Description of imaging methods in medicine including 2D and 3D ultrasonography

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Abstract

Diagnostic techniques have played an enormous role in medicine for several decades. Imaging methods allow for a thorough examination of organs and various diseases with minimal or even no invasiveness. The discussed 2D and 3D techniques allow to make accurate diagnoses and to get to know the human body. Experience shows that the methods in many cases not only do not replace each other, but are complementary.

Key words:

2D techniqes, 3D techniqes, diagnostics, ultrasonography

Introduction

Medical imagining allows to examine the condition of the human body by creating images that show physiological changes or pathological anomalies. Over the last few decades, dynamic progress has been made in this field, resulting in a significant increase in the effectiveness of disease diagnosis and, consequently, the implementation of specialist treatment. Medical imaging is used in visualization, quantitative analysis, localization, and screening.

Applications for imaging diagnostics

There are four main areas in which medical imaging techniques are used:

Visualization – consists in making the symptoms of disease visible through the use of appropriate technical procedures, such as: defuming, strengthening the edges, sharpening the blurred images, "revealing" the obscured organs, 3D visualization.

Quantitative analysis – collection and calculation of measurable traits describing selected organs in a patient. These may be e.g.: length of femur, volume of heart atria.

Localization – precise determination of the place of trauma, damage or pathological change. In surgery, the access route can be appropriately selected, specifying the depth or angle at which the puncture or biopsy needle should be inserted.

Screening tests – to extract from a large set of images those that require further analysis. The characteristic feature of this type of diagnostics is low probability of obtaining a result indicating pathological changes.

Methods of imaging diagnostics

The technological progress made in recent years in diagnostics has had a huge impact on current medical care. The main goal of imaging diagnostics is to examine various organs and various diseases in the body, with the least possible invasiveness of each of these methods (the least amount of harmful rays, the least interference with the patient's body and the shortest possible examination time). Some imaging methods are complementary. Classical radiology or computed tomography uses X-rays, ultrasonography uses ultrasound and magnetic resonance radio waves [2,3,6].

Image diagnostics includes sections such as:

1. Computed tomography (CT), one of the main methods of imaging diagnosis in recent years

- diseases of the central nervous system (pathologies, diagnosis of stroke, post-traumatic lesions, brain tumors, angiographies within the brain),
- abdominal diseases (tumours, pancreatitis, liver and kidney pathologies as well as virtual endoscopy such as CT colonoscopy)
- diseases within the lungs, mediastinum (diagnosis of coronary vessels, implanted stents, diagnosis of aortic-coronary bridges including: degree of calcification of plaques, analysis of anatomy of coronary artery outlet, course of the vessel, left atrial imaging, diagnosis of pericardium, morphological evaluation of heart valves).

The basis for CT examination is appropriate equipment, with multi-row systems – 16, 32, 64, and currently the latest 320-row and the use of the latest generation of contrast agents. The technique of multilayer CT scan by using multiple rows of detectors allows to obtain numerous, parallel sections of the examined organ during one lamp rotation. This allows to shorten the examination time – imaging of the whole chest is possible during a single breath stop and the resolution is higher. Average radiation doses obtained during the examination are currently in the range of 2-16 mSV (Fig. 1).

Contraindications to the test:

- Intensified cardiac arrhythmias.
- Lack of cooperation with the patient – e.g. inability to lie down, to follow orders (patients with limited contact, etc.).
- Difficulty in holding breath during the examination, advanced respiratory failure.
- General contraindications: pregnancy, allergy to iodine contrast agents, significant renal failure, significant obesity [2,3,6].

2. Magnetic resonance

It is a non-invasive, radiation-free method of imaging the human body using a magnetic field, and sometimes also generally well tolerated contrast agents (gadolinium chelates). It allows to obtain any image of body cross-sections. It allows to diagnose an increasing number of diseases. Recently, MR examination has become the main examination in some disease units and their diagnosis, e.g. myocardial infarction (evaluation of post-mortem scar), prostate cancer, inflammatory bowel diseases, rectal cancer. It also plays an important role in qualifying for surgical treatment and monitoring the effects of radio- or chemotherapy.

Magnetic resonance imaging is used in many medical fields: neurology, neurosurgery, surgery, cardiology, orthopaedics, gynaecology, obstetrics, gastroenterology (Fig. 2) [4].

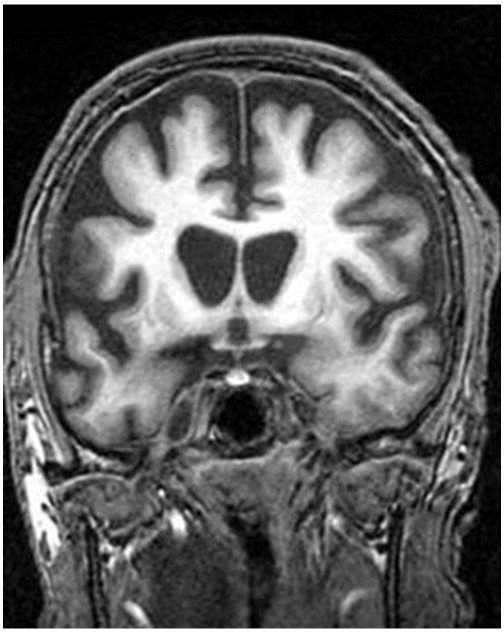

Fig. 1.
Computer tomography image of a patient with Huntington's disease [14].

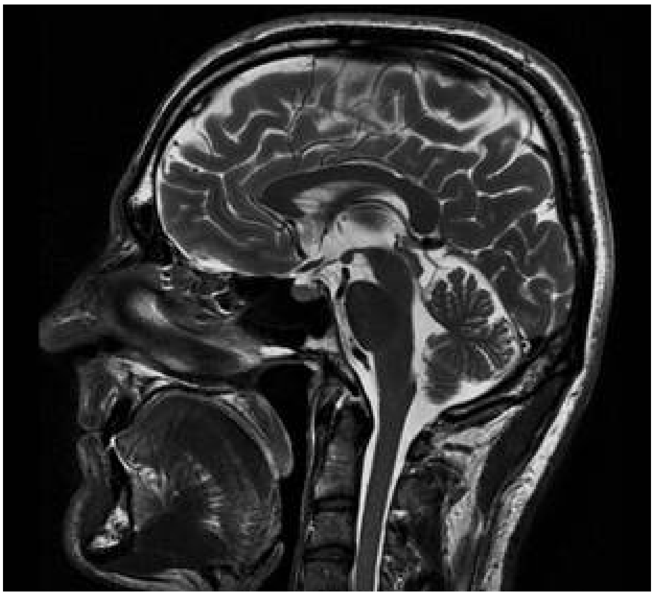

Fig. 2.
Magnetic resonance image [15].

Contraindications:

Contraindications for MR testing are related to the magnetic field produced by MR scanners, which is able to interfere with electrical equipment.

Absolute contraindications include in particular:

- pacemakers
- neurostimulators
- insulin pumps
- implanted hearing aids
- intracranial metal clips,
- metallic foreign bodies
- claustrophobia [4]

3. Ultrasonography

This is a common, cheap and very practical imaging method. It is safe and accurate, therefore it is widely used in medicine and diagnostics. Ultrasonography allows for non-invasive "viewing" of internal organs in real time, which allows the defendant to assess the movement of structures inside the body. The image is created by sending pulses of ultrasound waves. They are reflected on the borderline of different environments and, coming back, reach the head at different times and intensities, creating an image. The frequencies used range from 2 to 50 MHz. The closer the probe is to the examined organ, the greater the possibility of obtaining higher resolution and image accuracy. It is possible to introduce the probe into the oesophagus, stomach and duodenum, vagina, rectum, bladder, trachea, bronchi.

The great advantage of this examination is the lack of contraindications to its performance (Fig. 3) [7].

4. Classical radiology

Radiological examination is based on the patient's selected body part (e.g. the pelvis) passing through appropriate doses of X-rays (X-rays). The X-rays are received by a radiation detector located behind the examined area. The X-rays, which pass through soft tissues and bones, are partially absorbed by them, which is what gives an image of these structures. The X-ray detector can be an X-ray film or a specialised luminescent screen that converts the original X-ray image into a visible light image. In some cases, the patient is given an oral shading agent (contrast), which strongly absorbs the radiation, allowing the esophageal image to be obtained (Fig. 4) [8].

The basic types of x-ray examination:

- chest
- abdominal cavity
- Pelvis

Fig. 3.
Fetus ultrasound image [16].

Fig. 4.
Chest X-ray [17].

- skulls
- shoulder rim
- backbone all over
- upper and lower limbs

Using shading and contrasting agents:

- ugrafia
- Cystography
- sialography
- oesophageal and stomach x-ray
- colorectal shading infusion
- gut

Contraindications:

- Pregnancy
- Allergy to iodine contrast
- Kidney failure: GFR <45ml/min
- Multiple myeloma, Waldenstroem paraproteinemia
- Unstable, unstable hypertension [9]

Comparison of 2D and 3D techniques

1. Prenatal tests

Ultrasonography is a standard examination performed in pregnant women. According to the guidelines of the Polish Society of Gynaecologists and Obstetricians during pregnancy without complications, it should be performed at least three times [11]. Routine ultrasonography is routinely performed using the 2D technique; more and more often, the diagnosis is additionally extended by the use of the three-dimensional technique.

The use of the two-dimensional technique as the "gold standard" in prenatal examinations results from the fact that the 3D technique requires appropriate positioning of the foetus and the presence of an appropriate amount of amniotic fluid. Limitations may be caused by: too little amniotic fluid, unfavourable fetal position, presence of umbilical cord loops or limb positioning.

However, under favourable conditions, the 3D technique allows to obtain much more precise results compared to 2D techniques in the diagnosis of facial faults – cleft palate, cleft lip, and cleft gingival.

When it comes to assessing the chest and heart in the fetus, the 3D method does not show any advantage over the standard 2D examination. The situation is similar when assessing the fetus' abdominal cavity, but 3D ultrasound allows for accurate measurements of the volume of structures filled with regular shaped fluid such as the bladder and stomach.

3D ultrasound allows for a more accurate diagnosis of limb anomalies, compared to the standard two-dimensional technique. The sensitivity of the examination is as follows: 93.9% vs. 73.3%, for limbs: 96.3% vs. 48.2%, for the neck/face: 96.2% vs. 65.4%. As for the accuracy of fetal biometric measurements, significant differences between 2D and 3D techniques were not demonstrated.

It also turns out that the 3D method may be important in the detection of spina bifida with determination of its height and in the assessment of spinal cone level. Also the use of 3D Power Doppler technique allows the detection of flow abnormalities in large cerebral vessels in the fetus – anterior, middle and posterior arteries [10].

The use of 3D methods allows to extend the diagnostics in prenatal tests, as well as increase their accuracy. Although at the moment it is the 2D technique that remains the diagnostic standard in this field, it is possible that 3D techniques will contribute to the development of its development, increase the diagnostic possibilities and effectiveness of methods.

2. Echocardiography

The introduction of real-time 3D imaging (RT3D – real time 3D) allowed for a wide application of this technique in cardiology. The 2D method allows only to obtain an image in one plane, while RT3D allows to obtain an image of cardiac sections in different planes, together with an accurate assessment of organ size, structure and function. Its limitation is the small number of repetitions of images over time, which is particularly important in patients with heart rate. This type of technique is also used during transesophageal examination.

In transthoracic echocardiography the use of 3D technique is particularly important in the assessment of the left ventricle as it allows to present the curve of variability of left ventricular volume with calculation of end systolic and diastolic volume as well as ejection fraction. Using 2D technique the left ventricular volume was often underestimated due to inaccurate ventricular axis images and apical shortening.

In the assessment of the right ventricle, the role of the two-dimensional method is very limited as the assessment of the ventricular volume in plane is very difficult due to its complex shape. In clinical practice magnetic resonance imaging is used to assess its volume. Echocardiographic evaluation of right ventricle size is limited to short axis dimension in 4C projection taking into account its relation to LV size. Routine tricuspid ring mobility (TAPSE) and ventricular pressure calculated on the basis of Doppler examination are also assessed. RT3D allows for accurate mapping of the chamber shape and calculation of volume and ejection fraction. The previous tests have shown a very high compatibility with the results obtained during MRI.

The RT3D technique often allows for the precise visualization of the atrial septal defect, especially in transesophageal examination. In the case of atrial heart tumors, RT3D allows the surgeon to more accurately locate the tumor in relation to other heart structures and visualize it accurately. It also facilitates the assessment of the cancer involvement of adjacent heart structures.

Three-dimensional transthoracic echocardiography allows for accurate imaging of the mitral valve, which is important in the diagnosis of its regurgitation (which was not always visible on the plane), also much better than the 2D method, illustrates the geometry of the tricuspid valve, allowing to assess its structure and function. However, the advantage of this technique over 2D aortic valve imaging has not been demonstrated.

RT3D method is also increasingly used in echocardiographic stress tests performed during the diagnosis of coronary artery disease, however, its advantage over 2D technique has not been demonstrated yet [12].

3. Micapping sonocystigraphy

In 2013, studies were conducted to diagnose bladder-ureteral outflow using 2D, 3D and 4D techniques. 2D techniques allowed for the morphological evaluation of the urethra as well as the neck of the bladder, while the use of 3D and 4D techniques allowed for spatial evaluation of the bladder and urethra both before and during micapping and precise determination of the disease [13].

An example of the above study carried out in the University Children's Hospital in Lublin shows that 2D, 3D, 4D diagnostic techniques should be used together more often to extend the diagnostics and increase the accuracy of the performed tests.

Summary

The dynamic development of technology allows for the increasing use of precise imaging methods such as 3D techniques. In combination with two-dimensional techniques, it often allows for early and accurate diagnoses and the precise location of various anomalies. 2D and 3D imaging methods are non-invasive, widely used in medicine and have a huge impact on diagnostics.

References

1. Pruszyński B. Diagnostyka obrazowa. Podstawy teoretyczne i metodyka badań. Wydawnictwo Lekarskie PZWL, Warszawa 2000.
2. Walecki J, Zawadzki M. Nowe metody diagnostyki obrazowej – od struktury do funkcji. Przewodnik Lekarza/Guide for GPs. 2009;12(1):242-250.
3. Głaski J. Żadna z metod obrazowania nie ma wyższości nad inną, Kwartalnik KCO 2018 nr.3 (3).
4. Dobrowolska-Bąk M., Dubis A., Brandt Ł., Rożnawska K. [et al.]. Bezpieczeństwo pacjenta i personelu medycznego w pracowni rezonansu magnetycznego. Nursing Problems / Problemy Pielęgniarstwa 2018; 26(3):182-190.
5. http://www.cs.put.poznan.pl/kkrawiec/zim/diagnostykaObrazowa.pdf dostęp: 19.05.2020.
6. https://ecz-otwock.pl/299/diagnostyka-obrazowa-dlaczego-jest-tak-wazna; dostęp 19.05.2020.
7. https://www.mp.pl/pacjent/badania_zabiegi/174821,ultrasonografia dostęp:19.05.2020.
8. http://www.gorismed.pl/radiologia-klasyczna/ dostęp: 19.05.2020.
9. https://szpital4.gliwice.pl/radiologia-klasyczna--rtg dostęp: 20.05.2020.
10. Pietryga M., Toboła K. Ultrasonograficzna diagnostyka prenatalna- możliwości technik 3D. Ginekologia i Perinatologia Praktyczna 2017; 2:143–154.
11. Rekomendacje Sekcji Ultrasonografii Polskiego Towarzystwa Ginekologicznego w zakresie przesiewowej diagnostyki ultrasonograficznej w ciąży o przebiegu prawidłowym – 2015;7 : 86, 551-559.
12. Sonecki P. Nowe techniki w kardiologii: echokardiografia 3D. Kardiologia po Dyplomie 2010; 9 (11): 36-45.
13. Woźniak M. M., Pawelec A., Wieczorek A. P., [et al.]. Sonocystografia mikcyjna 2D/3D/4D w diagnostyce i monitorowaniu leczenia odpływów pęcherzowo -moczowodowych u dzieci - czy może zastąpić rentgenowską cystouretrografię mikcyjną? Journal of Ultrasonography 2013; 13: 394–407.
14. https://portal.abczdrowie.pl/obraz-tk-w-ktorym-doszlo-do-zaniku-glowy-jadra-ogoniastego-powiekszenie-komor-bocznych-i-zan
15. http://rezonans.almed.com.pl/assets/images/galeria/9.jpg?ver=5
16. http://uvsfajardo.sld.cu/ultrasonografia-en-ginecologia-y-obstetricia-tercer-nivel
17. https://www.hellozdrowie.pl/rtg-klatki-piersiowej-%E2%80%92-jak-wyglada-i-co-pokazuje/