Application of new technologies in echocardiography as a factor objectivizing test results

Zastosowanie nowych technologii w echokardiografii jako czynnik obiektywizujący wyniki badań

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STRESZCZENIE

ZASTOSOWANIE NOWYCH TECHNOLOGII W ECHOKARDIOGRAFII JAKO CZYNNIK OBIEKTYWIZUJĄCY WYNIKI BADAŃ

Współczesna diagnostyka echokardiograficzna dąży do pełnej obiektywizacji wyników badań. Na przełomie XX i XXI wieku wprowadzono nowe techniki ultrasonokardiografii: tkankową echokardiografię dopplerowską (TDE – tissue doppler echocardiography) oraz technikę śledzenia markerów akustycznych (STE – speckle tracking echocardiography). Rozwój tych metod i ich aplikacja do warunków diagnostyki klinicznej jest przykładem wspomagania przez nowe technologie pracy personelu medycznego. TDE i STE umożliwiają ocenę funkcji skurczowej lewej komory serca w postaci ilościowej, stopniowo eliminując wpływ subiektywnej oceny echokardiografisty. Wiedza o możliwościach współczesnej diagnostyki kardiologicznej jest użyteczna dla personelu pielęgniarskiego realizującego programy edukacji zdrowotnej w grupach osób zagrożonych schorzeniami kardiologicznymi.

Słowa kluczowe: **echokardiografia, ultrasonografia, kardiologia, historia medycyny**

ABSTRACT

APPLICATION OF NEW TECHNOLOGIES IN ECHOCARDIOGRAPHY AS A FACTOR OBJECTIVIZING TEST RESULTS

Contemporary echocardiographic diagnosis aims at a full objectification of test results. At the turn of the twentieth and the twenty-first century new ultrasound techniques such as tissue Doppler echocardiography (TDE) and speckle tracking echocardiography (STE) were introduced to medicine and their development and application in clinical diagnosis are an example of medical staff being supported by new technologies. TDE and STE allow for the assessment of the left ventricular (LV) systolic function expressed in quantitative terms and the elimination of the influence of the echocardiographers' subjective assessment. Knowledge on the possibilities of modern cardiological diagnostics is useful for nurses pursuing health education programs among people at risk of cardiac diseases.

Keywords: **echocardiography, ultrasonography, cardiology, history of medicine**

INTRODUCTION

The development of diagnostic techniques allows for a more accurate imaging of the interior of the human body both in the structural and functional aspect. Knowledge of the latest medical diagnostic capabilities is important for both doctors and nurses. It enables not only planning of the most beneficial diagnostic and therapeutic strategies but also makes full use of innovative technologies in primary and secondary prevention of heart diseases. The knowledge of the capabilities and principles of conducting diagnostic tests, which apply new medical technologies is useful in planning and implementation of health promoting plans and prophylactic activities for example in patients with hypertension.

An excellent example of the application of the latest technology in medical diagnostics is the immense progress in imaging of the structure and function of the human heart that has been made at the turn of the century. Echocardiographic technology development over the past sev-

eral years allows for a diagnostic "anticipation" of symptoms experienced by the patient [1]. A particular challenge for contemporary echocardiographic diagnosis, however, is complete objectification of test results. The gradual improvement of the classical ultrasound technology, three-dimensional imaging possibilities and the application of speckle tracking echocardiograpgy enabled the incremental shifting of some previously subjectively evaluated parameters of the structure and function of the heart in the direction of an objective quantitative assessment.

Subjectivity and objectivity in echocardiography

The issue of doctors' subjective assessment of symptoms is one of the most important issues that occurred in medicine since ancient times [2]. The differences in perception and evaluation of disease symptoms resulting from the educational process and psycho-social conditions were already pointed out by the chronologically last representative of the Polish School of Philosophy of Medicine, Ludwik Fleck [3]. It would seem that in the case of medical personnel specializing in diagnostic imaging, who receives a similar level of knowledge and analytical skill, subjectivity in test result interpretation should not affect the overall results. The problem of various interpretations of the same picture in diagnostic imaging, however, still remains valid [4] despite the significant progress made in the unification of educational schemes in postgraduate education. Currently, apart from the issue of an objective interpretation of mammographic images [5], one of the most important problems is the elimination of subjectivity in echocardiography, in particular with regard to the assessment of myocardial contractility disorders [6,7]. The development of the newest diagnostic technologies can increase objectivity in this regard and the chance to overcome the impact of the echocardiographers' subjective assessment on the final test result is the application of tissue doppler echocardiography (TDE) and speckle tracking echocardiography (STE) [8].

Standard ultrasonocardiography

Ultrasonocardiography is the basic modern cardiology imagining technique, which allows for making accurate assessment of the anatomy of the heart, pericardium, the valvular functions, and the hemodynamic and contractile function of the heart. The inspiration for the application of ultrasound in medicine was a technical solution developed for the army during the Second World War – Radio Detection and Ranging (RADAR). In 1946, a French scientist André Denier anticipated the application of ultrasound in imaging of anatomical structures of the human body [9]. Historically, the first registered imaging of cardiac structures using ultrasound waves is dated to 1954 and was conducted by a Swedish cardiologist Inge Edler and a physicist Carl Hellmuth Hertz [10,11].The first study of the cardiac structures using a one-dimension ultrasound technique (M-mode) was conducted in 1963 by Joyner and Reid.

Standard echocardiography or ultrasonography (the heart echo) belongs to a group of non-invasive diagnostic imaging techniques. It uses the reflection of an ultrasonic sound wave from the heart and/or large vessels at a frequency of 1.5-10 MHz. The test may be performed in various ways: through the chest wall (transthoracic echocardiography – TTE), through the patient's esophagus (transesophageal echocardiography – TEE) or intraoperatively through direct application of the head of the equipment to the endocardium during a cardiac intervention. Transthoracic echocardiography may utilize one or more of several special types of echocardiography; one-dimensional echocardiography allows for the assessment of cardiac structures (M-mode), two-dimensional (2-D) enables surface and volume measurement of the heart ventricle, including the determination of ejection fraction and a three-dimensional (3-D) echocardiography is very useful in diagnosing congenial and acquired heart defects. ultrasonocardiography is essential for diagnosing and determining the severity of the coronary artery disease. It allows for determining the ejection fraction (EF: percentage of blood volume that is pumped from the left ventricle of the heart during one heartbeat, standard: 50%-70%) and left ventricular fractional shortening (LVFS: reflects changes in the short-axis of the left ventricular dimension between diastole and systole, standard >30%).

Ultrasonocardiography also allows for evaluating wall motion abnormalities correlated with pathologies in coronary circulation. The evaluation of these disorders in standard echocardiography was done subjectively by the physician performing the diagnostic procedure. Substantial progress has been made when the standard ultrasonocardiographic testing was enriched by Doppler ultrasonography, which enabled measuring of the velocity of the objects reflecting the ultrasound beam.

Tissue Doppler imaging and speckle tracking echocardiography

An important contribution to a more objective assessment of the regional systolic function of the heart is the introduction of quantitative techniques, which allow for an analysis of myocardial deformation during the different phases of the cardiac cycle. The deformation is expressed as a percentage and determines the change of distance between two fixed points on the muscle tissue [8]. These parameters can be expresses using both Tissue Doppler echocardiography (TDE) and speckle tracking echocardiography (STE)

The Doppler technique was applied in echocardiography in the 90s of the twentieth century [12]. This enabled to record the muscle tissue movement velocity due to filters eliminating the recording of blood flow velocity. Doppler echocardiography (TDE) allows for a quantitative assessment of global and regional myocardial function and synchronization of the systolic heart function by replacing the existing qualitative techniques burdened with subjective evaluation. Myocardial movement velocity, usually measured above the mitral ring or on the anteroseptal areas of the left ventricle is expressed by the longitudinal fibers affecting cardiac systolic and diastolic function of the left ventricle. The most intense velocity of the muscle movement is recorded at the base of the heart, gradually

decreasing toward the tip. In a description of echocardiography testing, conducted using TDE, the results are defined by the mitral annulus velocity (S wave) and muscle segments of the left ventricle. On the basis of empirical and biostatistical findings, it was assumed that the value of systolic velocity greater than 7.5 cm/s, average of 6 walls of the left ventricle indicates a normal function of the left ventricle [13]. The reduced maximal value of mitral ring velocity is an indicator of impaired systolic function of the left ventricle, especially among patients with normal values of ejection fraction [14]. The drawback to Doppler echocardiography, however, is the possibility of obtaining false positive or false negative results. In TDE, the velocity of a given myocardial segment is determined in relation to the ultrasound head applied to the exterior wall of the chest, which results in the measurement of mitral ring velocity or a given segment of the left ventricle and is dependent on the pulling of the adjacent myocardial areas and/or on instantaneous displacement of the heart muscle in relation to the echocardiographic probe [15]. In addition, measurement of myocardial velocity is dependent on the angle of incidence of ultrasound beams, which can also distort the TDE test results. Negative impact on the accuracy of test results may also include the image's poor quality [8,13].

Speckling tracking technique in ultrasonocardiography, first applied in clinical diagnosis in the early twenty-first century, allows for measuring changes in the position of points set on the heart muscle in plane and space and at specific time interval [16]. Due to these measurements it is possible to determine the percentage change in the distance between two points on the myocardium with respect to its starting position. STE 2D technique, which uses a high resolution technology allows for the analysis of all segments of the myocardium in the longitudinal, transverse and circular direction [8]. The advantage of the new STE 2D method over tissue Doppler echocardiography (TDE) is connected to the independence of analyses from the angle of ultrasonic beam incidence and the myocardial wall velocity. It allows for the measurement of myocardial deformation (strain: longitudinal, transverse and circular) and a strain in rate. Obtained value of the myocardial deformation in the STE 2D variant is determined based on the measurement made on a two-dimensional plane and neglects the spatial movement of the heart. The newest application of speckle tracking in STE 3D echocardiography overcomes these limitations by enabling comprehensive assessment of both global and regional left ventricular systolic function by determining the deformation of the endocardial surface in the left ventricle systolic phase. This variable is a very sensitive and objective indicator of the left ventricular failure and is useful in differing between left ventricular hypertrophy and hypertrophic cardiomyopathy. It is also applicable in predicting myocardial function recovery after myocardial infraction [8]. It should be noted that the STE technique is an example of the application of the latest technology in medical diagnostics, although it is not yet included as a standard in clinical trials. It is expected, however that in a relatively short time, it may become the primary form of non-invasive cardiology – perhaps in some cases it may become an alternative to coronary arteriography, which is always associated with a significant risk of complications.

SUMMARY

Application of newest technologies in non-invasive cardiac diagnostics at the turn of the twentieth and the twenty-first century created the possibility of earlier diagnosis of heart failure and a more precise prognosis for patients who suffered from myocardial infraction. The described, new diagnostic perspective is subsequently applied in both primary and secondary prophylaxis of heart diseases. The knowledge of modern non-invasive cardiac diagnostic testing is becoming necessary for both medical and nursing staff implementing health education programs among people at risk of serious cardiac disorders.

PIŚMIENNICTWO

1. Hensel KO, Jenke A, Leischik R. Speckle-Tracking and Tissue-Doppler Stress Echocardiography in Arterial Hypertension: A Sensitive Tool for Detection of Subclinical LV Impairment. Biomed Res Int. 2014;2014:472562. doi: 10.1155/2014/472562.
2. Riha O. Subjectivity and objectivity, semiotics and diagnosis. An approach to the medieval concept of illness. Sudhoffs Arch 1996; 80(2):129-49.
3. Sak J, Pawlikowski J. Medicine and thought-styles: on the 50th anniversary of the death of Ludwik Fleck (1896-1961). Isr Med Assoc J. 2012;14(4):214-8.
4. Perera T, Moseley J, Munro P. Subjectivity in interpretation of portal films. Int J Radiat Oncol Biol Phys. 1999;45(2):529-34.
5. Tomas I, Kotoromanović Z, Belaj N et al. Computer-aided evaluation of radiologist's reproducibility and subjectivity in mammographic density assessment. Coll Antropol. 2013;37(4):1121-6.
6. Gosse P, Roudaut R, Dallocchio M. Is echocardiography an adequate method to evaluate left ventricular hypertrophy regression? Eur Heart J.1990;11 Suppl G:107-12.
7. Sühling M, Jansen C, Arigovindan M et al. Multiscale motion mapping: a novel computer vision technique for quantitative, objective echocardiographic motion measurement independent of Doppler: first clinical description and validation. Circulation. 2004;110(19):3093-9.
8. Szymczyk E, Lipiec P, Michalski B, Kasprzak JD. Technika śledzenia markerów akustycznych 2D i 3D: zastosowanie kliniczne Kardiol Pol. 2013;71(1):77-83.
9. Edler I, Lindstrom K. The history of echocardiography. Ultrasound Med Biol. 2004;30(12):1565-644.
10. Singh S, Goyal A. The Origin of Echocardiography. Tex Heart Inst J. 2007; 34(4): 431-8.
11. Acierno LJ, Worrell LT. Inge Edler: father of echocardiography. Clin Cardiol. 2002;25(4):197-9.
12. Sutherland GR, Stewart MJ, Groundstroem KW et al. Color Doppler myocardial imaging: a new technique for the assessment of myocardial function. J Am Soc Echocardiogr, 1994; 7(5): 441-58.
13. Łanocha M, Katarzyński S. Tkankowa echokardiografia dopplerowska. Kardiologia Oparta na Faktach 2010; 3: 287-94
14. Sanderson JE. Heart failure with a normal ejection fraction. Heart 2007; 93(2): 155-8.
15. Olszewski R. Zastosowanie techniki śledzenia markerów akustycznych w ocenie funkcji lewej komory serca. Badania in vivo i in vitro. IPPT Reports on Fundamental Technological Research 2012, 2: 5-161.
16. Helle-Valle T, Crosby J, Edvardsen T et al. New noninvasive method for assessment of left ventricular rotation: speckle tracking echocardiography. Circulation. 2005;112(20):3149-56.

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