MATHEMATICAL METHOD OF CALCULATING THE VOLUME OF THE CAVITIES OF THE HEART VENTRICLES ACCORDING TO ECHOCARDIOGRAPHY

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Abstract: Calculating of cavities of ventricles of the heart according to echocardiography, having big values in cardiology is considered in the article. Here the main attention is concentrated on the left ventricle of heart, as having the most correct form and the best available visualization. In article the area and length of cavities are defined, installing the ultrasonic sensor in a parasternal position on a short axis, at the level of the end of shutters of the mitral valve. Further, the ultrasonic sensor is installed in the apical four-chambered with access. The image is fixed, studied the long axis of the cavity is divided evenly pieces. Each of its points of division, held parallel to a line perpendicular to inter ventricular septum. Each short-axis corresponds to certain areas of the cavities of the ventricles, which are also perpendicular to inter ventricular septum. Corresponding to each piece of the volume of the cavities of the ventricles of the heart is determined by calculating the approximate volume of a truncated cone. Then summing all of the volumes, we finally obtain the formula to calculate the volume of the cavities of the ventricles of the heart. It is shown that this method is accurate and reliable over the other method.
Keywords: Echocardiography, ultrasound, mitral, apical, parasternal, non-invasive.

INTRODUCTION

In echocardiography there is no single approach to the calculation of volume indicators of heart cavities. Large amounts approaches proposed in the literature for assessing the volume indicators of heart cavities indicators based one-dimensional, and in some cases, two-dimensional [1]. But, these measurements do not satisfy the more exact determination of the cavities of the ventricles of the heart. Therefore, at present, determination of the cavities of the ventricles of the heart by echocardiography is an important issue of Cardiology. There are variety of ways and methods of calculation the volume of the ventricular chambers. So, for example the most common method for calculating the volume of the left ventricle is calculated according to the formula Teychholtsa (Teichholz) [2].

There is also way of calculation [3], based on the ellipsoidal models and models based on the representation of the left ventricle in the form of an ellipsoid of revolution. Depending on the available pathology for description the form of the left ventricle, also apply hyperboloid, hemisphere, truncated sphere and other figures of rotation [4]. All these methods are inadequate reflection of configuration of normal and pathological conditions of the human heart, the lack of comparability of the results of calculating the volume of cavity different methods and, as a consequence, the lack of uniform criteria for pathology.

Also, the impossibility of their application for calculation of volume of the right ventricle is connected as with features of its ultrasonic visualization, and complexity of its form. By the most acceptable method of determination of volumes of cavities of the left and right ventricles, it is possible to consider a method of sections – division of volume into n of similar volumes, offered in work [5]. It is based on anatomic feature of a structure of ventricular chambers. Being that the form of internal and external contours of ventricles on a short axis, despite difficult character, is preserved in the section of similar figures along a long axis of heart (perpendicular to inter ventricular partition).

Existence of this feature confirms the statistical analysis of the data obtained as a result of pathoanatomical researches of serial cuts of human heart. Using this feature, it is possible to calculate the volume of ventricles of heart, having only two sections: on short and long axes, in terms of an echocardiography - parasternal on a short axis at the level of the end of shutters of the mitral valve and apical with four-chamber access. Thus the area and length of a cavity in a parasternal position of the ultrasonic sensor on the short axis slightly lower than a level the mitral of valves are defined. Further, the ultrasonic sensor is installed in the apical four-chambered to access the image is fixed.

MATERIALS AND METHODS

The study is divided evenly cavity n parallel lines perpendicular to the inter ventricular septum, using standard means of echocardiography, determined by the size of ventricular long axis and the length of each piece between the points of intersection of the internal cavity of said circuit lines. However, this method also has some disadvantages, as for example, when calculating the volume accounted for similar length of short axis, the long axis of a partition into n piece, rather than the area of the proposed formula for determining the volume of the cavity of the ventricles of the heart is not justified from a mathematical point of view. Therefore, the accuracy of the formula is low. In this article, unlike the above mentioned works, first defined area and the length of the cavity in the parasternal position, setting the sensor on the short axis at the end of the mitral valve (Figure 1). Further, the ultrasonic sensor is installed in the apical four-chambered with access. The image is fixed, studied the long axis of the cavity is divided evenly, n piece (Figure 2). Each of its points of division, held parallel to a line perpendicular to inter ventricular septum (Figure 1).

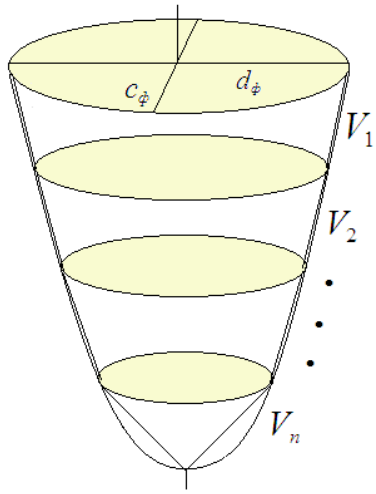

Figure 1. Evenly splitting the long axis of the n-pieces, each piece containing a curved volume of a truncated cone

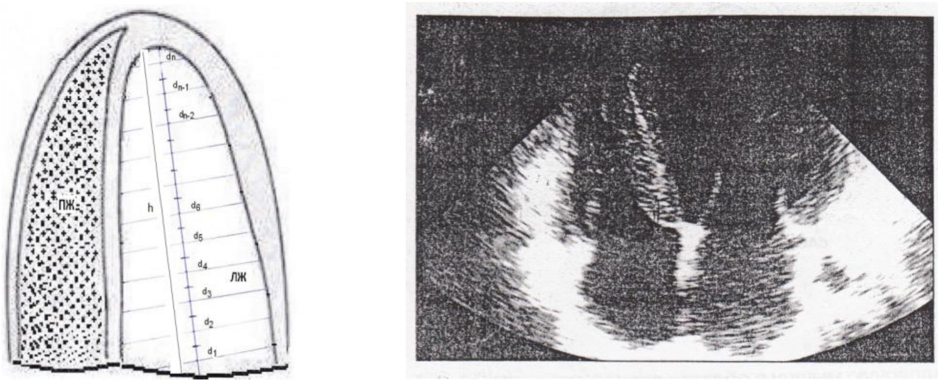

Figure 2. The apical four-chamber position (not shown in the atrium)

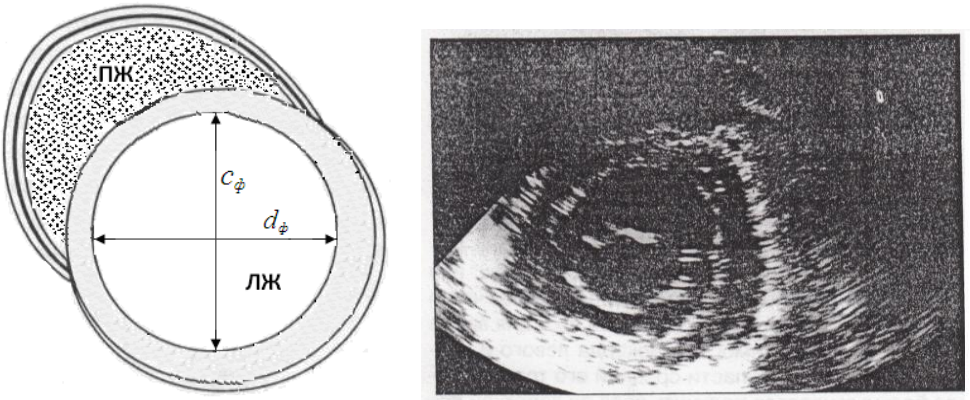

Figure 3. Parasternal short axis position at the end of the mitral valve

RESULT AND DISCUSSION

Each short axis corresponds to certain areas, which are also perpendicular to inter ventricular septum (Figure 3.). These similar areas are determined by following the formula

$$S_1 = Kc_1d_1,\ S_2 = Kc_2d_2,\ S_3 = Kc_3d_3 \ldots S_n = Kc_nd_n \qquad (1)$$

Where

K - coefficient of proportionality;

$c_1, c_2, c_3, \ldots, c_n$ - parallel axes;

$d_1, d_2, d_3, \ldots, d_n$ - perpendicular axis of inter ventricular septum;

From the condition of similarity S_n plane figures, it follows that

$$\frac{c_1}{d_1} = \frac{c_2}{d_2} = \frac{c_3}{d_3} =, \ldots, = \frac{c_n}{d_n} = N \qquad (2)$$

Hence we easily find

$$c_1 = Nd_1,\ \ c_2 = Nd_2,\ \ c_3 = Nd_3,\ \ldots,\ c_n = Nd_n \qquad (3)$$

Using (3) in (1), we determine

$$S_1 = KNd_1^2,\ S_2 = KNd_2^2,\ S_3 = KNd_3^2 \ldots S_n = KNd_n^2 \qquad (4)$$

Now, we will determine the lumpy volume of cavities of ventricles of heart with the help calculation approximately of the volume of the truncated cone. In this case corresponds to each piece defined the volume of the truncated cone which is calculated by following formula

$$\begin{cases} V_1 = KN\dfrac{H}{3n}(d_1^2 + d_1 d_2 + d_2^2) \\ V_2 = KN\dfrac{H}{3n}(d_2^2 + d_2 d_3 + d_3^2) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ V_{n-1} = KN\dfrac{H}{3n}(d_{n-1}^2 + d_{n-1} d_n + d_n^2) \end{cases} \quad (5)$$

$KN-$ coefficient is determined from any fixed the areas similar of plane figures such [6], so we denote it through the fixed.

$$S_\phi = KNd_\phi^2, \quad KN = \frac{S_\phi}{d_\phi^2} \quad (6)$$

Substituting (6) in (5), and summing all volumes, we finally find the formula for calculation the volume of the cavities of the heart ventricles

$$V_v = \frac{S_\phi}{d_\phi^2}\frac{H}{3n}(d_1^2 + d_n^2 + 2(d_2^2 + d_3^2 + ... + d_{n-1}^2) + + (d_1 d_2 + d_2 d_3 + ... + d_{n-2} d_{n-2})) \quad (7)$$

Where d_n – the size of the short axis, held points of division n-th piece perpendicular to the inter ventricular septum.

H - ventricle size on a long axis;

d_ϕ – fixations the cavity size in parasternal access on a short axis;

S_ϕ - fixations the area of cavity in parasternal access on a short axis;

$\frac{S_\phi}{d_\phi^2} = KN$ - dimensionless geometrical coefficient of similar plane figures. For known figures, such as for a sphere, ellipsoid, cone, cylinder, prism coefficient $KN-$ has exact values:

For a sphere $KN = \frac{\pi}{4}$, for an ellipsoid $KN = \frac{\pi}{4}\frac{c_\phi}{d_\phi}$, for a cone $KN = \frac{\pi}{4}$, for the cylinder $KN = \frac{\pi}{4}$, for a prism $KN = \frac{c_\phi}{d_\phi}$ and other well-known geometric figures we can determine the concrete values KN.

CONCLUSION

The proposed method allows achieving the following positive effects:

- sharp decrease in the time of data analysis echocardiography;

- the establishment of a more exact measurement of the volume of the cavities of the heart ventricles and reliable diagnosis for the patient.

- to test having known geometrical figures (sphere, cone, ellipsoid, and others.) the proposed formula, five times more exact than the proposed formula [6].

- the proposed formula is strictly mathematically justified, and each member has a physical meaning.

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