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Amniotic Fluid Pressure during Pregnancy

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Abstract. Intrauterine pressure was measured, at the time of diagnostic amniocentesis or cordocentesis, in 200 pregnancies at 10–38 weeks' gestation. Mean pressure decreased exponentially with gestation from 9 mm Hg at 10 weeks reaching a plateau of 5 mm Hg at 30 weeks. These findings are compatible with Laplace's law of pressure in spheroids.

Introduction

Amniotic fluid pressure in normal human pregnancy apparently increases with gestation. Thus, Nicolini et al. [1] and Weiner et al. [2] performed intrauterine pressure recordings with normal amniotic fluid volume in 36 and 50 pregnancies that were undergoing cordocentesis for a variety of indications at 19–35 weeks' gestation. They reported that the mean pressure increased from 4 or 9 mm Hg at 20 weeks to 9 or 18 mm Hg, respectively, at 35 weeks.

However, on theoretical grounds, intrauterine pressure should decrease with advancing gestation. If Laplace's law of pressure in spheroids is applicable to pregnancy, as suggested by Csapo [3], then pressure is directly related to muscle wall thickness and tension, and inversely related to the radius of the uterus. Wall thickness decreases and radius increases with gestation. Although the length of the myometrial fibres is increased, there is also an increase in elasticity, due to hormonal effects of pregnancy [4], and therefore tension would either be maintained or decreased.

The aim of this study was to establish a reference range for amniotic fluid pressure from the study of pregnancies at 10–38 weeks' gestation.

Patients and Methods

Amniotic fluid pressure was measured in 308 patients undergoing amniocentesis (n = 87) or cordocentesis (n = 221) at 10–38 weeks' gestation. Criteria for inclusion in this study were: (1) normal amniotic fluid volume, as subjectively assessed by ultrasonography; (2) fetuses appropriately grown for gestation, without chormosomal abnormalities or major malformations, and (3) in cases undergoing cordocentesis, normal fetal blood hemoglobin concentration, pO_2 and pH. These criteria were met by 200 patients (table 1). The 108 cases that were excluded did not meet these strict

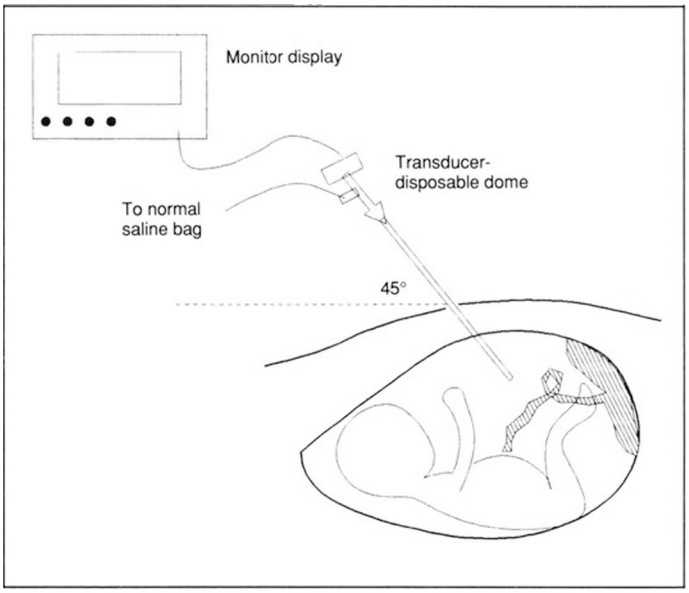


Fig. 1. Measurement of amniotic fluid pressure.

criteria because: (1) the amniotic fluid volume was increased or decreased (n = 23); (2) fetuses were growth-retarded, hypoxemic, or anemic (n = 49), or (3) fetuses had major malformations or chromosomal defects (n = 36).

With both amniocentesis and cordocentesis, amniotic fluid pressure was measured immediately after entry into the amniotic cavity and before withdrawal of amniotic fluid or fetal blood, respectively. Both procedures were performed without maternal sedation or local anesthesia.

The needle was flushed with sterile normal saline (0.2 ml), and the hub was attached directly to a transducer-disposable dome with a mounted solid-state pressure transducer (TA 1017 and P 10EZ(1) respectively, Spectramed Inc., Calif. USA), connected to an intensive-care monitor (Neonatal Monitor series 2330N, Marquette Electronics Inc., USA). Pressure was displayed digitally, and the angle of the needle was measured by a digital meter (DL-1000, Suehiko Tool Co., Japan). Before each procedure, amniocentesis or cordocentesis, the solid pressure transducer with attached needle was zeroed at an angle of 45° from the horizontal; this is the most commonly used angle for ultrasound-guided techniques in our centre (fig. 1). Actual intrauterine pressure was calculated

Table 1. Indications for amniocentesis or cordocentesis

Indication	Patients
Aniocentesis	
Fetal karyotyping for maternal age >34 years	76
Cordocentesis	
Diagnosis of blood disorders, e.g. hemophilia	11
Diagnosis of congenital infection, e.g. toxoplasmosis	8
Measurement of fetal hemoglobin in Rh disease	45
Fetal karyotyping for maternal age >34 years	104
Karyotyping for fetal malformations	32
Isolated ventriculomegaly	6
Choroid plexus cysts	3
Talipes	2
Facial cleft	2
Mild hydronephrosis	15
Unilateral renal dysplasia	4

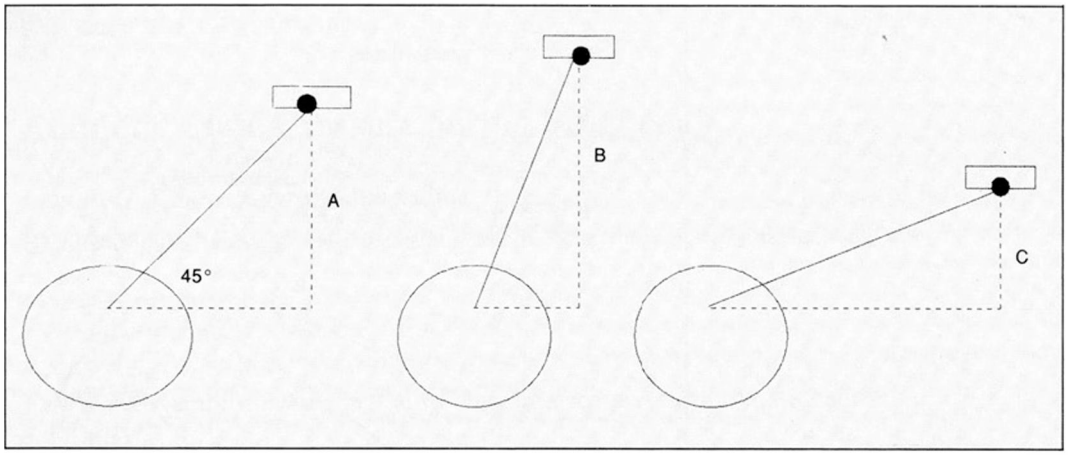


Fig. 2. Pressure transducer attached to the hub of the needle. The transducer is zeroed at an angle of 45° from the horizontal so that when amniocentesis is performed in this angle, pressure recorded is the true intrauterine pressure measured at the tip of the needle (A). If the needle is introduced in a more vertical position, the vertical distance between transducer and tip of the needle is greater (B), and if the entry is more horizontal, the vertical distance is smaller (C); in these cases the actual intrauterine pressure is calculated after correcting for angle deviations from 45°.

after correcting for angle deviations from 45°, because the angle determines the vertical distance between transducer and tip of the needle (fig. 2). This technique allows accurate measurements of pressure at the tip of the needle.

The significance of the association between pressure and gestational age was derived by regression analysis.

Results

There was a significant association between amniotic fluid pressure and gestation (GA, in weeks), and this was best described by a quadratic equation (fig. 3):

$$\text{pressure} = 18.086 - 0.553 \times GA + 0.009 \times GA^2,$$

residual SD = 2.557 mm Hg, r = 0.504, n = 200, $p < 0.01$.

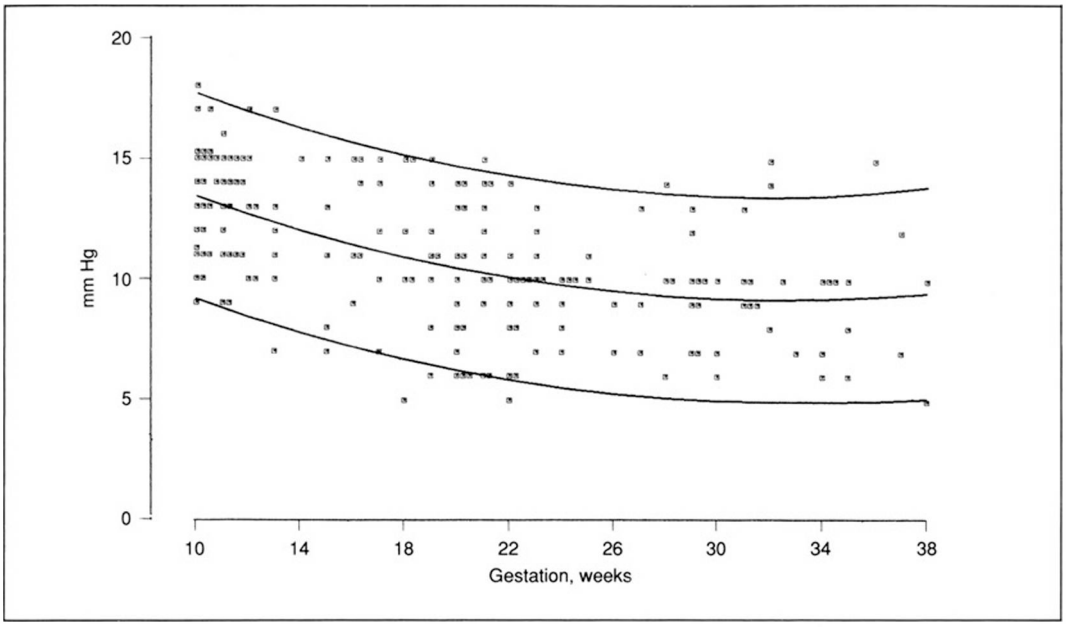
In a subsequent study, uterine wall thickness was measured ultrasonographically, both in a retroplacental and a nonplacental site, in 100 patients with morphologically normal fetuses and amniotic fluid volume who attended our unit at 9–38 weeks' gestation. The retroplacental wall thickness, which during early pregnancy was much greater than the nonplacental, decreased exponentially with gestation (fig. 4):

$$\log_{10} \text{thickness (mm)} = 1.824 - 0.074 \times GA + 0.001 \times GA^2,$$

r = 0.795, n = 100, $p < 0.0001$. The nonplacental wall thickness decreased linearly with gestation (fig. 3):

$$\text{thickness} = 7.8 - 0.09 \times GA,$$

r = –0.39, n = 100, $p < 0.0001$.



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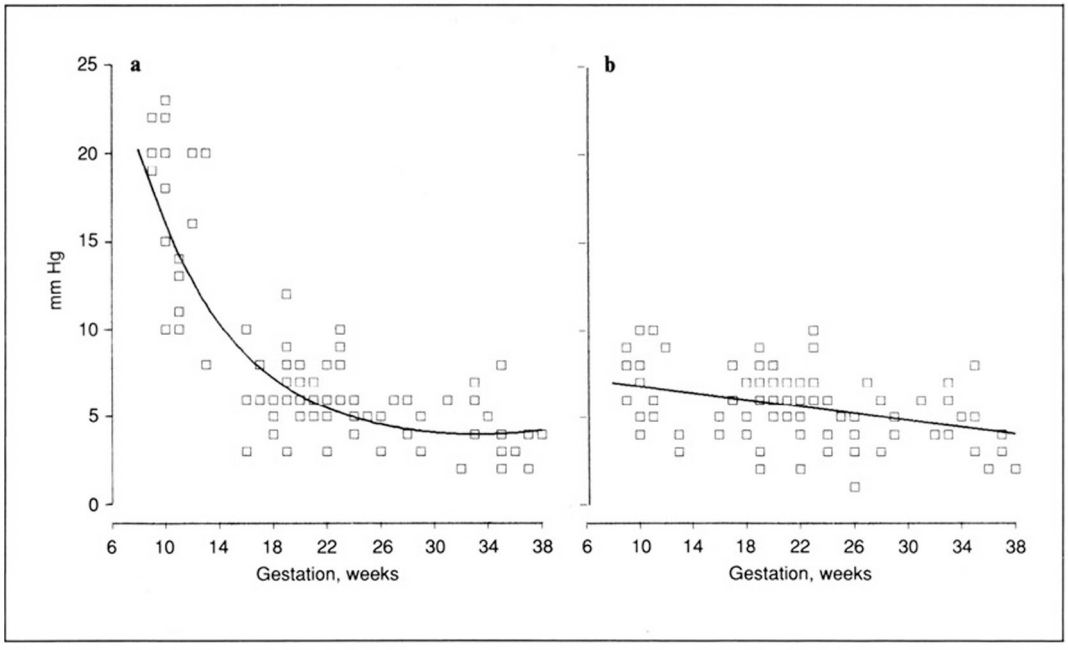

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Fig. 3. Individual values and reference range (mean, 5th and 95th centile) of amniotic fluid pressure with gestation.

Fig. 4. Retroplacental (**b**) and nonplacental (**a**) uterine wall thickness with gestational age in 100 women at 9–38 weeks' gestation.

Discussion

Intrauterine pressure decreases between 10 and 38 weeks' gestation, reaching a plateau at 30 weeks. This finding is contrary to that of Nicolini et al. [1] and Weiner et al. [2] who reported that intrauterine pressure increases with gestation. In these previous studies, the transducer, connected to the hub of the needle through a tube, was placed either on the surface of the maternal abdomen [1] or at the level of the fetal heart [2]. Since no corrections were made for the vertical distance between the tip of the needle and these apparently fixed positions, the measurements they have obtained may merely reflect the changing relation with gestation between them.

Although peak intrauterine pressure with spontaneous uterine activity increases with advancing gestation [5], resting pressure decreases. Data of this study are compatible with Laplace's law of pressure in spheroids:

$$P = 2W \times T/R,$$

where P = pressure, W = wall thickness, T = tension, R = radius. In the pregnant uterus, radius increases with gestation, due to the increase in both amniotic fluid volume and fetal size, and uterine wall thickness decreases (fig. 4). Furthermore, uterine wall tension may also decrease with gestation, due to increased extensibility of myometrial muscle fibres [6].

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