Pałka Justyna, Leśniewska Aleksandra, Przybylski Piotr. Application of multidetector computed tomography in the diagnosis of pulmonary embolism and new directions of development. Journal of Education, Health and Sport. 2019;9(9):614-627. eISNN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.3452291
http://ojs.ukw.edu.pl/index.php/johs/article/view/7474

The journal has had 5 points in Ministry of Science and Higher Education parametric evaluation. § 8. 2) and § 12. 1. 2) 22.02.2019.

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 10.09.2019. Revised: 19.09.2019. Accepted: 19.09.2019.

Application of multidetector computed tomography in the diagnosis of pulmonary embolism and new directions of development

Justyna Pałka, http://orcid.org/0000-0002-4639-4047, justyna.palka2@wp.pl, Medical University of Lublin, Poland

Aleksandra Leśniewska http://orcid.org/0000-0003-2513-9837, aleksandra.lesniewska96@wp.pl, Medical University of Lublin, Poland

Piotr Przybylski http://orcid.org/0000-0002-3352-3700, dr.przybylski@gmail.com, Ist Department of Radiology, Medical University of Lublin

Abstract

Introduction: Pulmonary embolism (PE) is a condition involving the mechanical part of the closure of the pulmonary arterial thrombus or other embolic material. Is the third the most typical cardiovascular disease - vascular, immediately after a heart attack and stroke. Clinical symptoms are often nonspecific and may result in an incorrect diagnosis. The most common complications of PE include: attack the lungs, impaired heart function, superinfection and development of pulmonary hypertension.

Objective: The purpose of the work was to discuss of the technical aspects and the use of multi-slice computed tomography in the diagnosis of PE. The presentation emphasized new directions of development of tomographic methods in imaging thromboembolic events of pulmonary arteries, including multi-energy CT and low-dose techniques.

Description of the state of knowledge: Angiography-CT is currently the gold standard in the diagnosis of PE, especially in patients with high and indirect clinical risk. It is characterized by high sensitivity and specificity in contrast enhancement imaging defects

within the pulmonary vasculature and blood changes in the pulmonary parenchyma, which may accompany the EP. It also allows to assess the features of right heart overload in the course of massive PE or radiological symptoms associated with the development of chronic PE.

Summary: Nowadays, the greatest challenges of CT diagnostics in PE are the improvement of image quality, minimization of artifacts and reduction of the radiation dose to which the patient is exposed. Effective diagnosis of PE is not only good quality CT imaging, but also the efficiency of the process of diagnosis. Hence the development of new applications of CT - called. computer aided diagnosis (CAD).

Key words: pulmonary embolism, multidetector computed tomography

Introduction:

Pulmonary embolism (PE) is a condition involving the mechanical part of the closure of the pulmonary arterial thrombus or other embolic material. It occurs most often as a venous - (VTE), which also includes venous thrombosis of the lower extremities [1].

Pulmonary embolism is the third most common cardiovascular disease - vascular, immediately after a heart attack and stroke[1]. In Poland, the annual incidence of PE is about 20 thousand. patients per year [2]. The precise incidence is very difficult to estimate due to nonspecific, and the disease of symptoms of clinical [3].

PE is the most common cause of death in patients after surgery, representing up to 15% of postoperative deaths. It`s also the leading cause of death in pregnant women. The mortality of untreated PE is about 30%.

A proper and fast diagnosis, resulting in an immediate switching anticoagulation is essential in the prognosis of patients with PE [3].

Clinical symptoms are often nonspecific and may result in an incorrect diagnosis. PE probability increases as the coexist symptoms or history of venous thrombosis, deep vein lower limbs history [1].

PE risk factors include: blood clotting disorders, pregnancy, use of oral contraceptives, recent surgery, prolonged immobilization, cancer, heart disease and kidney disease and systemic lupus erythematosus [1]. The risk also increases the innate and acquired coagulation disorders, including protein C deficiency and antithrombin III [4].

The most common complications include PE: attack the lungs, impaired heart function, superinfection and development of pulmonary hypertension.
Solid PE can lead to life-threatening acute right heart failure (ang. Right ventricle, RV) [3].

The aim:

The aim was to discuss the technical aspects and the use of multislice computed tomography in the diagnosis of PE. The analysis carried out also highlights the new developments in tomographic imaging methods change thromboembolic pulmonary arteries, including multi-energy CT and low-dose techniques.

Description of knowledge:

PE diagnosis is based on clinical assessment of the likelihood that an a key role in making the appropriate diagnostic strategy and the correct interpretation of results [3]. In clinical practice, the most common: Wells scale and the scale of the Geneva modified [5]. They allow you to estimate the probability of PE based on predisposing factors, signs and symptoms.

(Table 1).

Wells score	
Symptom	**Points**
Predisposing factors	
Venous thromboembolism in interview	+1.5
Recent operation	+1.5
Malignant neoplasm of immobilization	+1
Symptoms	
Hemoptysis	+1
Signs	
Heart rate> 100 per minute	+1.5
Clinical symptoms of deep vein thrombosis	+3
Clinical evaluation	
Another cause pulmonary embolism than less likely	+3
The likelihood of clinical pulmonary embolism (3 levels)	
Low	0-1
Intermediate	2-6
High	≥7
The likelihood of clinical pulmonary embolism (2 levels)	
Inlikely	0-4
Probable	> 4

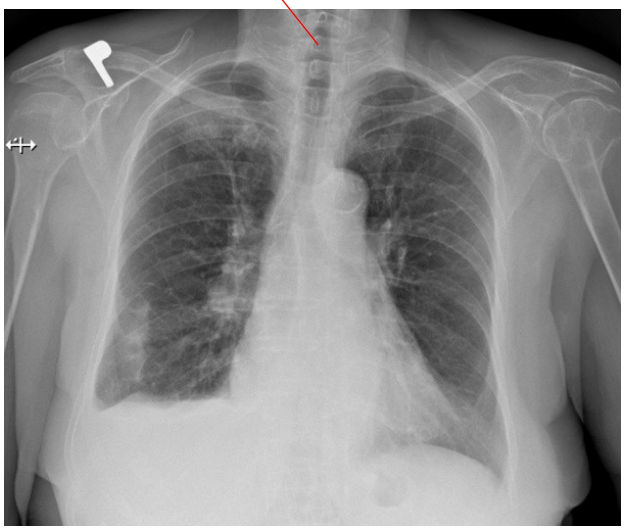
Table 1. Assessment of clinical probability of PE by Wells scale [5].

The basic laboratory test performed on patients with suspected PE is to determine the levels of D-dimer in the blood serum or fibrin degradation products. In patients with PE their concentration increases due to the activation of coagulation and fibrinolysis. This parameter has a high negative predictive value. This means that normal levels of D-dimer almost excludes the probability PE. This assay is also characterized by a low specificity [1, 6]. Elevated levels of D-dimer can occur in other clinical situations such as pregnancy, pneumonia, pulmonary infarction, tumors, infections, injuries, and in postoperative.

Therefore, determining the level of D-dimer can`t be the only study performed to confirm or rule out Ltd. [3].

In the diagnostic imaging in patients with suspected pulmonary embolism following methods are used:

- Chest X-ray image - The primary goal of X-rays with suspected PE is a preliminary differential diagnosis intended to exclude conditions such as pneumonia, pneumothorax or pulmonary infarction (as complication PE) which can manifest clinical symptoms similar [7].



Dig. 1. Chest X-ray of Hampton's hump (marked red lines in the picture).

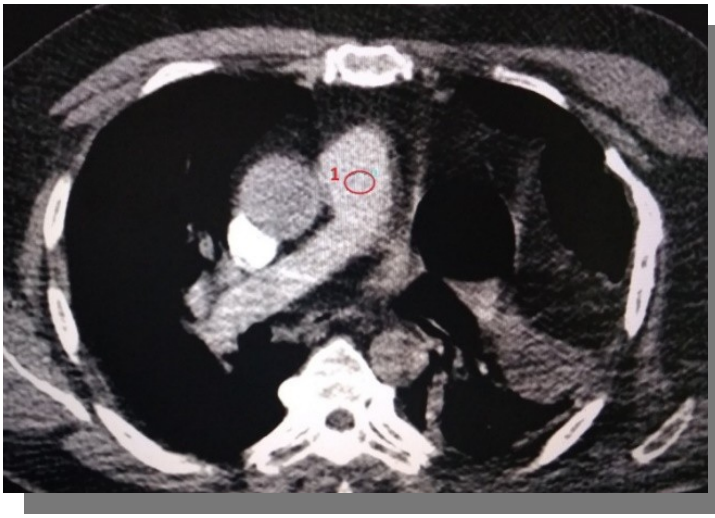
- Ventilation scintigraphy - lung perfusion using albumin macroaggregates labeled with technetium (Tc-99m) (scintigraphy V / Q) - This study allows the indirect diagnosis of venous thromboembolic events in the pulmonary arteries. Until 1990, scintigraphy V / Q is the "gold standard" (imaging modality of choice) is suspected PE [8]. It`s currently used mainly in patients with a high probability of a diagnostic result – that`s, in young people with a normal chest X-ray, in whom there`s a high clinical probability of PE [7]. It`s also used as an alternative method, you can`t perform CT.

- Echocardiography through the chest wall (ang. Transthoracic echocardiography, TTE) - TTE test has a high specificity but low sensitivity in the diagnosis of PE, as assessed respectively approx. 95% and 74%. This method is mainly used as a method for screening patients in a serious condition with suspected PE who can`t be made of other studies [4, 10]. Symptom echo confirming the presence of PE is the presence of blood clots in the cavities of the right part of the heart, which goes to show in 3-5% of patients. TTE doesn`t

knock most unambiguous confirmation or exclusion of PE, but it helps determine the risk group. It`s particularly useful in pregnant women, because of no risk of radiation and the limited diagnostic value of D-dimer in this population [1, 9].

- Ultrasound/transesophageal chocardiography (ang. Transesophageal echocardiography, TEE) -TEE is used in the diagnosis of PE, particularly in patients with features of massive changes in thromboembolic pulmonary circulation, with the symptoms of the so-called. acute pulmonary heart. Study confirms the high sensitivity and specificity of the above cases, reaching 84% and 84%. TEE is also the leading method for unstable patients whose clinical condition does not allow for transport to the lab CT. TEE allows visualization of blood clots in the cavities of the right heart and the proximal sections of the main pulmonary artery, ie. In the pulmonary trunk and the right pulmonary artery (Fig. 9). A negative test result doesn`t exclude the presence of a thromboembolic event in the left pulmonary artery or peripheral features PE subsegmental small branches [10].

- Multidetector computed tomography (Ang. Multiple-detector row computed tomography, MDCT) - Angiography, computed tomography (CT angiography) was first used in the diagnosis of acute PE in the early 90 [18]. The dynamic development of multi-technology at the turn of the last decade caused that MDCT has now become the gold standard for the diagnosis of PE [11]. Development of a rapid scan technique and improve the quality of imaging allowed the marked decrease in the percentage of non-diagnostic results, with approx. 10% of single-tomography (ang. Single-detector row computed tomography, SDCT)To approx. 6% for MDCT[11, 12]. Scanners allow a new generation to explore the entire range of the chest in less than 4 seconds, the sub-millimeter layers. This allows visualization of venous thromboembolic events in a very small, subsegmental pulmonary artery branches. Use of additional secondary image reconstruction techniques to exclude PE in the arteries to the level of the sixth division of the sensitivity and specificity of 83% and 96% [13, 14].



Dig. 2. One-axis cross-section of the angio-CT pulmonary arteries.

The negative predictive value of angio-CT pulmonary arteries in ZPE is high and amounts to 96,2-99,1%. Valid image examination to exclude PE in patients with high clinical probability of its occurrence [8].

Among the additional features MDCT imaging PE can be mentioned: the assessment of radiological signs of overload right heart imaging pulmonary lesions associated with chronic PE (mosaic perfusion characteristics, the type of shading glass opacities), or symptoms of pulmonary hypertension complications (eg. Pulmonary infarction).

PE is a major cause of deep vein thrombosis of the lower extremities, most often located in the proximal parts of the limbs. Hence, an important part of diagnosing patients with PE remains the assessment of this part of the venous system.

One of the main methods allowing for imaging veins of the lower extremities is a Doppler ultrasound. The diagnosis of PE test is performed mainly in patients who angio-CT image is inconclusive or scintigraphy V / Q is suspected deep-vein thrombosis [15].

An alternative to ultrasound in the assessment of deep vein thrombosis is a CT venography. The survey can be done in two ways:

- In the protocol angio-CT arterial disease, venous phase (approx. 2-3 minutes)
- As late phase angio-CT pulmonary arteries ranging from the abdomen to the popliteal pits

The second type of research allows concurrent evaluation of tetnic for pulmonary PE and deep veins of the abdomen, pelvis and lower limbs for thrombosis, with a single injection of

contrast agent. The following table shows the advantages and disadvantages study CTV (Tab. 2).

Many studies have shown that supplement research angio-CT pulmonary arteries optional intermediate venography increases the value of the diagnostic test, both in the case of negative results, and which supporting PE [16].

Advantages	Disadvantages
➢ One study in suspected DVT and PE	➢ Nephrotoxicity of iodinated contrast
➢ The high diagnostic accuracy, similar to Doppler ultrasound	➢ Exposure to ionizing radiation
➢ Others do not detect embolic - thrombotic pathologies (eg. Tumors)	➢ The test can not be performed at the bedside (the need for transport to the laboratory CT)
➢ High availability mode ER(unlike Doppler ultrasound)	➢ The relatively high cost of research
➢ Allows the assessment of leg veins and iliac veins, which are sometimes difficult to obtain in ultrasound imaging	➢ Limited accuracy in the diagnosis of venous thrombosis of lower leg
	➢ Streak artifact associated with the supply of orthopedic or too weak venous contrast enhancement

Table 2. Advantages and disadvantages of CT venography

The role of CT angiography in the diagnosis of pulmonary arteries PE:

In 2007. angio-CT pulmonary artery has been accepted as the reference method for the diagnosis of acute pulmonary embolism [17, 18], replacing scintigraphy V / Q and classical pulmonary artery catheterization [19].

CT protocol in the PE has a high negative predictive value, estimated at approx. 98-99%. This means that the correct image of the pulmonary arteries can safely exclude PE in patients with low or intermediate clinical probability of it [3]. The sensitivity and specificity of the diagnosis of a central PE exceeds 90%, the perimeter is slightly smaller.

In comparative studies scintigraphy V / Q lung was found that angio-CT has a higher sensitivity in the detection of PE. It also allows imaging of pathology other structures of the chest, in contrast to scintigraphic studies [20].

Classical pulmonary arterial catheterization as a sensitive method, but invasive, also lost its importance in the diagnosis of PE. Current indications for its implementation are cases in which non-invasive imaging studies don`t allow for a clear diagnosis and place when it`s planned invasive treatment [5]. The test should be considered for patients with high risk of mortality associated with recurrent thrombosis (i.e. loaded diseases like chronic obstructive pulmonary disease or severe heart failure), in which the result angio-CT is negative or inconclusive [7].

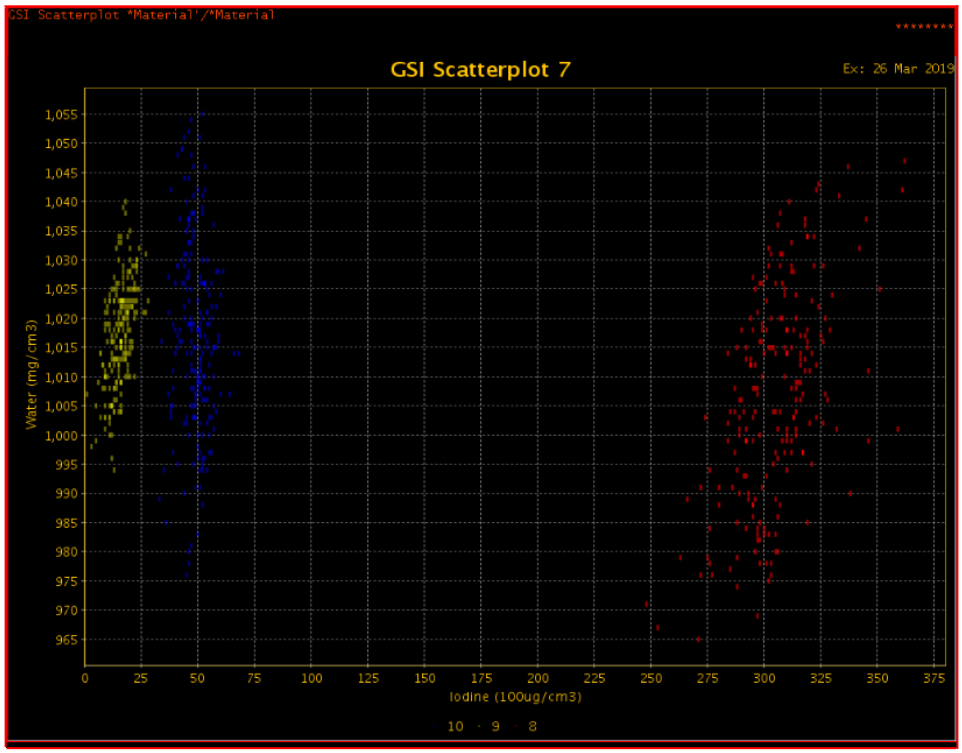
New developments

1) In recent years studies angio-CT pulmonary arteries was introduced technique ,, low-iodine and low-dose, "which accordance with the principle of ALARA aims to reduce exposure to X-rays and at the same time to obtain valuable diagnostic images.

The technique for the low dose and loq-iodine a reduction of the voltage at the X-ray tube with 120KVA to 80kV and the use of contrast agents in a lesser concentration of approx. 270 mg / ml. Thanks to the reduction of radiation dose by nearly63.6% and reduction of the dose of the contrast about 22.9% compared to the standard protocol employed (120KVA, 40ml, MGI 350 / ml). [21].

1) DECT (ang. Dual-energy computed tomography, DECT) was introduced as a diagnostic method designed to achieve high resolution, mainly of cardiac imaging [22].

In the evaluation of patients with PE imaging dual-energy maps are used depending J. They allow displaying images based on the absorption curve J, the amount of iodinated contrast agent at any voxel. This is possible due to the fact that J is characterized by a very different X-ray absorption spectrum using a voltage of 80kV and 140, compared to the soft tissue (Fig. 3).

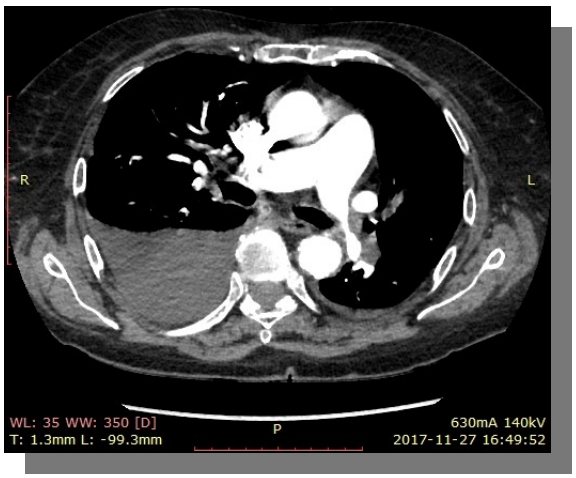


Dig. 3. GSI graph showing the iodine content of the water content.

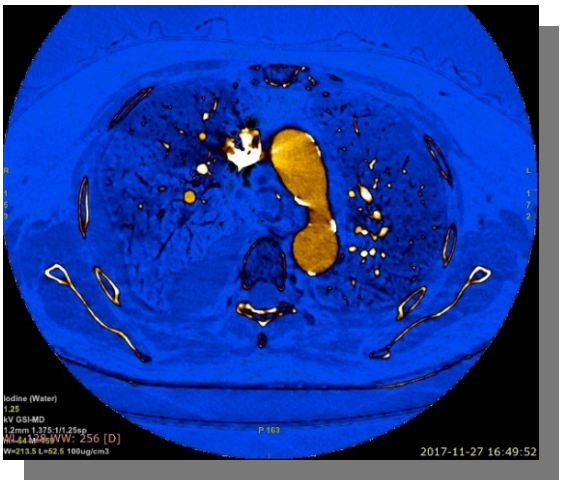
J-dependent maps show in great detail the degree of contrast enhancement pulmonary arteries to the level of the microcirculation, and the images are called "perfusion." However, "perfusion" DECT is a term ambiguous. The study dwuenergetycznym in a report, pulmonary embolism term is used in relation to that shown strengthen the contrast-induced lung parenchyma and doesn`t meet specific (quantification / semi-quantitative) analysis of the blood flow [22].

DECT imaging perfusion defects shows contrast enhancement of the pulmonary parenchyma in PE, appearing peripherally from the obstructed vessel (Fig. 27). This clearly improves the ability to detect small changes thromboembolism.

g



Dig. 4 An io-CT



imaging of pulmonary arteries dual-energy. (A) Scan-axis.

Features of PE on the right side. (B) Map of dependent iodine. Peripheral perfusion defects associated with embolic-thrombotic changes.

A B

DECT data obtained from scanning at both energy levels are further averaged and presented in the form of a hybrid monoenergetic image (as a counterpart scans obtained using a voltage of approx. 120KVA) that can be used to evaluate the morphology and anatomy of [22]

The development of modern applications tomographic led to the creation of computer-aided diagnosis (ang. Computer aided diagnosis CAD) to facilitate and improve the accuracy of the evaluation by the radiologist, improving the detection of small peripheral venous - thromboembolic events, and the detection and evaluation of lesions.CAD should, however, be always used as the "second assessment" and verified by a radiologist. It`s associated with a high percentage of false positive and negative, which only effect of computer assessment of the study [23].

Summary:

Pulmonary embolism is often diagnosed in patients presenting to the Emergency Department, as well as hospitalized patients. Because the clinical manifestations of the disease are nonspecific and may be associated with many other pathologies, the most important in the diagnosis of PE role properly carried out and fast diagnostics. CT-angiography is currently the gold standard in the diagnosis of PE.

It has a high sensitivity and specificity for imaging defects arterial contrast enhancement within the pulmonary vasculature, and pulmonary lesions which may be accompanied PE. It also allows the evaluation of the characteristics of overload right heart for massive PE or radiological symptoms associated with the development of chronic PE.

Currently the biggest challenges tomographic diagnosis of PE is to improve the quality, minimizing artifacts and a reduction in radiation dose at which a patient is exposed. They`re implemented by using modern multi-row scanners, standardized protocols acquisitions and injection of kontrastosuch as that which should be properly modified depending on the patient-dependent factors. In recent years, there is also a dynamic development of techniques for low dose and low-iodine allowing the detection of PE by dose reduction of up to approx. 53% and a reduced volume of contrast agent [24].

More widely used in the diagnosis of PE is Also DECT allows to improve the detection of small defects in the arteries subsegmentalnych contrast enhancement and accompanying perfusion.

Effective diagnosis of PE is not only good quality CT imaging, but also the efficiency of the process of diagnosis. Hence the development of new applications of CT - called. computer aided diagnosis (CAD), aimed at facilitating and improving the accuracy of the evaluation by the radiologist.

Bibliography:

1. Pruszyński B., Leszczyński S. *Diagnostyka obrazowa. Płuca i śródpiersie.* Wyd. Lekarskie PZWL, Warszawa 2010, ISBN 97-83-200-3688-6
2. Bělohlávek J, Dytrych V, Linhart A. Pulmonary embolism, part I *Epidemiology, risk factors and risk stratification, pathophysiology, clinical presentation, diagnosis and nonthrombotic pulmonary embolism*. Exp Clin Cardiol. 2013 Spring;1 8(2)
3. Ciurzyński M., Pruszczyk P. *Algorytmy diagnostyczne w zatorowości płucnej*. Rozdział III
1. Bakoń L., Pacho R. *Diagnostyka obrazowa Płuca i śródpiersie. Ocena radiologiczna w zatorowości płucnej. Sylabus.* Szkoła Radiologii PLTR, Kielce 2011
4. Smarż K. *Zatorowość płucna.* Borgis - Postępy Nauk Medycznych 2-3/2007
5. https://radiopaedia.org/articles/pulmonary-embolism
6. Brant W., Helms C. *Podstawy diagnostyki radiologicznej Tom II.* Wyd. MediPage, Warszawa 2008, ISBN 978-83-89769-67-1
2. Doğan H, de Roos A, Geleijins J, Huisman MV, Kroft LJ. *The role of computed tomography in the diagnosis of acute and chronic pulmonary embolism.* Diagn Interv Radiol. 2015 Jul-Aug; 21(4)

3. Małek G, Drygalska A, Kober J, Wawrzyńska L, Debski R, Dabrowski M, Torbicki A. *Chest ultrasound in the diagnosis of pulmonary embolism in a pregnant patient – a case report.* Pneumonol Alergol Pol. 2009; 77(6)
4. Vieillard-Baron A, Qanadli SD, Antakly Y, Fourme T, Loubières Y, Jardin F, Dubourg O. *Transesophageal echocardiography for the diagnosis of pulmonary embolism with acute cor pulmonale: a comparison with radiological procedures.* Intensive Care Med. 1998 May; 24(5)
5. Hartmann I.J., Wittenberg R., Schaefer-Prokop C. *Imaging of acute pulmonary embolism using multi-detector CT angiography*: an update on imaging technique and interpretation. Eur J Radiol 74, 2010
6. Stein P.D., Matta F. *Acute pulmonary embolism.* Curr Probl Cardiol. 2010 Jul; 35(7)
7. Hoffer M., MD, MPH, MME. *Podręcznik tomografii komputerowej. Medyczne podejście do interpretacji badań TK*. Copyringht by MediPage, Warszawa 2008
8. PIOPED Investigators. *Value of the ventilation/perfusion scan in acute pulmonary embolism. Results of the prospective investigation of pulmonary embolism diagnosis* (PIOPED). JAMA. 1990 May 23-30; 263(20)

7. Sąsiadek M. *Diagnostyka obrazowa narządów klatki piersiowej.* Wyd. Elsevier Urban & Partner, Wrocław 2014, wyd.1
8. Ciccotosto C, Goodman LR, Washington L, Quiroz FA. *Indirect CT venography following CT pulmonary angiography: spectrum of CT findings.* J ThoracImaging. 2002 Jan;17(1):18-27. Review
9. Kumamaru K. K., Hoppel B. E. Mather R. T., Rybicki F. J. *CT angiography: current technology and clinical use.* Radiol Clin North Am. 2010 Mar; 48(2)
10. Remy-Jardin M, Mastora I, Masson P, Galland E, Delannoy V, Bauchart JJ, Remy J. *Severity of acute pulmonary embolism: evaluation of a new spiral CT angiographic score in correlation with echocardiographic data*. Eur Radiol. 2003 Jan; 13(1)
11. Patel UB, Ward TJ, Kadoch MA, et al. *Radiographic features of pulmonary embolism: Hampton's hump.* Postgraduate Medical Journal 2014
12. Yılmaz Ö., Üstün E. D., Kayan M., Kayan F., Aktaş A. R., Unlü E. N., Değirmenci B., Cetin M. *Diagnostic quality of CT pulmonary angiography in pulmonary thromboembolism: a comparison of three different kV values.* Med Sci Monit. 2013 Oct 30;19

13. Hu X, Ma L, Zhang J, Li Z, Shen Y, Hu D. Author Correction. *Use of pulmonary CT angiography with low tube voltage and low-iodine-concentration contrast agent to diagnose pulmonary embolism.* Sci Rep. 2018 Mar 12; 8(1)
14. Lu GM, Wu SY, Yeh BM, Zhang LJ. *Dual-energy computed tomography in pulmonary embolism.* Br J Radiol. 2010 Aug; 83(992)
15. Zhou C, Chan HP, Patel S, Cascade PN, Sahiner B, Hadjiiski LM, Kazerooni EA. *Preliminary investigation of computer-aided detection of pulmonary embolism in three-dimensional computed tomography pulmonary angiography images.* Acad Radiol. 2005 Jun;12
16. Gill MK, Vijayananthan A, Kumar G, Jayarani K, Ng KH, Sun Z. *Use of 100 kV versus 120 kV in computed tomography pulmonary angiography in the detection of pulmonary embolism: effect on radiation dose and image quality*. Quant Imaging Med Surg. 2015 Aug;5(4)