

Fetal foramen ovale flap tracings, as determined by M-mode echocardiography between weeks 24 and 39 of gestation

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INTRODUCTION

The fetal heart's contractions are the first markers of live pregnancy [1]. What makes the fetal cardiovascular system unique are cardiac shunts. One of them is foramen ovale (FO), which allows oxygenated blood to enter the left atrium from the right atrium. It is shaped like a tunnel created by a flap, which in normal conditions, should be seen in the left atrium. The FO size, interatrial flow patterns, velocities, and FO flap angle were studied before [2, 3]. Also, the ratio between the FO diameter and that of the right atrium was calculated [4], but still, fetal FO studies lack in quantitative assessment of its function. M-mode echocardiography, because of its very high frame rate, seems to be a reasonable tool to analyze features of FO function during the cardiac cycle of the fetal heart, as it turned out so far to be useful for fetal heart function monitoring [5, 6]. This study aimed to analyze M-mode echocardiography at an atrial level in normal healthy fetuses and to establish normal ranges of quantitative parameters assessing FO flap movements relative to the atrial wall diameter.

METHODS

This was a single-center, prospective case series of fetuses, who had fetal genetic ultrasound and fetal echocardiographic examinations at our tertiary center in 2019–2021. Clinical information was collected from medical registries and the database of our unit (Tricefy 4). All the fetuses had labels of "normal heart anatomy and normal heart study", were delivered at term and were discharged from the neonatal department by the 4th day after birth. Maternal chronic diseases and *in vitro*

fertilization were excluded. Gestational age (GA) was calculated based on fetal biometry. Every patient in our unit is requested to give consent to collect their data for scientific analyses. In our research, we performed additional measurements that did not influence clinical management, and we focused on the interpretation of the collected data, thus, additional approval from Ethical Committee was not necessary. Only good-quality atrial M-mode tracings were selected for further evaluation.

Perinatal characteristics

Terminated pregnancies were excluded from the analysis. All fetuses had a cardiovascular profile score (Huhta score) of 10 points. Fetuses with any functional or structural anomalies or malformations were excluded.

Fetal echocardiography

Apart from obstetrical ultrasound examinations, detailed echocardiography was performed on GE Voluson E8, GE Voluson 10, and Philips iU22. Additionally new measurement — the FO index was applied. M-mode of the atria was recorded with the largest scale possible and with a rapid sweep speed, only when the fetal position was favorable. Favorable fetal position means the apex of the heart is on "the clock as on 9th or 3rd hours", and the M-mode beam is perpendicular to the atrial septum, or almost perpendicular, with no more than 15° from the zero line. For more precise evaluation an option zoom was used. The measurements were taken at the time of examinations, and later another person performed an offline calculation on the Tricefy 4 database. We did not use angle correction or anatomical M-mode.

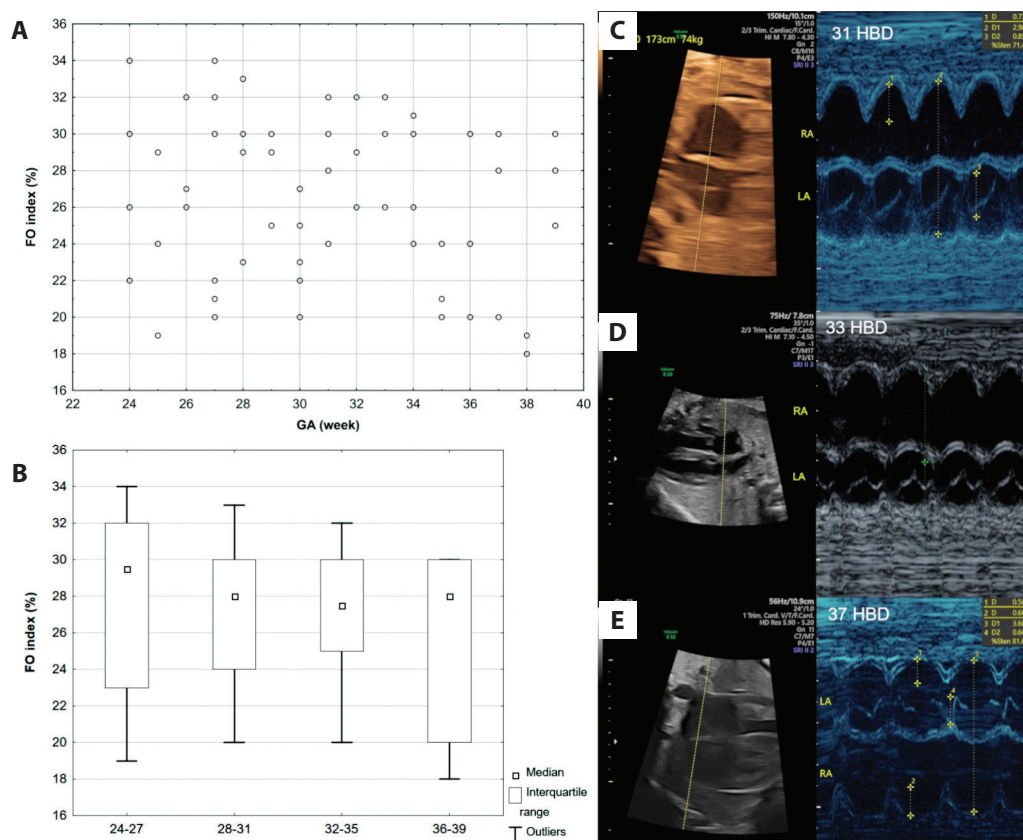


Figure 1. A. Scatter graph of the FO index by GA. B. Median and interquartile range of the FO index during gestation. C. FO flap and atrial wall movements of the fetal heart presented by M-mode echocardiography: there is right atrial dominance and progressive left atrial activity, which is most prominent shortly before birth. Week 31 of gestation. D. Week 33 of gestation. E. Week 37 of gestation

Abbreviations: FO, foramen ovale; GA, gestational age

Foramen ovale index

The quantitative assessment included the FO flap tracing index calculated on the basis of the following new formula:

$$\text{FO flap tracing index} = (B/A) \times 100\%$$

A — maximal length of both atria in diastole, measured in a transverse plane

B — maximal excursion of the FO flap tracing in the same transverse plane

Statistical analysis

Statistical analysis was performed using Statistica 13.1 and Excel 2007 programs. The minimal and maximal values, median with interquartile range were calculated when the data were not normally distributed. The Kruskal-Wallis test was used to analyze the FO index in subgroups according to GA. A *P*-value <0.05 was considered statistically significant.

To present relative intraobserver and interobserver variability the following equation was used:

$$\text{Variability} = |A-B| / [(A+B)/2] \times 100\% [7]$$

A scatter graph of FO index during pregnancy was created.

RESULTS AND DISCUSSION

Our study group, in the beginning, included 130 fetuses. Forty-six cases were excluded due to congenital heart defect, 10 cases were excluded due to additional functional cardiac or extracardiac abnormalities, and 8 cases before 24 weeks of gestation were excluded due to an insufficient number of cases for appropriate calculations. Finally, a total of 66 healthy fetuses were selected for analysis. Their GA was between 24 and 39 weeks of gestation according to fetal biometry. A scatter graph for the FO index during pregnancy was prepared (Figure 1A).

The study group was divided into 4 subgroups according to GA: 24–27 weeks of gestation, 28–31 weeks of gestation, 32–33 weeks of gestation, and 36–39 weeks of gestation (the Kruskal-Wallis test *P* >0.05) (Figure 1B). Median values and interquartile ranges were established for the following gestational weeks (Supplementary material, Table S1). The interobserver variability was 7%. The intraobserver variability was 16%.

M-mode atrial echocardiography is unique to fetal cardiology, and it was studied previously [8, 9]. In our research, we evaluated a new simple index for the objective assessment of FO flap movements. Despite increased blood flow through the FO with gestation [10], the FO

index showed relatively stable values corresponding to the other observations [11]. However, very thin FO trace movement in the left atrium is not easy to observe and record. M-mode technique is very helpful to obtain its trace; however, it requires some experience and a suitable fetal position (zoom, speed, recording of stable pattern without fetal movements).

Pulmonary vein blood flow velocity at the level of their connection to the left atrium plays a role in shape and movement of FO, in normal and abnormal conditions [12]. In normal fetuses with advancing gestational age, there is an increase in pulmonary blood flow [13], so one might expect a decrease in the FO index, as it should be closed postnatally [14]. On the other hand, it may suggest that despite an increased pulmonary blood flow in fetal lungs, there is still preserved functional stability at the atrial level. We noticed that the left atrial wall is more active close to the term (Figure 1C–E), and probably it could be responsive to bilateral blood flow at the end stage of pregnancy, as a variant of normal fetal physiology.

The function of the FO flap might be assessed quantitatively using the new FO index, based on atrial M-mode. Normal ranges of the FO index for the second half of pregnancy were presented. The FO flap function seemed to be relatively stable in normal conditions.

Article information

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