

# Mobility of the *Septum Primum* Does Not Depend on the Foramen Ovale Diameter in Normal Fetuses

Paulo Zielinsky, Marcelo Sallum, Fabíola Satler, Eduardo Ioschpe Gus, Luiz Henrique Nicoloso, João Luiz Mânica, Antônio Luiz Piccoli Jr  
Porto Alegre, RS - Brazil

## Objective

To test the hypothesis that a correlation exists between the maximum foramen ovale diastolic diameter and the excursion index (EI) of the septum primum in normal fetuses.

## Methods

One hundred and two normal fetuses with gestational ages ranging from 20 to 40 weeks were submitted to echocardiography. The foramen ovale diameter and the "maximal excursion" of the septum primum were measured in a 4-chamber view. The data were analyzed by Pearson's correlation coefficient.

## Results

The mean foramen ovale (FO) diameter was  $5.06 \pm 1.29$  mm; the maximal excursion of the septum primum was  $5.42 \pm 1.41$  mm; the left atrium diameter  $11.47 \pm 2.76$  mm; the septum primum "excursion index" was  $0.48 \pm 0.09$ . Mean FO/EI ratio was  $11.35 \pm 3.94$  mm. No FO/EI correlation ( $r = -0.03$ ) existed, and a weak foramen ovale/left atrium correlation ( $r = 0.31$ ) was observed, as well as a weak foramen ovale/excursion of septum primum correlation ( $r = 0.21$ ).

## Conclusion

Septum primum mobility does not depend on the foramen ovale diameter in normal fetuses, suggesting that the modifications of its diastolic displacement is not influenced by the size of the interatrial opening.

## Key words

fetal echocardiography, foramen ovale, septum primum, ventricular diastolic function

In fetal life, the *septum primum* acts as a valve to close the foramen ovale when atrial contraction occurs. In diastole, it protrudes within the left atrium, enabling maximal opening and flow from right to left. This protrusion is used as a reference to identify the left atrium (LA) in fetal echocardiography<sup>1,2</sup>.

In previous studies, the mobility of the *septum primum*, its involvement during intrauterine life<sup>3</sup>, and its correlation with the presence of atrial extrasystoles<sup>4,5</sup> were assessed. To quantify the excursion of the *septum primum* during the cardiac cycle, an index that correlates its maximal excursion with the left atrium diameter was created, the so-called "excursion index" (EI).

A previous study<sup>6</sup> showed that the excursion index is decreased in fetuses with ventricular septal hypertrophy secondary to maternal diabetes after 32 weeks of gestational age. An inverse correlation was present between the excursion index and interventricular septal thickness, suggesting that the excursion index could be used as a more suitable index for ventricular diastolic function than those usually accepted, since it was shown a more accurate inverse correlation with interventricular septal hypertrophy than the atrio-ventricular flows.

Another previous study has already demonstrated that, during fetal breathing, the excursion index of the *septum primum* is significantly increased; this finding was explained by an increase in left ventricular distensibility due to respiratory movements<sup>7</sup>.

Therefore, excursion of the *septum primum* depends on multiple factors, and its correlation with the foramen ovale size has not been studied. The present study was designed to test the hypothesis that a correlation exists between the foramen ovale diameter and the maximal excursion of the *septum primum* in normal fetuses.

## Methods

This was a noncontrolled, transversal study, assessing 102 fetuses without structural or functional abnormalities of the heart; mothers had no risk factors for heart disease. Fetal echocardiography being performed sequentially from 20 weeks of gestation through term, in a specialized center of Fetal Cardiology.

We excluded from the study fetuses with anatomical or functional abnormalities of the heart or any other organs and systems; fetuses whose mothers had systemic disease or risk factors for fetal heart disease; those in which it was impossible to obtain a suitable echocardiographic window; and gestational age below 20 weeks.

Instituto de Cardiologia do Rio Grande do Sul/Fundação Universitária de Cardiologia

Mailing address: Paulo Zielinsky – IC/FUC - Av. Princesa Isabel, 395 – 90620-001- Porto Alegre, RS – Brazil

e-mail: pesquisa@cardnet.tche.br

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Fetal echocardiographic examinations were obtained following the segmental sequential approach<sup>8,9</sup>, starting at the maternal umbilical region, and using the fetal dorsal spine, liver, and *septum primum* as anatomic references. Atrial *situs* was determined, together with heart position in the chest, type and mode of atrio-ventricular and ventriculoarterial connections, aortic arch, and associated defects.

ACUSON models XP-10 and ASPEN echocardiographic equipments were used for two-dimensional images, with a 4 to 7 MHz convex transducer or a 2.25 to 5 MHz *phased array* transducer.

The excursion index (EI) of the *septum primum* was determined from the following measures obtained at a 4-chamber view: A) maximal excursion of the *septum primum* towards the interior of the LA; B) maximum LA diastolic diameter. The ratio between A and B expresses EI (fig. 1).

The foramen ovale diameter was measured in a 4-chamber view, at the end of diastole. This parameter was obtained using the electronic cursor of the equipment, and the largest distance between the free edges of the interatrial septum was considered (fig. 2).

Pearson's correlation coefficient was established between the

foramen ovale diameter and the "excursion index" of the *septum primum*. The correlation coefficient between the foramen ovale and the maximum excursion of the *septum primum*, as well as left atrial diameter, were calculated as well.

This research was approved by the Ethical Committee in Medical Research of the institution, and all the patients gave their written informed consent. The standard Research Unit form was used to ensure data confidentiality.

## Results

Mean maternal age was  $26.26 \pm 6.18$  years. Gestational age ranged from 20 to 40 weeks (mean  $29.45 \pm 4.15$  weeks).

Figure 3A shows the variation in the foramen ovale diameter among the 102 fetuses studied. The mean diameter was  $5.06 \pm 1.29$  mm.

Values of the maximal excursion of the *septum primum* are displayed in figure 3B. The mean value obtained was  $5.42 \pm 1.41$  mm.

Figure 3C represents the maximal left atrium diastolic diameter of fetuses. The mean value obtained was 11.47 mm, with a 2.76 mm standard deviation.

The mean value of the excursion index of the *septum primum* in the 102 fetuses was  $0.48 \pm 0.09$ , according to figure 3D.

The Pearson's correlation coefficient between the foramen ovale diameter and the excursion index of the *septum primum* was -0.03 (fig. 4A).

The correlation coefficient between the foramen ovale size and the maximal left atrium diameter was 0.31. The correlation between the foramen ovale diameter and the excursion of the *septum primum* was 0.21 (fig. 4B and 4C).

## Discussion

In human embryology, the development of the cardiac septum represents a continuous system of protrusions together with the development of the external forms of cardiac walls. The free edges grow toward each other until they merge<sup>10</sup>. Septation of the two atria starts when the *septum primum* begins to grow from the posterior/superior portion of the common cavity of the wall, towards the atrioventricular junctions, where the developing endocardial cushions are separating atria and ventricles<sup>11</sup>. The *septum primum* is a thin structure with fenestrations in its medium portion, which partially separates the two atria. The low portion of the *septum primum* merges with the tissue from the endocardial cushions<sup>12</sup>. Later, *septum secundum* is developed, parallel and towards the right of the anterior. It starts in the posterior/superior region of the atrial wall and grows toward the atrioventricular junction. It has a semilunar edge with a hollow anterior/inferior portion, and it only partially covers the central hole of the *septum primum*. This edge forms the *crista dividens* of the fetal heart. The space between the *crista dividens* and the free edges of the *septum primum* is called the foramen ovale. This hole will only close after birth, through apposition of these two structures<sup>13</sup>.

The foramen ovale is important because of the decreased intrauterine pulmonary blood circulation. Most of the blood flow reaching the fetal heart comes from the right atrium, and then

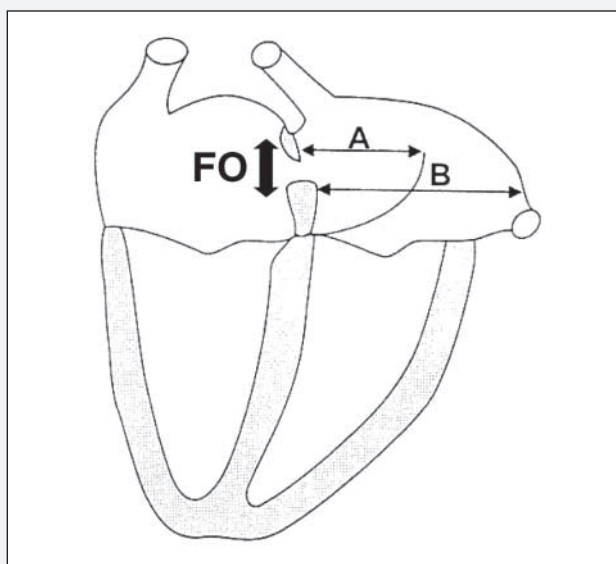


Fig. 1 - Picture of a 4-chamber view. FO- foramen ovale diameter; A- maximal excursion of the *septum primum*. B- maximal diameter of the left atrium.



Fig. 2 - Echocardiographic image of a 4-chamber view, demonstrating how to obtain foramen ovale diameter and locate the *septum primum*.

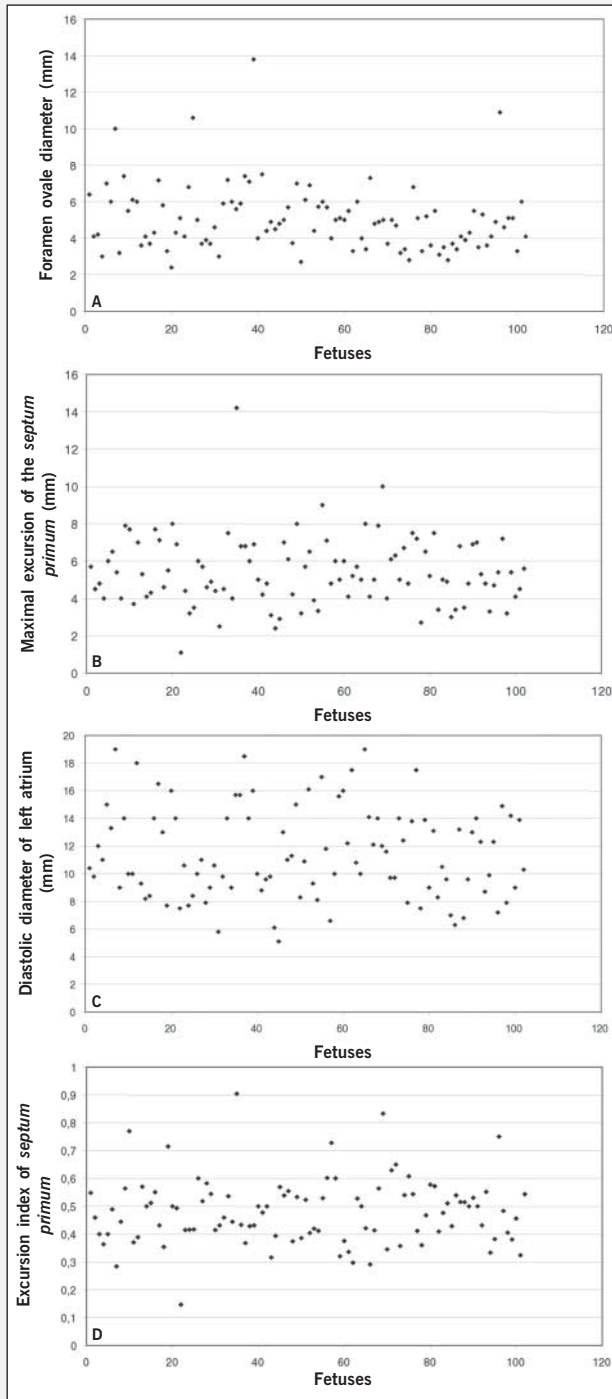


Fig. 3 – Echocardiographic fetuses of the sample. A) foramen ovale diameter; B) maximal excursion of the *septum primum*; C) diastolic diameter of left atrium; D) excursion index of *septum primum*.

from this structure part of the blood reaches the left atrium, joining the blood flow that returns through the pulmonary veins.

The literature has already studied the foramen ovale diameter, and suggests that it is approximately equal to the aortic diameter<sup>14</sup> or slightly smaller<sup>15,16</sup>. A restrictive foramen ovale (diameter < 2mm of maximum opening)<sup>17,18</sup> has been associated with left ventricular hypoplasia, interatrial septum congenital aneurysms, supraventricular fetal tachycardia, and intrauterine heart failure<sup>19,20</sup>.

Knowledge of the fetal cardiac circulatory dynamics has improved in recent years, with constant addition of new concepts. This study has tested the hypothesis that changes in the excursion of

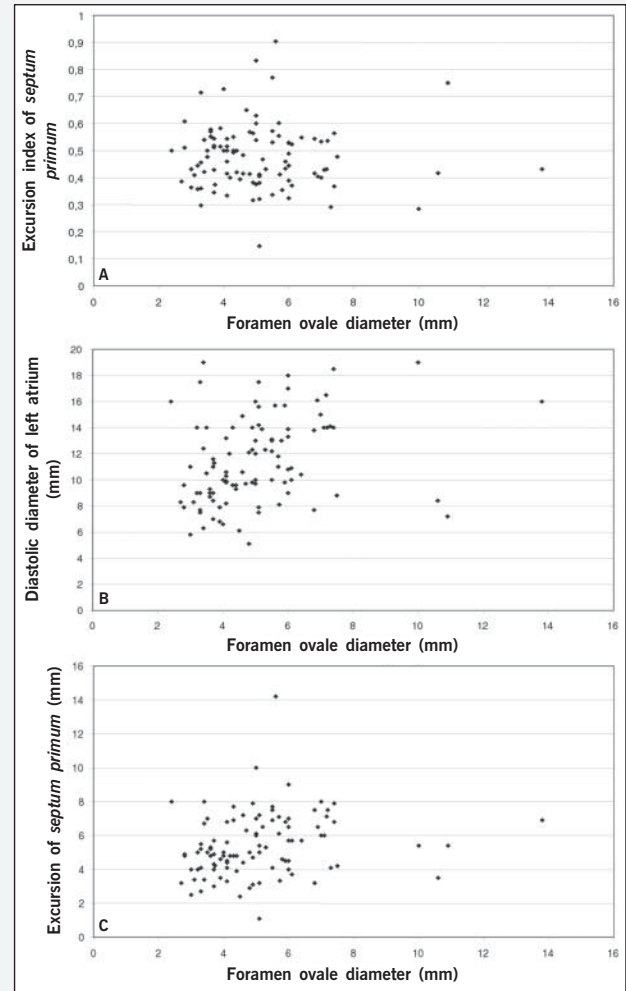


Fig. 4 – Correlation of foramen ovale diameter, and other echocardiographic parameters: A) FO/EI ratio; B) FO/LA ratio; C) FO/excursion ratio.

the *septum primum*, which correlates with alterations in left ventricle compliance and/or relaxation, could also be influenced by the foramen ovale diameter, which is the link between the two sides of the heart.

However, the results obtained in the present study demonstrated that no correlation exists between foramen ovale diameter and the excursion index of the *septum primum*. A weak correlation between the foramen ovale diameter and the maximal left atrium diameter, as well as the foramen ovale diameter and the excursion of the *septum primum* was observed, although not clinically significant.

Previous studies have demonstrated that *septum primum* mobility is influenced by left ventricle diastolic function, both in a model with a decrease in compliance (left myocardial hypertrophy)<sup>6</sup> and in a model with an increase in ventricular compliance (fetal breathing)<sup>3</sup>. A possible confusion bias could be represented by the foramen ovale diameter, thus prompting the present investigation. Positioning of the foramen ovale edges observed in the same moment of the cardiac cycle, according to measures described in the literature<sup>14-16</sup>, should minimize the possible limitations of measuring the foramen ovale in the cross-sectional echocardiographic image.

This study is a step in the research line aiming at studying left ventricle diastolic function in fetuses. Studies performed with flow



velocity through the foramen ovale, already under way and not part of this study, have proven to be useful to quantify left ventricular compliance in fetuses with myocardial hypertrophy.

In conclusion, data from the present study suggest that alterations in diastolic excursion of the septum primum do not depend on the level of interatrial opening in normal fetuses.

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