET in ischemic heart failure. Heart Failure Reviews, 22(2), 243-261.

49. Heo, R., Nakazato, R., Kalra, D., & Min, J. K. (2014). Noninvasive imaging in coronary artery disease. Seminars in Nuclear Medicine, 44(5), 398-409.

50. Camici, P. G., Prasad, S. K., & Rimoldi, O. E. (2008). Stunning, hibernation, and assessment of myocardial viability. Circulation, 117(1), 103-114.

51. Bateman, T. M., Heller, G. V., McGhie, A. I., Friedman, J. D., Case, J. A., Bryngelson, J. R., et al. (2006). Diagnostic accuracy of rest/stress ECG-gated rb-82 myocardial perfusion PET: Comparison with ECG-gated tc-99m sestamibi SPECT. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 13(1), 24-33.

52. Javadi MS, Lautamaki R, Merrill J, et al. Definition of vascular territories on myocardial perfusion images by integration with true coronary anatomy: A hybrid PET/CT analysis. J Nucl Med. 2010;51:198–203

53. Bellenger, N. G., Burgess, M. I., Ray, S. G., Lahiri, A., Coats, A. J., Cleland, J. G., et al. (2000). Comparison of left ventricular ejection fraction and volumes in heart failure by echocardiography, radionuclide ventriculography and cardiovascular magnetic resonance; are they interchangeable? European Heart Journal, 21(16), 1387-1396.

54. Health Quality Ontario. (2010). Positron emission tomography for the assessment of myocardial viability: An evidence-based analysis. Ontario Health Technology Assessment Series, 10(16), 1-80.

55. Health Quality Ontario. (2010). Magnetic resonance imaging (MRI) for the assessment of myocardial viability: An evidence-based analysis. Ontario Health Technology Assessment Series, 10(15), 1-45.

56. Hansson, N. H., Tolbod, L., Harms, J., Wiggers, H., Kim, W. Y., Hansen, E., et al. (2016). Evaluation of ECG-gated [(11)C] acetate PET for measuring left ventricular volumes, mass, and myocardial external efficiency. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology, 23(4), 670-679.

57. Wood, P. W., Choy, J. B., Nanda, N. C., & Becher, H. (2014). Left ventricular ejection fraction and volumes: It depends on the imaging method. Echocardiography (Mount Kisco, N.Y.), 31(1), 87-100.

58. Khorsand, A., Gyongyosi, M., Sochor, H., Maurer, G., Karanikas, G., Dudczak, R., et al. (2011). Assessment of left ventricular volumes, ejection fraction and mass. Comparison of model-based analysis of ECG-gated ((9)(9)m)tc-SPECT and (1)(8) F-FDG-PET. Nuklearmedizin.Nuclear Medicine, 50(1), 9-14.

59. Li, Y., Wang, L., Zhao, S. H., He, Z. X., Wang, D. Y., Guo, F., et al. (2014). Gated F-18 FDG PET for assessment of left ventricular volumes and ejection fraction using QGS and 4D-MSPECT in patients with heart failure: A comparison with cardiac MRI. PloS One, 9(1), e80227.

60. Meave, A., Ricalde, A., Sierra Fernandez, C., Rojas Castillo, L. G., & Alexanderson, E. (2005). Study of myocardial viability: Comparison of PET and MRI. [Estudio de la viabilidad miocardica: comparacion de tomografia por emision de positrones y resonancia magnetica] Archivos De Cardiologia De Mexico, 75(1), 71-78.

61. Garg, N., Dresser, T., Aggarwal, K., Gupta, V., Mittal, M. K., & Alpert, M. A. (2016). Comparison of left ventricular ejection fraction values obtained using invasive contrast left ventriculography, two-dimensional echocardiography, and gated single-photon emission computed tomography. SAGE Open Medicine, 4, 2050312116655940.

62. Greenland, P., Alpert, J. S., Beller, G. A., Benjamin, E. J., Budoff, M. J., Fayad, Z. A., et al. (2010). 2010 ACCF/AHA guideline for assessment of cardiovascular risk in asymptomatic adults: A report of the american college of cardiology Foundation/ American heart association task force on practice guidelines. Journal of the American College of Cardiology, 56(25), e50-103.

63. Neglia, D., Rovai, D., Caselli, C., Pietila, M., Teresinska, A., Aguade-Bruix, S., et al. (2015). Detection of significant coronary artery disease by noninvasive anatomical and functional imaging. Circulation.Cardiovascular Imaging, 8(3), 10.1161/CIRCIMAGING.114.002179.

64. Rahmim, A., & Zaidi, H. (2008). PET versus SPECT: Strengths, limitations and challenges. Nuclear Medicine Communications, 29(3), 193-207.

65. Mulvagh, S. L., Rakowski, H., Vannan, M. A., Abdelmoneim, S. S., Becher, H., Bierig, S. M., et al. (2008). American society of echocardiography consensus statement on the clinical applications of ultrasonic contrast agents in echocardiography. Journal of the American Society of Echocardiography: Official Publication of the American Society of Echocardiography, 21(11), 1179-201; quiz 1281.

66. Farzaneh-Far, A., Phillips, H. R., Shaw, L. K., Starr, A. Z., Fiuzat, M., O'Connor, C. M., et al. (2012). Ischemia change in stable coronary artery disease is an independent predictor of death and myocardial infarction. JACC.Cardiovascular Imaging, 5(7), 715-724

67. Pepper, J. (2004). Surgery for hibernation. Heart (British Cardiac Society), 90(2), 144-145.

68. Wilson S Colucci, MD. Determining the etiology and severity of heart failure or cardiomyopathy. UpToDate, Post TW (Ed), UpToDate, Waltham, MA. (2017). Link: https://www.uptodate.com/contents/determining-the-etiology-and-severity-of-heart-failure-or-cardiomyopathy

69. Ph. Gabriel Steg, Stefan K. James. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC). Eur Heart J (2012) 33 (20): 2569-2619.

70. Wijns W, Vatner SF, Camici PG. Hibernating myocardium. N Engl J Med. 1998;339(3):173-81.

71. Pagano D, Fath-Ordoubadi F, Beatt KJ, Townend JN, Bonser RS, Camici PG. Effects of coronary revascularisation on myocardial blood flow and coronary vasodilator reserve in hibernating myocardium. Heart. 2001;85(2):208-12. PMCID: 1729621.

Diagnostics and treatment of ruptured cerebral aneurysms at the HLUHS Kauno klinikos in 2015 – 2018 year

Arnolda Marija Baškytė[1], Agnė Kavaliauskaitė[1], Saulius Lukoševičius[2]

[1] *Lithuanian University of Health Sciences, Kaunas Lithuania*
[2] *Department of Radiology, Lithuanian University of Health Sciences, Kaunas Lithuania*

ABSTRACT

The aim: To analyze diagnostic and treatment data of ruptured cerebral aneurysms to evaluate the advantages, disadvantages, and effects of the treatment methods on the patient's life expectancy.

Methods: The data of 80 patients, who had a rupture of a cerebral aneurysm, underwent a radiological examination at the HLUHS KK department of Radiology and treatment at the departments of Neurology and Neurosurgery in 2015-2018 were analyzed.

Results: The average age of the patients was 58,36 ± 13,89 of women and 53,83 ± 16,05 of men. Totally 174 radiological examinations were performed: CT – 41,38%, CT angiography – 41,95%, digital subtraction angiogram – 16,67%. Ruptured aneurysms were most commonly treated using surgical clipping – 65,91%, endovascular embolization – 31,82%, and just a few times conservative treatment was used – 2,27%.

Conclusions: 1. 40-60 years old patients were most commonly diagnosed with a rupture of the anterior communicating artery aneurysm, with no significant difference between genders (p = 0.256). 2. The most common short-term symptoms of a ruptured aneurysm were severe headache, nausea, vomiting, unconsciousness, vasospasm, long-term symptoms - biosocial dysfunction, hemiparesis, hemiplegia, disorientation. 3. The primary diagnostic method was CT angiography; if the origin of symptoms was unclear, digital subtraction angiogram was required.

4. The surgical clipping is a dominant method of treatment with a higher risk of postoperative complications, while endovascular treatment has a higher probability of reoperations.

Keywords: cerebral aneurysm, digital subtraction angiogram, CT angiography, endovascular coiling, surgical clipping, subarachnoid hemorrhage.

INTRODUCTION

A cerebral aneurysm is one of the most hazardous pathologies of the brain arteries, which is caused by localized dilatation of the blood vessel. An unruptured aneurysm is clinically silent, sometimes causing headaches, visual changes, double vision, eyelid collapse, an enlarged pupil of one eye. Usually, an intracranial aneurysm is determined by rupture of the sack leading (which leads) to the formation of subarachnoid hemorrhage (SAH). SAH can cause severe symptoms and consequences: sudden headache, nausea, vomiting, neck rigidity, loss of consciousness, seizures, fear of the light, paralysis, and other brain damages, or even death. The incidence of SAH is about 10 to 11 per 100,000 persons per year, with 1,24 times higher risk for females [1]. The typical age of the patient when aneurysm ruptures are more than 50 years. Most of the ruptured aneurysms are more significant than 7mm [2].

CT angiography is the gold standard to diagnose an aneurysm. However, it can be successfully detected using CT, MRT angiography, or digital subtraction angiogram [3]. There are several treatment options: endovascular coiling, surgical clipping, or conservative when the condition of the patient is severe. The standard diagnostic method before surgical treatment is CT angiography, while endovascular treatment requires a digital subtraction angiogram. Endovascular treatment is characterized by a less invasive and shorter duration of the procedure, but it is riskier because of the increased chance of repeated bleeding [4-5].

AIM

To analyze diagnostic and treatment data of ruptured cerebral aneurysms to evaluate the advantages, disadvantages, and effects of the treatment methods on the patient's life expectancy.

METHODS

We performed the retrospective observational study at the largest healthcare institution in Lithuania, HLUHS KK, in 2015-2018. Data of 80 patients diagnosed with a ruptured subarachnoid aneurysm based on brain CT, CT angiography, or digital subtraction angiogram. Data about the age and gender of the patients, quantity, size, localization of aneurysms, duration of treatment, and dynamics of symptoms were collected from patients' charts. Patients were grouped by the method of treatment: conservative, endovascular coiling, surgical clipping. Patients' medical histories were chosen randomly. Significance level p<0,05 was chosen.

RESULTS

The study population consisted of 80 patients: 50 (62,5%) were women and 30 (37,5%) men. Age of patients in this group ranged from 24 to 87 years with an average age - 58,36 ± 13,89 of women and 53,83 ± 16,05 of man. There was no significant age difference between genders (P=0,206). Totally 174 radiological examinations were performed: CT – 41,38% (Fig. 1), CT angiography – 41,95% (Fig. 2, Fig. 3, Fig. 4), digital subtraction angiogram – 16,67% (Fig. 5).

Fig. 1. Simple, non-contrasting brain CT. SAH foundation tanks (white arrow), complicated intraventricular hemorrhage (blue arrow).

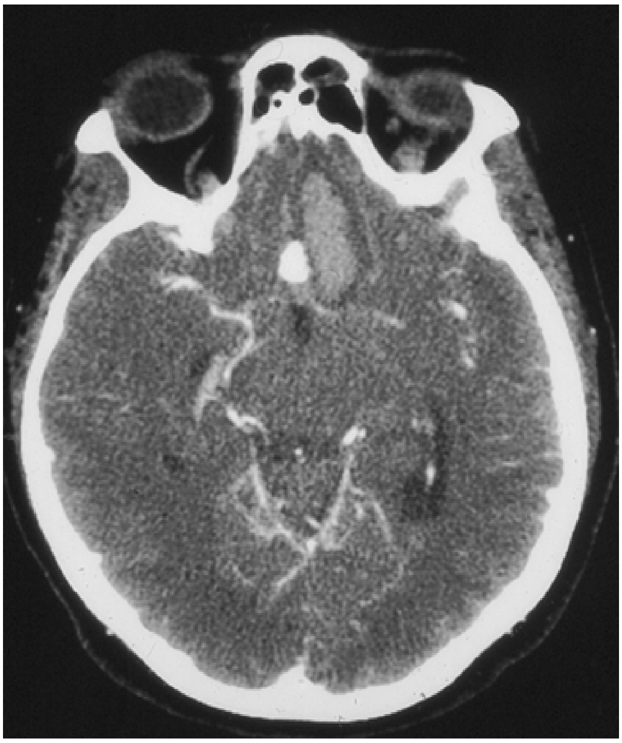


Fig. 2. Cerebral CT angiography, axial projection, unedited (raw) image. Contrast media in arteries (thin black arrow), contrast media in the aneurysm (blue arrow). Bleeding into the brain near the aneurysm sac (thick black arrow).

Fig. 3. Brain CT angiography 3D reconstruction with MIP (maximum intensity pixels). Aneurysm of the anterior communicating artery (grey arrow).

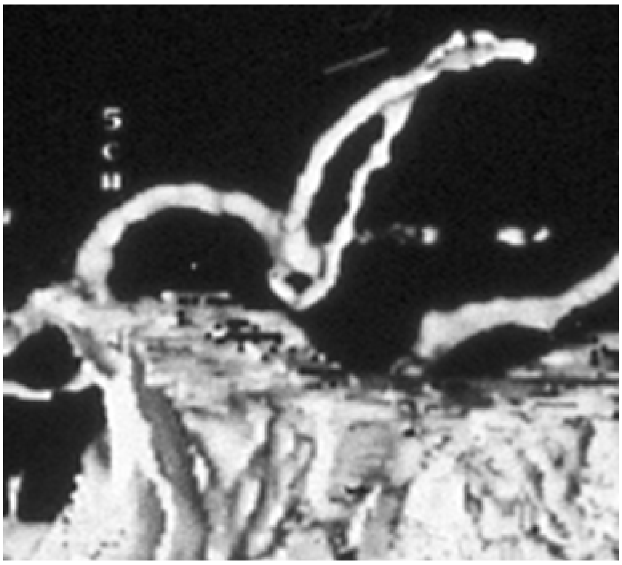


Fig. 4. Brain CT angiography 3D reconstruction in SSD (surface shaded display). Aneurysm of the anterior communicating artery (blue arrow).

Fig. 5. Brain digital subtraction angiogram. Aneurysm of the anterior communicating artery (blue arrow).

The diagnosis was based on CT and CT angiography for 63,75% patients, digital subtraction angiogram – 7,5%, CT angiography, and digital subtraction angiogram – 28,75%. Patients were diagnosed with 94 intracranial aneurysms, of which 85 were ruptured. In a total of 80 patients, 13 cases (16,25%) had multiple aneurysms: 12 patients had two aneurysms, for three patients both were ruptured, one patient had three aneurysms (1 ruptured). The most frequent localizations of ruptured aneurysms were: anterior communicating artery – 32,96%, right and left middle cerebral artery distributed into 26,38 % and 20,89 %, right and left internal carotid artery – 11 % and 3,33 % (Table 1), there was no significant difference between the genders (P = 0.068).

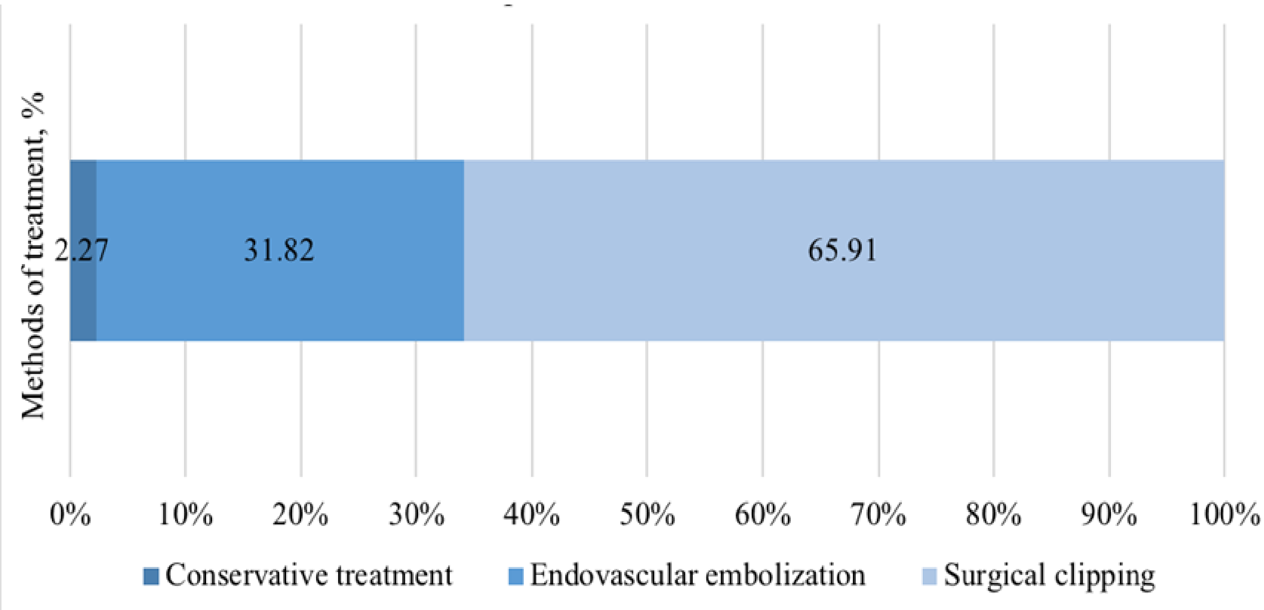
Table 1. Distribution of aneurysms' localization

Localization of aneurysms	Distribution among male (%)	Distribution among female (%)
ACoA	15,38	17,58
MCA (right)	14,29	12,09
MCA (left)	3,31	17,58
ICA (right)	1,11	9,89
ICA (left)	1,11	2,22
Ach (left)	-	1,11
BA	-	2,22
VA (left)	1,11	-
PICA	-	1,11
Total	36,2	63,8

Here: - ACoA – anterior communicating artery, MCA - middle cerebral artery, ICA - internal carotid artery, Ach – anterior choroidal artery, BA - basilar artery, VA – vertebral artery, PICA – posterior inferior cerebellar artery.

During the study, the mean cerebral aneurysm size was detected 8,6x7,52mm (minimum – 0,6x0,7mm, maximum - 35x45mm). According to our research, ruptured aneurysms were most commonly treated using surgical clipping – 65,91%, endovascular embolization – 31,82%, and just a few times conservative treatments were used – 2,27% (Fig. 6).

Fig. 6. Distribution of performed treatment methods



Repeated endovascular coiling was performed for 3,41% of patients, coiling after surgical clipping for 2,27% patients, and 4,55% of patients underwent surgical clipping after coiling. The average duration of endovascular coiling was 65,23 min, and the surgical clipping - 220,45 min. Postoperative complications occurred for 10,13% of patients and were 1,67 times more frequent after surgical clipping. Analyzing dynamic of symptoms after treatment, positive condition occurred to 56,25% of patients (for 71,1% clipping was performed), negative – 37,5% (of which 26,67% died), and there was no significant change of condition to 6,25% patients. According to our study, in many cases short-term symptoms were (Fig. 7): headache (72,5%), nausea (45%), vomiting (30%), unconscious (32,5%), vasospasm (8,75%); long-term symptoms (Fig. 8): biosocial dysfunction (7,5%), hemiparesis (7,5%), hemiplegia (6,25%), disorientation (7,5%).

Fig. 7. Distribution of short-term symptoms by frequency

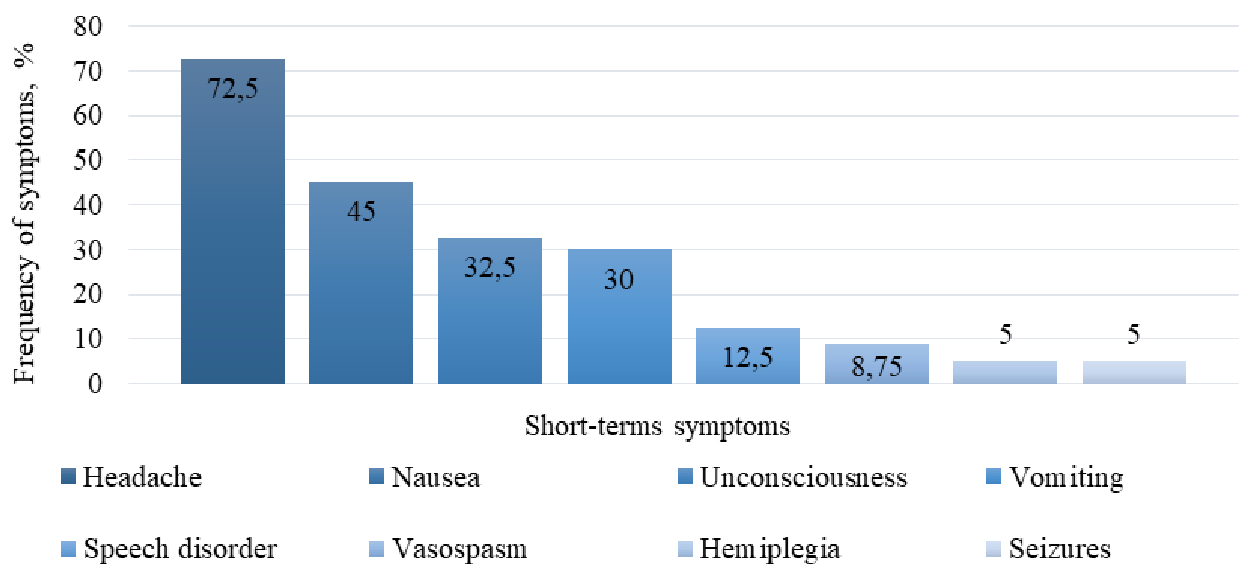
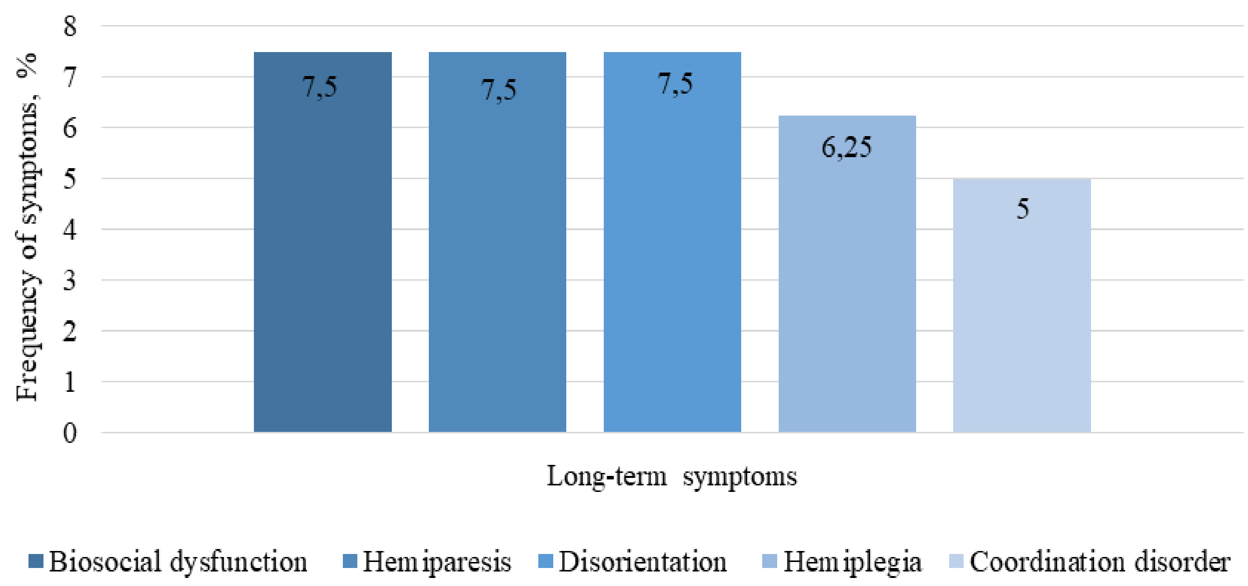


Fig. 8. Distribution of long-term symptoms by frequency



DISCUSSION

The study group consisted of 80 patients, who had a rupture of a cerebral aneurysm, underwent a radiological examination at the HLUHS CK Radiology Clinic and treatment at Neurology and Neurosurgery Clinic in 2015-2018. The age of patients in this population ranged from 24 to 84 years, with an average age of 58,36 ± 13,89 in women and 53,83 ± 16,05 in man. Relatively, the similar average age of patients (50-59 years) is also indicated in literature sources [6-8]. In our study, the average size of the ruptured aneurysm was 8,6x7,52mm. Similar results were obtained during the studies of other studies, whose average size was 5-10mm [4,5]. To our knowledge, the most common localizations of aneurysms were: ACoA – 34,04%, right and left MCA distributed into 25,53% and 20,21 %, right and left ICA – 11,70% and 3,19%, comparable results were recorded in other studies [6-8]. According to our findings, it became evident that multiple aneurysms were spotted in 16,25% of cases. The similar results were found in other research (multiple aneurysms were detected for 14.57% patients) [6]. Our study shows that CT angiography is the gold standard for ruptured aneurysms examination before choosing treatment, although the meta-analysis of E. Thomas Chappell and co-authors suggests, that digital subtraction angiogram is the standard method, but specialists who use CTA says that this method is good or even better than digital subtraction angiogram in the diagnosis and treatment of cerebral aneurysms [9]. During the study, we found that the most common short-term symptoms were headache, nausea, vomiting, unconscious, vasospasm. Most frequent long-term symptoms were biosocial dysfunction, hemiparesis, hemiplegia, disorientation, similar results were obtained in a study, conducted in the Philadelphia, where was found that SAH survivors had increased problems in the quality of life: mobility, self-care, usual activities, and anxiety/depression [10]. In our study, we found that endovascular coiling results in fewer poor clinical outcomes comparing with surgical clipping. Relatively, Cameron G. McDougall and co-authors in a study, conducted in California, estimated that coiling results in fewer complications, thus not all aneurysms should be treated by coil embolization [11]. Having reviewed the results of our and previous studies, as well as the literature data, we can observe that diagnostic, treatment, and outcomes of ruptured cerebral aneurysms, which cause SAH, are quite similar.

CONCLUSIONS

1. 40-60 years old patients were most commonly diagnosed with a rupture of anterior communicating artery aneurysm, with no significant difference between genders (p = 0.256).

2. The most common short-term symptoms of a ruptured aneurysm were severe headache, nausea, vomiting, unconsciousness, vasospasm, long-term symptoms - biosocial dysfunction, hemiparesis, hemiplegia, disorientation.

3. The primary diagnostic method was CT angiography; if the origin of symptoms was unclear, digital subtraction angiogram was required.

4. The surgical clipping is a dominant method of treatment with a higher risk of postoperative complications, while endovascular treatment has a higher probability of reoperations.

REFERENCES

1. Carter LP, Spetzler RF, Hamilton MG. Neurovascular surgery. New York: McGraw-Hill, 1995; 625-26,631, 651-52.

2. M. Korja, H. Lehto, S. Juvela. Lifelong Rupture Risk of Intracranial Aneurysms Depends on Risk Factors: A Prospective Finnish Cohort Study. Stroke, 2014; Available from https://www.ahajournals.org/doi/10.1161/STROKEAHA.114.005318.

3. LR SAM: Diagnostikos ir gydymo protokolai. Subarachnoidinės kraujosruvos diagnostika ir gydymas, Vilnius, 2014; Available from: https://sam.lrv.lt/diagnostikos-gydymo-metodikos-ir-rekomendacijos/diagnostikos-ir-gydymo-protokolai.

4. Marcinkevičius E., Simaitis K. Galvos smegenų arterinės aneurizmos: literatūros apžvalga. Neurologijos seminarai 2015; 19(65):192-202.

5. Dr. Andrew J Moluneux FRCR, Richard SC Kerr FRCS, Ly-Mee Yu MSc, Mike Clarke DPhil, Mary Sneade BA, Julia A Yarnold MA, Peter Sandercock MD. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. The Lancet, September 2005; Available from https://www.sciencedirect.com/science/article/pii/S0140673605672145.

6. Zhao L, Zhang L, Zhang X, Li Z, Tian L, Wang Y-XJ. An Analysis of 1256 Cases of Sporadic Ruptured Cerebral Aneurysm in a Single Chinese Institution. PLoS ONE, 2014; Available from: https://doi.org/10.1371/journal.pone.0085668.

7. Heng Liu, Tijiang Zhang, Song Jiao, Bangguo Li, Jing Guan, Yi-Xiang J Wang. Epidemiological investigation of 264 sporadic cases of a ruptured cerebral aneurysm at a single institution in southwest China. DovePress, 2015 Jul;

8. Giovanni Grasso, Giancarlo Perra. Surgical management of ruptured small cerebral aneurysm: Outcome and surgical notes. Surgical Neurology International, 2015; Available from https://www.ncbi.nlm.nih.gov/pubmed/26677419.

9. E. Thomas Chappell, M.D. Federico Castro Moure, M.D., Ph.D. Matthew C. Good. Comparison of Computed Tomographic Angiography with Digital Subtraction Angiography in the Diagnosis of Cerebral Aneurysms: A Meta-analysis. Neurosurgery, March 2003; Available from https://academic.oup.com/neurosurgery/article-abstract/52/3/624/2732368?redirectedFrom=fulltext.

10. Wolter Kluwer Health. The ruptured aneurysm has lasting impact on quality of life. Neurosurgery, March 2013; Available from: https://www.eurekalert.org/pub_releases/2013-03/wkh-rah031213.php?fbclid=IwAR0IIcesgnJKBLSF2Ew-zdC-EQk9fF-d7XvcW65kGdaQQmvDjQlZBlWY62Ho.

11. Cameron G. McDougall, M.D., Robert F. Spetzler, M.D., Joseph M. Zabramski, M.D., Shahram Partovi, M.D., Nancy K. Hills, Ph.D., Peter Nakaji, M.D., Felipe C. Albuquerque, M.D. The Barrow Ruptured Aneurysm Trial. Journal of Neurosurgery, November 2011.

Aortoenteric fistula: clinical case presentation

Viktorija VITKUTĖ [1], Eglė BAKUČIONYTĖ [2], Paulina TEKORIUTĖ [1]

[1] *Lithuanian University of Health Sciences, Academy of Medicine, Faculty of Medicine, Kaunas, Lithuania*
[2] *Republic Hospital of Klaipeda, Klaipeda, Lithuania*

ABSTRACT
Aortoenteric fistula (AEF) is a rare but life-threatening condition characterized by abnormal communication between the aorta and any part of the intestinal tract. It has been suggested that primary AEF arises from an abdominal aortic aneurysm, and secondary is caused by an infection, usually consistent with aortic graft. We present a case report of secondary AEF presented with severe bleeding from the gastrointestinal (GI) tract followed by aortic graft infection.

Keywords: Aortoenteric fistula, gastrointestinal bleeding, abdominal aortic aneurysm, aortic graft

INTRODUCTION

There are many reasons for bleeding from the GI tract, and it is essential not to miss an uncommon cause such as AEF. It is a pathological communication between the aorta and any part of an intestinal tract (1). AEF is an uncommon but life-threatening condition with an incidence rate of 1.6 – 4% (2). This pathology was described for the first time by Sir Ashley Cooper in 1818 (3). AEF is associated with diagnostic challenges - it requires careful attention to a patient's history and relies on clinical acumen (4).
There are two different types of AEF – primary and secondary, depending on their etiology. Primary AEFs commonly arise from an abdominal aortic aneurysm (AAA), and secondary is a complication of reconstructive surgery of an AAA (2 - 6).
The immediate diagnosis and urgent surgery is the only way to save a patient. Otherwise, the mortality of untreated pathology reaches almost 100% (1).
We report a rare case of a secondary AEF followed by abdominal aortic graft infection, presented with GI bleeding. Our purpose is to raise awareness of this catastrophic condition.

CASE REPORT

A 72–year-old man presented to our hospital to the emergency department with general weakness, vomiting of blood, and black tarry stools for the last 24 hours. On the day of admission, his vitals were normal. His past medical history included primary arterial hypertension and heart failure. Six years earlier, the patient was diagnosed with an AAA and undergone treatment with an aortic graft. The initial examination was unremarkable. The digital rectal examination revealed melena. Initial laboratory tests showed haemoglobin level 117 g/l, white blood cells (WBC) count 7,5 x 109/l, platelet count 217 x 109/l, prothrombin time 33,4 seconds, international normalized ratio (INR) 1,14, C – reactive protein (CRB) 5 mg/l , creatinine 85 µmol/l and urea 14,91 mmol/l. Electrolytes were normal.
In the emergency room, esophagogastroduodenoscopy (EGDS) was performed immediately due to melena. EGDS showed bleeding from the lower part of the duodenum. However, there was no possibility to stop the bleeding during the examination.
Later the patient became hemodynamically unstable (blood pressure 70/30 mmHg)
. Repeated laboratory investigation showed a hemoglobin level decrease 97 g/l, INR 1,28, CRB 5 mg/l. In the department of intensive care, two units of packed red blood cells, and two units of fresh frozen plasma were transfused.
Due to the history of AAA repair, computer tomography aortography (CTA) was performed urgently for a potential life-threatening secondary AEF. CTA revealed adhesion between the aortic graft distal part, near the anastomosis, and

Figure 1. CTA coronal view- contrast media extravasation in the duodenum

Figure 2. CTA sagittal view- communication between aorta and duodenum

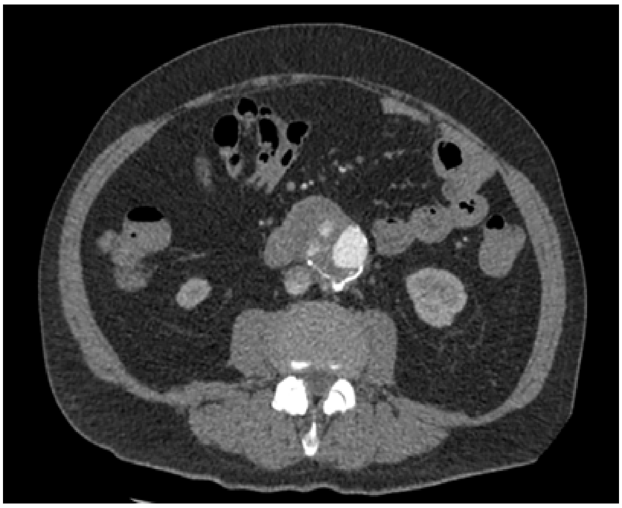


Figure 3. CTA axial view- contrast media extravasation in the duodenum

Figure 4. CT with contrast media after AEF closing surgery - air in the aortic graft, perigraft infiltration

duodenum. There was enhanced blood in the duodenum, indicating communication between the aorta and the intestinal tract (Figure – 1, 2, 3). CTA undoubtedly helped facilitate the diagnosis of AEF.

The patient was shifted to another hospital for further treatment of the vascular surgery unit. During the surgery, a suppurative aortic graft and 1 cm defect in the duodenum were found. The graft was resected, and axillobifemoral bypass surgery was performed, the AEF was occluded. Unfortunately, after some days, the patient had the following complication – sepsis caused by E.coli occurred, which was correctly treated, and the patient remained alive.

DISCUSSION

AEFs are divided into two types - primary and secondary. According to statistics, the incidence rate of secondary AEF is approximately 2,5 times more common than primary (3, 4, 6).

Primary AEFs commonly arise from an AAA of which 85% are atherosclerotic (3, 5, 6), and it occurs when an erosive aortic segment opens into the adjacent gastrointestinal lumen (4). Rare known conditions related to primary AEF are tuberculosis, syphilis, infection, cancer, foreign bodies, and collagen vascular disease (2, 3, 6). Even the case of vertebral osteophyte has also been shown to influence the development of an AEF (7).

Secondary AEF is a complication of reconstructive surgery of an AAA, involving open repair surgery and endovascular treatment, as well as vascular grafts (2, 4). It is more common in patients with a history of open aortic repair comparing with patients after endovascular stent placement. An abnormal communication can develop between the aorta and any part of the intestinal tract. An estimated 80% of secondary AEFs affect the duodenum, mostly the third and fourth parts (the horizontal and ascending duodenum) and the proximal suture line of the aorta (3), just as in our case. The involvement of the other gastrointestinal segments are less frequent; for instance, aortocolonic fistulae occur only 5 to 6% of all cases (4).

MacDougall L. et al., in the article 'Aorto-enteric fistulas: a cause of gastrointestinal bleeding not to be missed,' says that the pathogenesis of this disease has not yet been fully understood (3), but there are two theories. The first theory suggests that fistula formation is caused by repeated mechanical trauma between the pulsating aorta and duodenum, and the second asserts low-grade infection as the primary event with abscess formation and subsequent erosion through the bowel wall. The second theory is the most likely because the majority of grafts show signs of infection at the time of bleeding, and approximately 85% of cases have blood cultures positive for enteric organisms (5). In our case, there was the graft infection caused by E. coli positive culture, which also applies the second theory.

AEF is characterized by the classical triad: abdominal pain, gastrointestinal blood loss, which can be acute or chronic, and pulsating abdominal mass (1, 8, 9). However, this triad is only found in 11 – 38,5% patients, which makes diagnosis even more challenging (1). Abdominal pain can occur only in 35% of patients, pulsating mass in 25% patients, and the most frequent gastrointestinal bleeding presents in 94% cases, as in our case. In addition to severe bleeding, significant hemodynamic instability often occurs (10). Other symptoms consistent with this pathology may be intermittent back pain, fever, sepsis, weight loss, and syncope (1). Our patient presented with melena, haematemesis, and general weakness.

Commonly used diagnostic methods for AEFs are abdominal CT with intravenous contrast, interventional angiography, and EGDS (3). The detection rates for each of these modalities are 61%, 26%, and 25%, respectively (6). According to Chick JFB et al. in the article 'Aortoenteric fistulae temporization and treatment: lessons learned from a multidisciplinary approach to 3 patients', CT angiography is the first-line imaging modality for the detection of aortoenteric fistula and has a reported sensitivity of 94% and specificity of 85% (8).

Concerning CTA findings, active extravasation of contrast media in the GI tract is reported the most often, any part of intestines are seen in close contact with an AAA or an aortic graft, there is often fat infiltration around the aortic graft, consistent with infection. Just after secondary AEF closing, CT findings such as fluid, ectopic gas, and per graft soft tissue edema can be normally seen (Figure 4). However, 3 – 4 weeks later, any ectopic gas is abnormal means perigraft infection and possibly fistulization to a GI tract. In 2 – 3 months after surgery, the perigraft soft tissue thickening, hematoma, or fluid should be resolved (3).

The main goals of treatment are control of bleeding and revascularization, repair of intestinal defects, and eradication of related infection. In this case, surgical intervention is performed, and antibiotics are supplied (1, 3). The treatment has been improved for many years. Despite numerous surgical techniques, many patients do not survive or may remain weak after surgery.

Survival depends on the onset of bleeding severity and how quickly the operation is performed. Mortality rates range from 24 to 45,8% (2), and up to 100% if untreated (3). That is why it is so vital to suspect and diagnose the rare pathology as fast as it is possible.

CONCLUSION

Our case report is a reminder for doctors that secondary AEF should be strongly suspected in all patients with a prior history of aorta repair presenting with GI bleeding. Urgent diagnosis of AEF is vital and may save a patient from the catastrophic outcomes.

REFERENCES

1. Ahmad BS, Haq MU, Munir A, Abubakar Mohsin Ehsanullah, Saiyed Abdullah, Ashraf P. Aortoenteric fistula - A fatal cause of gastrointestinal bleeding. Can it be missed? - A case report. JPMA. The Journal of the Pakistan Medical Association 2018 Oct;68(10):1535.
2. Saito H, Nishikawa Y, Akahira J, Yamaoka H, Okuzono T, Sawano T, et al. Secondary aortoenteric fistula possibly associated with continuous physical stimulation: a case report and review of the literature. Journal of medical case reports 2019 Mar 15, 13(1):61.
3. Xiromeritis K, Dalainas I, Stamatakos M, Filis K. Aortoenteric fistulae: present-day management. Int Surg 2011;96(3):266-273.
4. Ömer Faruk Çiçek, Mustafa Cüneyt Çiçek, Ersin Kadiroğulları, Alper Uzun, Mahmut Ulaş. Successful Treatment of Secondary Aortoenteric Fistula with a Special Graft. Case reports in medicine 2016;2016:9874187-3.
5. Zemsky CJ, Sherman SW, Schubert HD, Suh LH. Case Report. Optometry and Vision Science 2019 Feb;96(2):137-141.
6. Costea R, Vasiliu EC, Zarnescu NO, Neagu S. Primary aortoenteric fistula: case report. Chirurgia (Bucur) 2015;110(1):78-80.
7. Janko M, Ciocca RG, Hacker RI. Vertebral Osteophyte as Possible Etiology of Aortoenteric Fistula. Annals of Vascular Surgery 2018 May;49:313.e5-313.e7.
8. Chick JFB, Castle JC, Cooper KJ, Srinivasa RN, Eliason JL, Osborne NH, et al. ScienceDirect. 2017(10):125-126.
9. Karthaus EG, Post ICJH, Akkersdijk GJM. Spontaneous aortoenteric fistula involving the sigmoid: A case report and review of the literature. International Journal of Surgery Case Reports 2016;19:97-99.
10. Davie M, Yung DE, Plevris JN, Koulaouzidis A. Aortoenteric fistula: a rare but critical cause of small bowel bleeding discovered on capsule endoscopy. BMJ Case Reports 2019 May;12(5):e230083.

Non-Surgical Pneumoperitoneum: Causes and Imaging Findings

Gerta Repečkaitė[1], Tomas Jurevičius[1], Jurgita Zaveckienė[1]

[1] *Department of Radiology of Lithuanian University of Health Sciences Kaunas, Lithuania.*

ABSTRACT

Background: Typically, the presence of air or fluid in the thoracic and abdominal cavities is considered to be of separate origin. However, it is essential to take into consideration that a non-surgical pneumoperitoneum (NSP) may develop without a perforated viscus, and due to thoracic causes, such as mechanical ventilation, cardiopulmonary resuscitation, and pneumothorax. This is important in clinical practice, because exclusion of intestinal perforation alters patient management, and prevents unnecessary surgical interventions.

Aim: This article aims to review the causes and imaging findings of an NSP and present a patient with unilateral tension pneumothorax, pneumomediastinum, pneumoretroperitoneum, subcutaneous emphysema, and pneumoperitoneum, which were not associated with a perforated viscus.

Case report: A 65-year-old male was admitted to the Emergency Department (ED) due to seizures and impaired consciousness. Prior to arrival, the ambulance personnel had intubated the patient. A chest x-ray and chest-abdomen-pelvis CT scan showed a massive left pneumothorax with mediastinal shift to the right, lung collapse, and pronounced bilateral subcutaneous emphysema, a small pleural effusion on the right, an eighth rib fracture on the left, pneumomediastinum, ectopic air in the abdominal cavity, between the muscle/fascia layers, and in the retroperitoneum. A laparotomy and esophagogastroduodenoscopy excluded duodenal and other intestinal perforation. The patient was treated conservatively, and within fifteen days, was discharged home.

Conclusion: In conclusion, attention, critical thinking, and knowledge of atypical causes are crucial when evaluating a patient with pneumoperitoneum, as it may develop without the perforation of a hollow viscus, and may not require surgical treatment.

Keywords: pneumothorax, pneumomediastinum, pneumoperitoneum, pneumoretroperitoneum, subcutaneous emphysema.

INTRODUCTION

Typically, the presence of air or fluid in the thoracic and abdominal cavities is considered to be of separate origin. Trauma, such as rib fracture or a penetrating injury, is a common cause of intra-pleural air, better known as pneumothorax (1). Meanwhile, the presence of pneumoperitoneum is most frequently associated with a perforated hollow viscus (2). Abdominal injury may also be the cause of free air in the peritoneal cavity due to a damaged intestinal wall (3). Non-surgical pneumoperitoneum is defined as free intra-peritoneal air observed during a radiological examination, yet not related to neither a viscus perforation nor to surgical intervention. In clinical practice, however, it is essential to take into consideration that non-surgical pneumoperitoneum (NSP) may develop due to thoracic causes, such as mechanical ventilation, cardiopulmonary resuscitation, and pneumothorax (2). Other typical and atypical causes are listed in Table. The significance of this knowledge relies on the fact that, in the setting of pneumoperitoneum, clinical exclusion of intestinal perforation alters patient management, and prevents unnecessary surgical interventions.

Radiology plays a crucial role in the diagnosis of free intra-abdominal air. Although it is not the most informative imaging modality, a plain X-ray is portable, easily accessible, inexpensive, and, therefore, is usually the first radiological study to evaluate the patient when there is suspicion of pneumoperitoneum (4,5). A left decubitus or upright abdominal X-rays are typically performed, however, even supine, and chest

X-rays are useful and should not be discarded as screening tests (5). Ultrasound and CT have been observed to be far more sensitive and informative when diagnosing the origin of free intraperitoneal air. Nonetheless, CT is currently considered to be the diagnostic gold standard (6,7). All in all, X-ray, sonography, and CT are perhaps not equal yet still essential diagnostic methods that aid in the detection and assessment of pneumoperitoneum and its causes.
This article aims to review the causes and imaging findings of an NSP and present a patient with unilateral tension pneumothorax, pneumomediastinum, pneumoretroperitoneum, subcutaneous emphysema, and pneumoperitoneum, which were not associated with a perforated viscus.

CASE REPORT

A 65-year-old male was admitted to the Emergency Department (ED) due to seizures and impaired consciousness. Prior to arrival, the ambulance personnel had administered medication to stop the seizures and had intubated the patient. During the initial inspection at the ED, the patient was being sedated and ventilated, his blood pressure was 200/120 mmHg, heart rate 120 beats per second, while auscultation and percussion findings suggested pneumothorax on the left. The patient's family members denied trauma, and previous interventions, however, the patient was a known alcohol user, had been diagnosed with epilepsy in the past, and had spent a week prior to hospitalization consuming alcohol.
The patient underwent multiple imaging studies. The findings of a chest x-ray included the following: air in the left pleural cavity, mediastinal displacement to the right, left lung collapse, and bilateral subcutaneous emphysema of the thorax and neck. The end of the endotracheal tube was located in the right main bronchus and, therefore, required correction (Figure 1). A head computed tomography (CT) scan revealed no anomalies. Laboratory tests showed hyperglycemia, hyponatremia, leukocytosis, slightly elevated C-reactive protein (11.6 mg/l), elevated erythrocyte, leukocyte, protein, glucose levels in the urine. The abdominal ultrasound was inconclusive, possibly due to the pneumoperitoneum and/or subcutaneous emphysema. A chest-abdomen-pelvis (CAP) CT scan without intravenous contrast material was performed and confirmed a massive left pneumothorax with mediastinal shift to the right, lung collapse, and pronounced bilateral subcutaneous emphysema, as well as diagnosing a small pleural effusion on the right, pneumomediastinum, ectopic air in the abdominal cavity, between the muscle/fascia layers, the retroperitoneum, and an eighth rib fracture on the left without dislocation (Figure 2, 3).
Because clinical and imaging findings were indicative of a tension pneumothorax, a thoracic surgeon was consulted, and chest drains were inserted into the left pleural cavity.
Later on, a bronchoscopy through the intubation tube was performed. However, the findings were unremarkable.
The patient was moved to the Intensive Care Unit (ICU) for further care, where laparotomy and revision were performed. The surgery confirmed to air in the peritoneal cavity. However, excluded intestinal perforation, which led to the belief that the origin of pneumoperitoneum might have been the tension pneumothorax and massive subcutaneous emphysema. The patient's condition improved following drainage tube insertion, chest X-ray showed a decreased left pneumothorax, and he was extubated the very same day (Figure 1). Due to suspicion of retroperitoneal duodenal perforation, an esophagogastroduodenoscopy was performed. Nonetheless, only a diaphragmatic hernia was diagnosed. Although the abdominal X-ray was not repeated, the patient's clinical condition continued to improve, the drainage tubes were removed on the fourteenth day of hospitalization, the subcutaneous emphysema had disappeared, and no signs of pneumoperitoneum or pneumothorax were observed in the last chest X-ray (Figure 1). After fifteen days, the patient was discharged home.

Table. Most common causes of pneumoperitoneum (2,3,21).

PNEUMOPERITONEUM CAUSES			
Related to hollow viscus perforation (85 - 95%)	**Iatrogenic perforation**	**Spontaneous**	**Traumatic**
	Surgery	Ulcer perforation	Blunt/penetrating trauma that results in hollow viscus perforation
	Endoscopy	Bowel obstruction	
	Feeding tube placement	Intestinal ischemia, necrotizing enterocolitis	Miscellaneous
	Gynaecologic manipulations	Various inflammatory conditions: appendicitis, diverticulitis, etc.	Foreign bodies
	Peritoneal dialysis	Toxic megacolon	Ruptured pneumatosis cystoides intestinalis
	Respiratory resuscitation		
Non-surgical pneumoperitoneum (5 - 15%)	**Pseudoperitoneum**	**Abdominal**	**Thoracic**
	Chilaiditi's syndrome	Surgery: open or laparoscopic	Mechanical ventilation
	Hollow viscera overdistention	Peritoneal dialysis	Pneumothorax
	The air between soft tissue wrinkles	Endoscopic procedures	Cardiopulmonary resuscitation
	Gas within lesions	Enteromesenteric emphysema causes	
	Subphrenic fat pad		
	Linear lung atelectasis		
	Gynaecologic	**Miscellaneous**	
	Coitus, orogenital sex, vaginal douching	Drug use (cocaine)	
	Exercises following labour	Scleroderma	
	Pelvic inflammation	Diving with decompression	
	Gynaecologic manipulations	Tooth extraction	

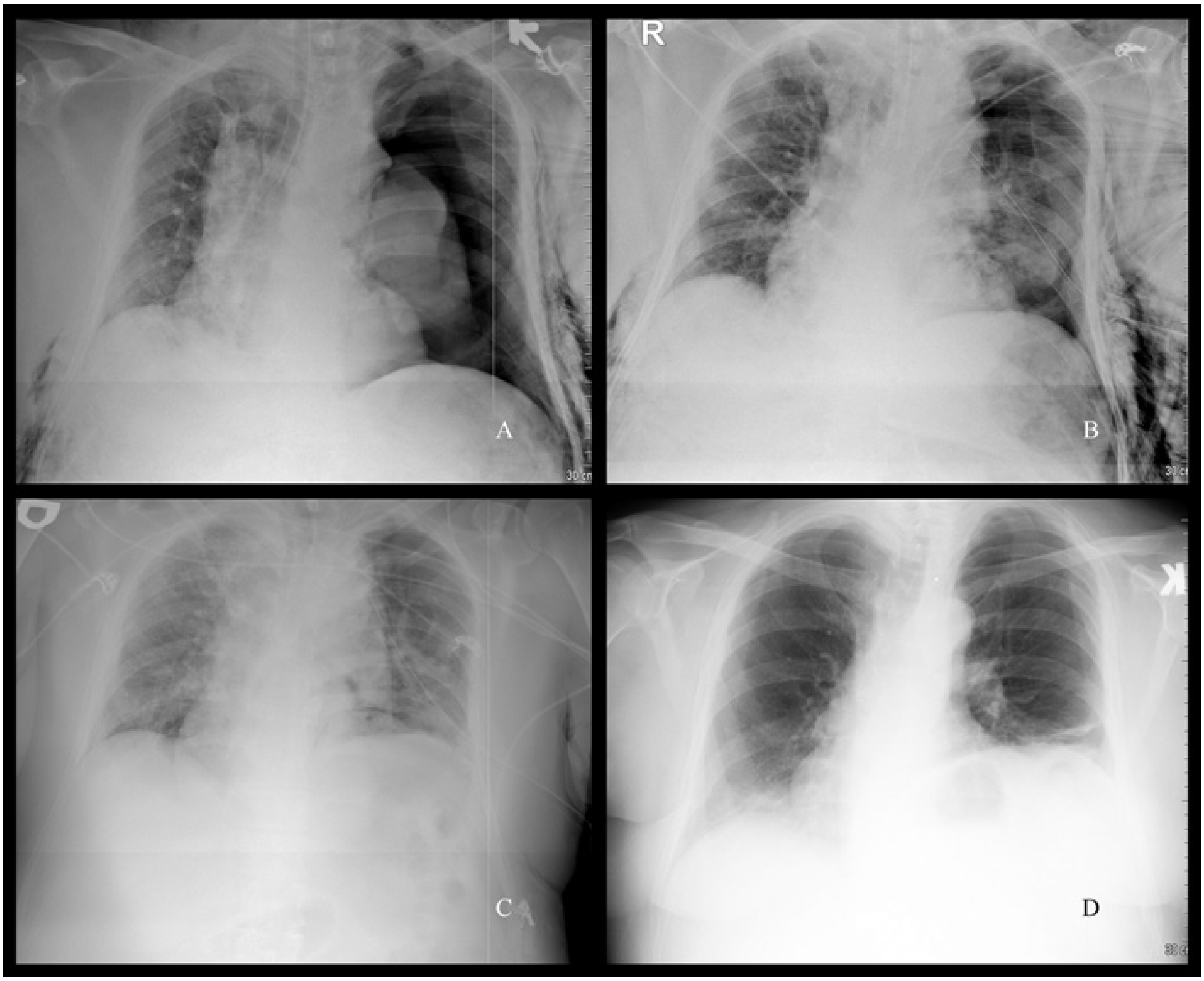


Figure 1. A, B, C - supine, C - erect chest X-rays. A - upon arrival: the patient is rotated to the right, left pneumothorax, collapsed left lung, pronounced subcutaneous emphysema, and endobronchial intubation; B - following drainage: drainage tubes have been inserted into the left pleural cavity, the amount of air has decreased, the left lung has expanded, the endotracheal tube's placement has been corrected; C - after extubation: the left pneumothorax and subcutaneous emphysema have decreased; D - fifteen days after hospitalization: the drainage tube has been removed from the left pleural cavity, a discoid atelectasis and minimal pleural effusion can be seen on the left.

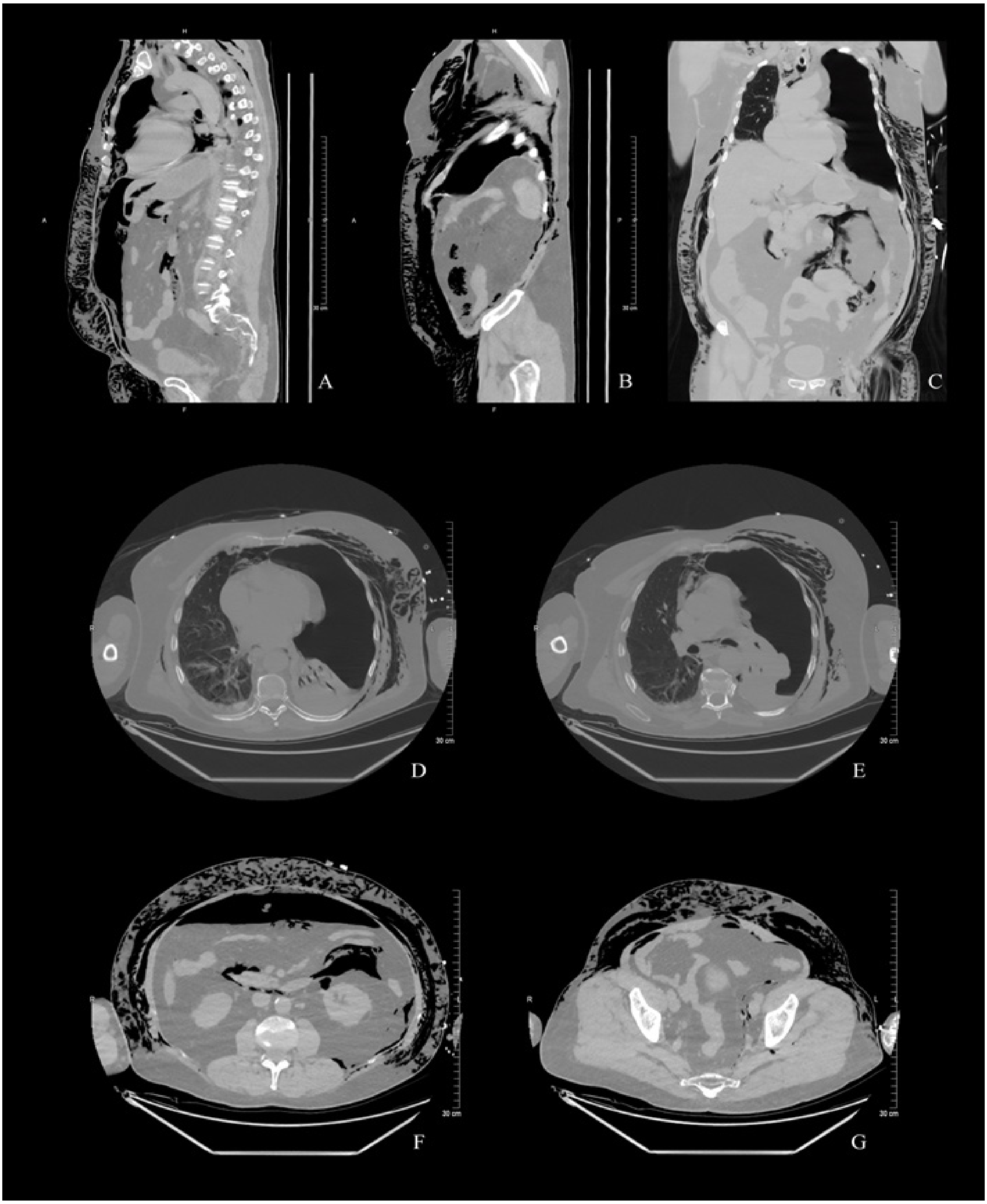


Figure 2. Chest-abdomen-pelvis CT scan findings. A, B - sagittal reconstructions; C - coronal reconstruction, D - G axial view: massive left pneumothorax with left lung collapse and mediastinal dislocation to the right, pleural effusion on the right, pneumomediastinum, pneumoretroperitoneum, pneumoperitoneum, subcutaneous emphysema.

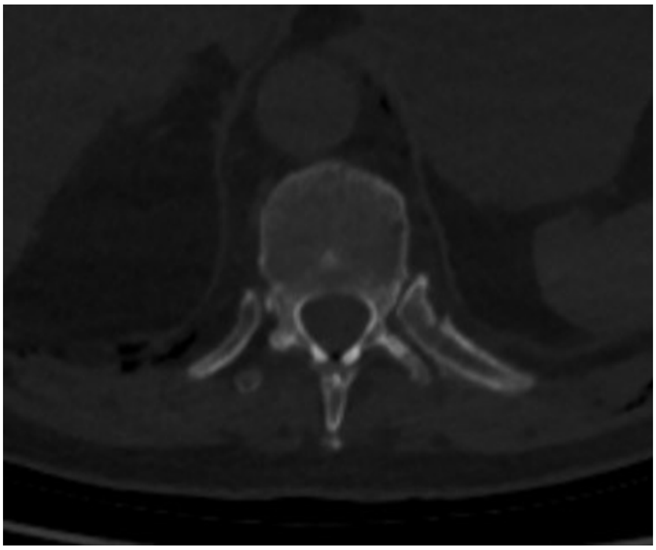


Figure 3. CT scan, axial. Fracture of the left eight rib without dislocation.

DISCUSSION

In the presented case, one of the more probably pneumothorax causes is the fracture of the left eight rib. However, multiple factors may cause doubt. First of all, the patient was a known alcoholic diagnosed with epilepsy. Therefore, we cannot exclude the possibility that the fracture may have occurred before the pneumothorax. Secondly, there was no dislocation and very little air within the soft tissues surrounding the fractured rib (Figure 3), while the amount of air in the pleural, abdominal, and other bodily cavities, as well as the soft tissues, was considerable (Figure 2). Finally, the patient's clinical condition and the chest X-rays greatly improved following the drainage and cessation of mechanical ventilation, which leads to the conclusion that the pneumothorax and the NSP could have developed due to barotrauma.

As mentioned previously, the patient had been intubated by the ambulance personnel. Therefore, the subsequent mechanical ventilation could have been complicated by the following conditions: a tension pneumothorax, pneumomediastinum, and later on - pneumoretroperitoneum and pneumoperitoneum. It has been reported that mechanical ventilation is the most common cause of iatrogenic pneumothorax in the ICU (8). Moreover, there are documented cases of intubation and mechanical ventilation related to thoracoabdominal ectopic air conditions (9–14).

In the presented case, although the patient was hemodynamically stable upon admission, the free air in the peritoneum may have developed consequently to the left tension pneumothorax. The increased intrathoracic pressure was a potentially life-threatening condition and could have progressed to a quick and severe cardiopulmonary collapse, mainly due to the patient's ventilatory status (15–17). However, the presence of intra-abdominal air without any abnormal surgical and imaging findings was suggestive of a potentially lifesaving air dissection from the thorax. Pneumoperitoneum associated with pneumothorax is rare, however, not unheard of. There are two mechanisms of intra-pleural air drainage into the abdominal cavity: the first is via mediastinal perivascular connective tissues or diaphragmatic connections to the retroperitoneum and peritoneum; while the second is directly through pleuro-diaphragmatic defects (2). Such etiopathogenesis of intra-abdominal air should be considered whenever clinical, and laboratory findings are not suggestive of peritonitis.

Free air in the peritoneum is not always indicative of visceral perforation, as is clearly illustrated by the reviewed case. Clinical and imaging data that should provoke suspicion of NSP are as follows: the lack of peritoneal irritation, the presence of a pneumothorax, and the absence of intra-peritoneal effusion (18–20). X-ray and CT findings cannot be evaluated separately from clinical and laboratory data when determining the best treatment approach (3,18–20). Nonetheless, conservative treatment should be accompanied by careful observation, as a deteriorating condition and signs of tension pneumoperitoneum would determine the need for emergency surgery, even in the setting of an NSP (14).

In conclusion, attention, critical thinking, and knowledge of atypical causes are crucial when evaluating a patient with pneumoperitoneum, as it may develop without the perforation of a hollow viscus, and may not require surgical treatment. The presence of pneumothorax and the absence of clinical/objective data indicative of peritoneal irritation should arouse suspicion of an NSP. The responsibility to consider an unusual origin of pneumoperitoneum falls on clinicians, radiologists, and surgeons alike. Therefore, a multidisciplinary approach is essential when optimizing patient management.

REFERENCES

1. Imran JB, Eastman AL. A pneumothorax (collapsed lung, dropped lung) is the entry of air into the pleural space (the space between the lungs and chest wall). JAMA - J. Am. Med. Assoc. 2017: 318:974.
2. Mularski RA, Sippel JM, Osborne ML. Pneumoperitoneum: A review of nonsurgical causes. Crit. Care Med. 2000: 28:2638–2644.
3. Pinto A, Miele V, Laura Schillirò M et al. Spectrum of Signs of Pneumoperitoneum. Semin Ultrasound, CT MRI 2016: 37:3–9.
4. Levin& MS. Diagnosis of Pneumoperitoneum on Supine Abdominal Radiographs. 1991www.ajronline.org (accessed 26 Nov2019).
5. Baker SR. Pneumoperitoneum-the radiographic and clinical virtues of the supine abdominal film. Emerg. Radiol. 2012: 19:547–548.
6. Chen CH, Yang CC, Yeh YH. Role of upright chest radiography and ultrasonography in demonstrating free air of perforated peptic ulcers. Hepatogastroenterology 2002: 48:1082–1084.
7. Hefny AF, Abu-Zidan FM. Sonographic diagnosis of intraperitoneal free air. In: Journal of Emergencies, Trauma and Shock. 2011: 511–513.
8. De Lassence A, Timsit JF, Tafflet M et al. Pneumothorax in the intensive care unit: Incidence, risk factors, and outcome. Anesthesiology 2006: 104:5–13.
9. Ono Y, Okubo Y, Hashimoto K et al. Massive subcutaneous emphysema, bilateral pneumothorax, pneumomediastinum, pneumoperitoneum, pneumoretroperitoneum, and pneumoscrotum after multiple direct laryngoscopies: an autopsy case report. J Anesth 2015: 29:622–626.
10. Den Os MM, Vermeulen M, Naafs Di et al. Tension pneumothorax and pneumoperitoneum after double-lumen endotracheal intubation. BMJ Case Rep. 2017: 2017. doi:10.1136/bcr-2017-223275
11. Strauss CE, De Munter C. Life-saving pneumoperitoneum. BMJ Case Rep 2018: 11. doi:10.1136/bcr-2018-227397
12. Okamoto A, Nakao A, Matsuda K et al. Non-surgical pneumoperitoneum associated with mechanical ventilation. Acute Med Surg 2014: 1:254–255.
13. Stringfield JT, Graham JP, Watts CM et al. Pneumoperitoneum: A Complication of Mechanical Ventilation. JAMA J Am Med Assoc 1976: 235:744–746.
14. Ahmed K, Amine EGM, Abdelbaki A et al. Airway management: induced tension pneumoperitoneum. Pan Afr Med J 2016: 25:125.
15. Roberts DJ, Leigh-Smith S, Faris PD et al. Clinical presentation of patients with tension pneumothorax: A systematic review. Ann. Surg. 2015: 261:1068–1078.
16. Yoon JS, Choi SY, Suh JH et al. Tension pneumothorax, is it a really life-threatening condition? J Cardiothorac Surg 2013: 8. doi:10.1186/1749-8090-8-197
17. Hsu C-W. Iatrogenic pneumothorax related to mechanical ventilation. World J Crit Care Med 2014: 3:8.
18. Di Saverio S, Filicori F, Kawamukai K et al. Combined pneumothorax and pneumoperitoneum following blunt trauma: an insidious diagnostic and therapeutic dilemma. Postgrad Med J 2011: 87:75–78.
19. Karaman A, Demirbilek S, Akin M et al. Does pneumoperitoneum always require laparotomy? Report of six cases and review of the literature. Pediatr. Surg. Int. 2005: 21:819–824.
20. Kane NM, Francis IR, Burney RE et al. Traumatic pneumoperitoneum. Implications of computed tomography diagnosis. Invest Radiol 1991: 26:574–578.
21. Dähnert W. Radiology Review Manual, 7th ed. 2011