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REVIEW ARTICLE

# Fetal Organ Volume Measurements by Three-dimensional Ultrasonography in Clinical Practice

Rodrigo Ruano

## ABSTRACT

The present manuscript reviews the main three-dimensional ultrasound (3DUS) methods that are clinically available to measure fetal organ volumes. Nowadays, it is possible to measure the volume of different organs (lungs, heart, liver, kidneys, adrenal glands and brain) using 3DUS. Those measurements are clinically useful to predict pulmonary hypoplasia, cardiac dysfunction and anomalies, fetal growth, renal function and prematurity as well as to predict adequate and normal neurodevelopment.

**Keywords:** Fetal adrenal gland, Fetal brain volume, Fetal heart volume, Fetal kidney volume, Fetal liver volume, Fetal lung volume, Fetal organ volumes, Three-dimensional ultrasonography.

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## INTRODUCTION

The past three decades are remarkable for the impressive technological advance in ultrasound imaging methods. The three-dimensional ultrasonography (3DUS) represents one of these advances with the option to evaluate and measure fetal organ volumes in a three-dimensional image. Nowadays, new methods allow a volumetric measurement to be obtained faster and with more reproducibility. Particularly in maternal-fetal medicine, the possibility of evaluating the fetal organ volumes can impact in the perinatal management of the fetuses. In addition, new investigations have demonstrated that new methods can be used to estimate fetal weight in order to improve the diagnosis of intrauterine growth disorders. There are several studies that evaluated the impact of fetal organ volumes estimated by 3DUS on the clinical prenatal management of those fetuses. This article presents the different methods of assessing volumes by 3DUS and its potential clinical applications in actual fetal medicine.

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## DIFFERENT METHODS TO CALCULATE THE VOLUME USING THE THREE-DIMENSIONAL ULTRASONOGRAPHY

Basically, there are two simple and direct methods to assess the fetal organ volume using 3DUS approach.[1] The first one, which is the oldest method, consists in adding together the areas of serial parallel slices of the studied organ. The 'technique of the parallel slices' is based on 'cutting' the organ in many slices and measuring the areas from one side to another with specific pre-established thickness (Fig. 1). The main disadvantage of this method is that it may be difficult for small organs with irregular shapes.[1] Other limitations are described, such as the impossibility of repairing one incorrect area contouring.

More recently, a specific organ volume can be assessed by the rotational technique, which has become possible through the introduction of the 'virtual organ computer-aided analysis' (VOCAL™) imaging program, an extension of the 3D View TM (GE, Kretztechnik, Zipf, Austria). This method allows measuring the organ volume by fixing one axis and then serial contouring the organ surface after rotating the volumetric image (Fig. 2). The volumetric image can be rotating using different angles. This is faster than the first method, and has the great advantage over the other in allowing corrections and verifications on the three-dimensional image. Despite of many studies have been demonstrating similar values, variations and reproducibility (agreement) with these two methods, nowadays the 'rotational technique' is more employed and preferable due to its facilities.[1]

## MEDICAL APPLICATIONS OF THE THREE-DIMENSIONAL VOLUMETRIC EVALUATION

### Fetal Weight Estimation

One of the main objectives of the prenatal care is the correct detection of fetal growth abnormalities. The large number of methods published in this respect is a clearly evidence of the importance of fetal weight estimation

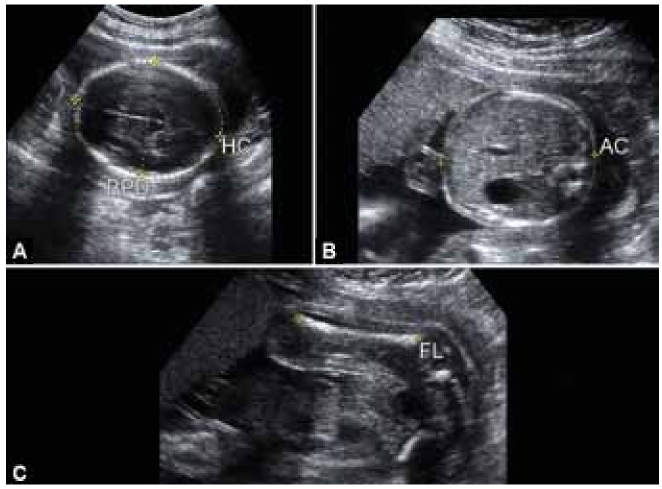

**Fig. 1:** Three-dimensional ultrasonographic parallel slices technique

**Fig. 2:** Three-dimensional ultrasonographic rotational technique rendered imaging of right and left fetal lung volumes

during prenatal care. Both fetal macrosomia and growth restriction increase perinatal morbidity and mortality. Fetuses with growth restriction are at increased risk of hypoxia and perinatal deaths. On the other hand, macrosomic fetuses are associated with increased risk of cesarean-section, postpartum hemorrhage, and maternal-fetal injuries. Macrosomic fetuses are generally associated with shoulder dystocia leading to clavicular fracture and brachial plexus injury.

Two-dimensional ultrasonography (2DUS) is applied routinely with this purpose. It estimates fetal weight indirectly by measuring defined segments of the body and then using specific mathematical equations, appropriate tables and integrated computer programs. The most frequently used fetal parameters are the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (Figs 3A to C).[2-5] There are so many formulas for estimating fetal weight, which is clear evidence that none of those is accepted universally. All these formulas for fetal weight estimation have a mean error of 7 to 10%, even in ideal ultrasound conditions.

The reason for the high error of these formulas may be the fact that none of these established equations takes the soft tissue thickness into account. It is known that fetal fat deposition represents approximately 90% of caloric accretion at term, and that neonatal fat mass constitutes 12 to 15% of birth weight. There have been many studies




**Figs 3A to C:** Fetal parameters for fetal weight estimation: (A) Biparietal diameter and head circumference, (B) abdominal circumference and (C) femur length

using different methods to take the soft-tissue content into account on 2DUS, especially by including the limb diameters, with varying results.[6]

Recently, with the advent of new volumetric methods using 3DUS technology, measurements of circumference and volume have become possible and reproducible through the three orthogonal sections of the specific fetal organ. Regarding the potential use for the estimation of fetal weight, the main interest becomes the possibility of measuring fetal limb diameters and volumes on these sections, which has the advantages of being more efficient and faster than the 2DUS technologies.[6-9] In addition, these new methods allow incorporation of direct measurements of the fetal soft tissue in the equations to estimate fetal weight. The method used to measure the fetal limb volumes is called fractional limb volumes.[6-9]

The fractional limb volume is a method that the fetal soft tissue is evaluated from a central portion of the limb (arm and thigh) diaphysis (Figs 4 and 5). Transverse slices of the mid-limb are more likely to display the soft tissue borders. This technique reduces the measuring times and also improves the reproducibility of the method. Tables 1 and 2 present different mathematical equations and reference values of the limb volumes by gestational age.

## Fetal Organ Volume

Three-dimensional ultrasound was first introduced during the 1980s, and has gained increasing acceptance in obstetrics as technological improvement. Its use has revolutionized the prenatal detection of fetal structural anomalies, growth aberrations, and multiple gestations. In recent years, 3DUS has undergone rapid advances, and continues to progress quickly. More recently, the estimation of fetal organ volumes is a promising application in maternal-fetal medicine. Different studies have

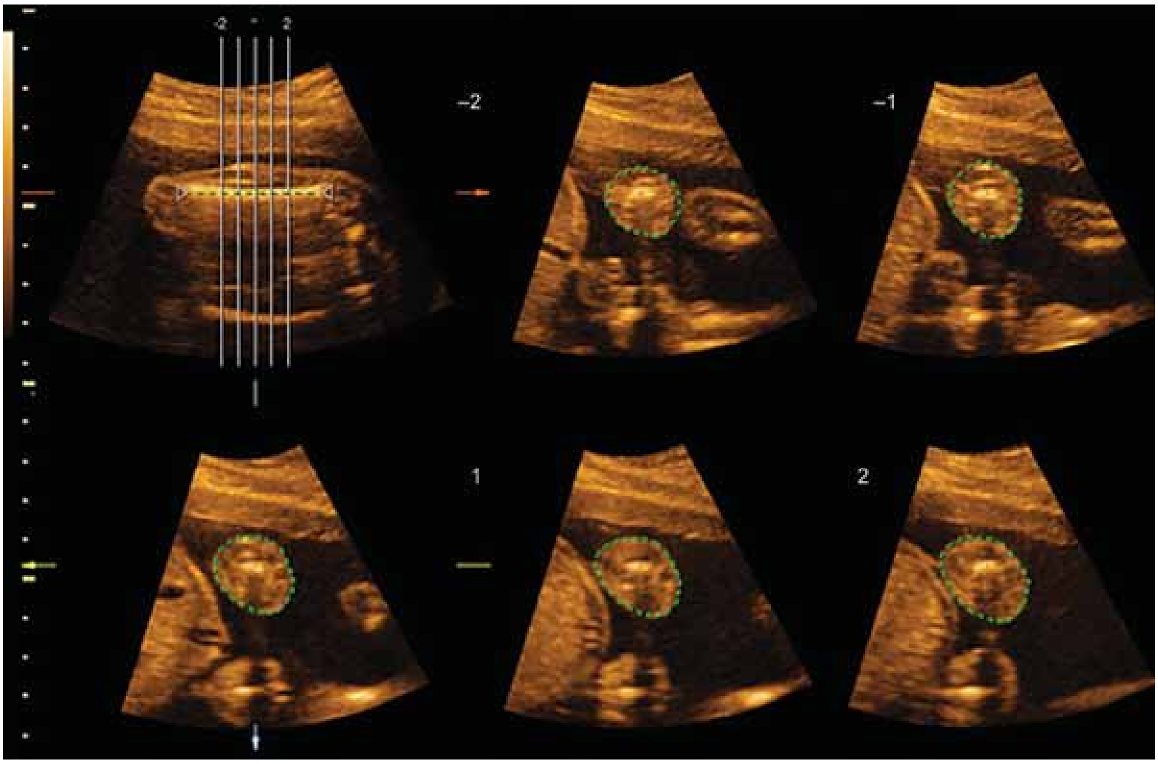



**Fig. 4:** Fractional thigh volume

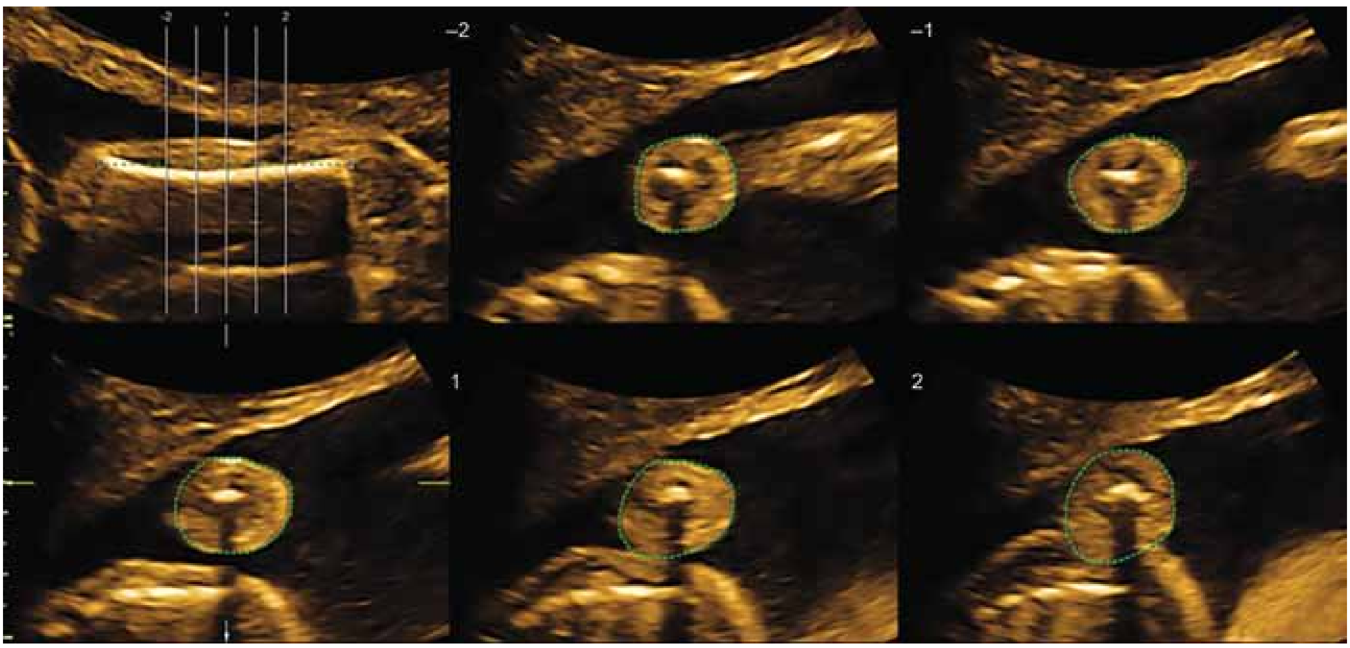



**Fig. 5:** Fractional arm volume

proposed the use of 3DUS to measure different fetal organ volumes (heart, liver, lung, brain, renal, adrenal gland and thymus). Unquestionably, 3DUS of fetal organs is gaining increasing importance in prenatal diagnosis, and will likely become an integral part of it in the near future.

The general essential prerequisites for measurement of a fetal organ volume are: first, acquisition of the volume with 'the organ of interest' facing the transducer; second, this acquisition must be in the absence of fetal movements and, third, accurate definition of the whole organ with good identification of its borders. Gestational age may interfere with the quality of the volumetric acquisition, and may limit posterior analysis of the 'organ of interest'. For example, lung volumes are more reproducible before 32 weeks, differently of the kidney volumes. Other important point is that acquisition and volumetric analysis depend on the amount of amniotic fluid and other organs shadows.

**Table 1:** Fetal weight estimation formulae using 3DUS measurements

| *Author* | *Regression equation* |
|---|---|
| Lee et al 2001[6] | FW = 20.95 × Tvol + 113.571 × AC–2375.068 |
| Lee et al 2009[7] | LogFW = 11.1372 × $BPD^2$ –67.2281 × BPD + 1.2175 × $AC^2$ –17.3004 × AC–0.0490 × $Tvol^2$ + 25.3052 × Tvol + 285.429 |

FW: Fetal weight; BPD: Biparietal diameter; HC: Head circumference; AC: Abdominal circumference; FL: Femur length; Tvol: Thigh volume; ABDvol: Abdominal volume

**Table 2:** Percentiles of fetal humerus volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Fetal humerus volume ($cm^3$)* | | |
|---|---|---|---|
| | *Percentiles* | | |
| *GA* | *10%* | *50%* | *90%* |
| 20 | 0.71 | 0.77 | 0.82 |
| 22 | 0.86 | 0.97 | 1.07 |
| 24 | 1.05 | 1.20 | 1.35 |
| 26 | 1.28 | 1.48 | 1.67 |
| 28 | 1.54 | 1.78 | 2.02 |
| 30 | 1.84 | 2.12 | 2.41 |
| 32 | 2.17 | 2.50 | 2.83 |
| 34 | 2.54 | 2.91 | 3.29 |
| 36 | 2.94 | 3.36 | 3.79 |
| 38 | 3.38 | 3.85 | 4.32 |
| 40 | 3.85 | 4.36 | 4.88 |

Modified from Chang et al. Ultrasound in Medicine and Biology 2005[9]

## Fetal Lung Volume

Clinically, fetal lung volume measurements can be useful to predict the severity of postnatal pulmonary hypoplasia more accurately in determined conditions, such as congenital diaphragmatic hernia, hyperechogenic lung lesions and oligohydramnios. Conventional 2DUS, which is used routinely in obstetrics, has proved to be insufficiently reliable to diagnose and predict prognosis of determinate congenital malformation, e.g. in fetuses at high risk for pulmonary hypoplasia. Recent studies have demonstrated the use of 3DUS in predicting pulmonary hypoplasia.[10-21] This technology has the same advantages as 2DUS related to cost-effectiveness, feasible and speed of use and patient acceptability, but in addition, enables visualization of perpendicular planes simultaneously (multiplanar imaging) and acquisition of the entire organ volume.

Nowadays, studies demonstrate that both methods of measuring fetal lung volumes can be used, the parallel slices or the rotational technique. However, the rotational technique is preferable for small and irregular lungs, especially to evaluate lung volumes in congenital diaphragmatic hernia with better resolution (Figs 6A to D).

Assessing fetal lung volumes have been shown to be one of the best ways to predict neonatal prognosis in cases with congenital diaphragmatic hernia.[10,12,14,18-21] The importance of predicting neonatal outcome in those fetuses is based on the possibility to select cases for antenatal interventions. Actually, fetuses with congenital diaphragmatic hernia presenting worse prognosis with high risk to develop severe pulmonary hypoplasia after birth may benefit from transitory tracheal occlusion during fetal life.[22-30] The advantages of evaluating fetal lung volumes by 3DUS over assessing measurements on 2DUS are that the entire lung is considered in one image alone and that the lung ipsilateral to the diaphragmatic defect may be included in the analysis.

Predicting the severity of pulmonary hypoplasia may also be useful in fetuses with large hyperechogenic pulmonary lesions (adenomatoid malformation or pulmonary sequestration). For those fetuses, depending on the severity of the pulmonary hypoplasia, a few cases will benefit for early postnatal intervention such *ex utero* intrapartum treatment (EXIT) and extracorporeal membrane oxygenation (ECMO).[31-33]

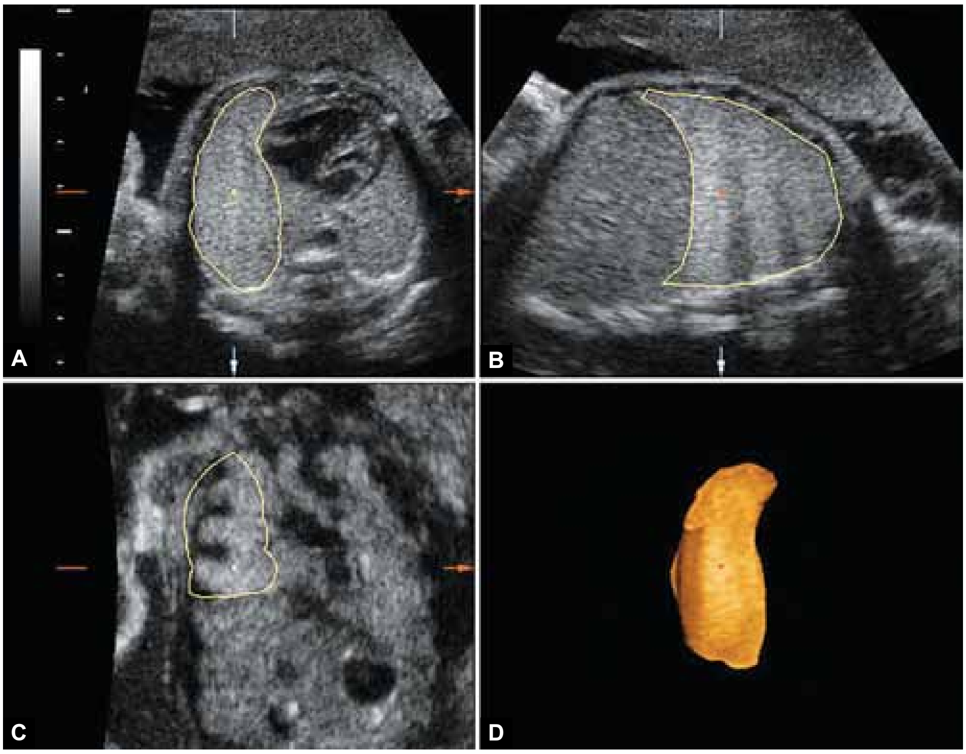
More recent studies have also suggested that fetuses with very early and prolonged premature rupture of the membranes may also benefit from fetal tracheal occlusion.[34-36] Fetal lung volumetric analysis may also be useful for the selection process in those cases.

There are so many reports on normal values and ranges of fetal lung volumes throughout gestational age. We have demonstrated that the right, left and total lung volumes vary from 5.37, 4.66 and 9.95 $cm^3$ at 20 weeks to 46.6, 37.34, and 84.35 $cm^3$ at 37 weeks, based on mathematical formulas: right lung volume = exp {4.07/[1 + exp (21.90 – gestational age/5.44)]}; left lung volume = exp {3.82/[1 + exp (22.03 – gestational age/5.17)]}, and total lung volume = exp {4.72/[1 + exp (20.30 – gestational age/6.05)]} (Table 3).[15]

## Fetal Heart Volume

Congenital heart disease is a leading cause of infant mortality in many countries, with an estimated incidence of about 3 to 8 per 1000 live births. Prenatal diagnosis of congenital heart diseases is responsible for a better planning of the perinatal management improving the postnatal care and outcomes.

Heart volume is a valuable parameter used in the evaluation of fetal heart condition, being mandatory for early detection of impending collapse of fetal circulation. Its accurate assessment becomes indispensable for prenatal diagnosis and management of fetal cardiac situations, such as in fetal high-output failure, hydrops fetalis, and many clinical-pathological conditions. The classical




**Figs 6A to D:** Fetal lung volume: (A) Transverse section, (B) sagittal section, (C) coronal section and (D) rendered imaging

**Table 3:** Percentiles of fetal lung volume (cm$^3$) estimated by 3DUS using the rotational technique (VOCAL$^{TM}$) in accordance to gestational age in weeks

| | *Right fetal lung volume (cm$^3$)* | | | *Left fetal lung volume (cm$^3$)* | | | *Total fetal lung volume (cm$^3$)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Percentiles* | | | *Percentiles* | | | *Percentiles* | | |
| *GA* | *10%* | *50%* | *90%* | *10%* | *50%* | *90%* | *10%* | *50%* | *90%* |
| 20 | 4.31 | 5.37 | 6.75 | 3.60 | 4.66 | 6.05 | 8.03 | 9.95 | 12.45 |
| 22 | 6.23 | 7.77 | 9.68 | 5.21 | 6.69 | 8.58 | 11.59 | 14.66 | 18.28 |
| 24 | 8.94 | 11.25 | 14.15 | 7.61 | 9.68 | 12.30 | 16.83 | 21.22 | 26.88 |
| 26 | 12.81 | 15.96 | 20.09 | 10.28 | 13.60 | 17.12 | 23.66 | 29.70 | 37.52 |
| 28 | 17.12 | 21.54 | 27.11 | 14.15 | 18.36 | 23.34 | 31.97 | 39.74 | 50.17 |
| 30 | 21.98 | 27.66 | 34.47 | 18.73 | 23.34 | 29.96 | 40.73 | 50.63 | 63.99 |
| 32 | 27.39 | 33.78 | 42.95 | 21.98 | 28.22 | 35.87 | 49.47 | 61.50 | 76.90 |
| 34 | 32.14 | 39.25 | 49.90 | 24.78 | 32.46 | 41.68 | 57.84 | 71.62 | 92.03 |
| 36 | 35.87 | 43.82 | 54.60 | 27.66 | 35.87 | 46.53 | 64.55 | 80.47 | 101.85 |

Modified from Ruano, et al. Journal of Ultrasound in Medicine 2006[15]

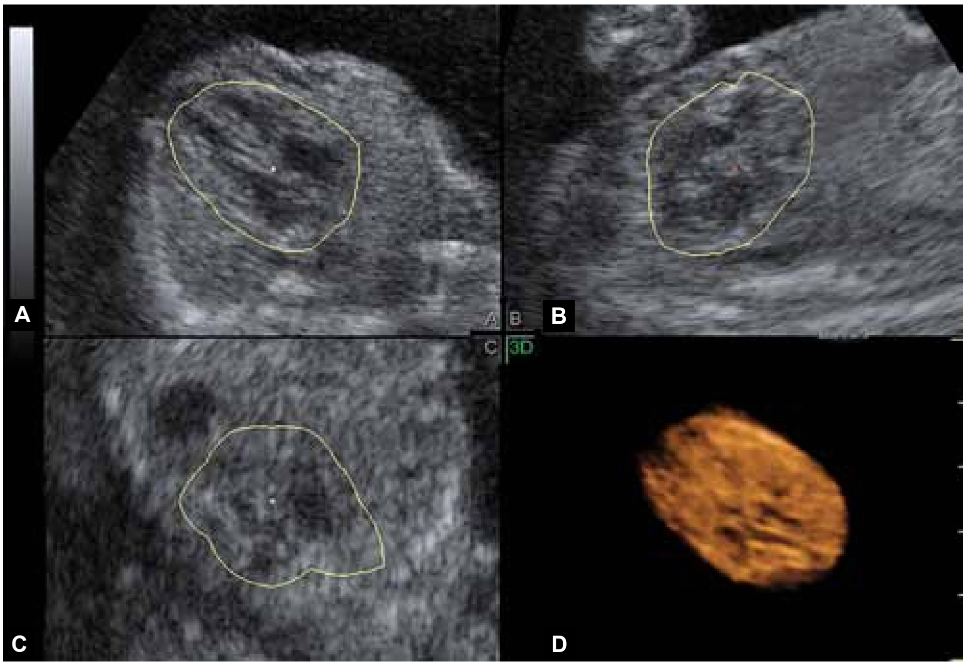
method using 2DUS for assessing heart volume, which assumes that heart shape is spherical or elliptical is imprecise. However, before the advent of an appropriate noninvasive research tool, such as 3DUS, this was difficult to be evaluated in human fetuses.

Traditionally, fetal heart volume has been assessed by the equation: heart volume = 0.5233 × H1 × H2 × H2, where H1 is the largest longitudinal diameter of the fetal heart at the four-chamber view, and H2 is the largest transverse diameter at the same plane.

Fetal heart volumes can be evaluated by the rotational technique on 3DUS (Figs 7A to D).[37,38] There have been a very few reports on normal values of fetal heart volume throughout gestational age. Fetal heart volume may vary from 0.63 (0.40–0.86) cm$^3$ at 12 weeks to 26.60 (16.40–36.80) cm$^3$ at 32 weeks (Table 4).[37,39]

## Fetal Liver Volume

Determination of fetal liver volume is very useful in assessing the status of fetal growth and nutrition. Fetuses with intrauterine growth restriction or macrosomia have different liver volumes. However, to measure human fetal liver *in utero* precisely and noninvasively is not an easy task. In the past, many studies have performed several attempts to indirectly assess liver size, using different parameters, such as AC and diameters (anteroposterior, transverse and cephalocaudal) using 2DUS, and then multiplied by a constant which had been obtained



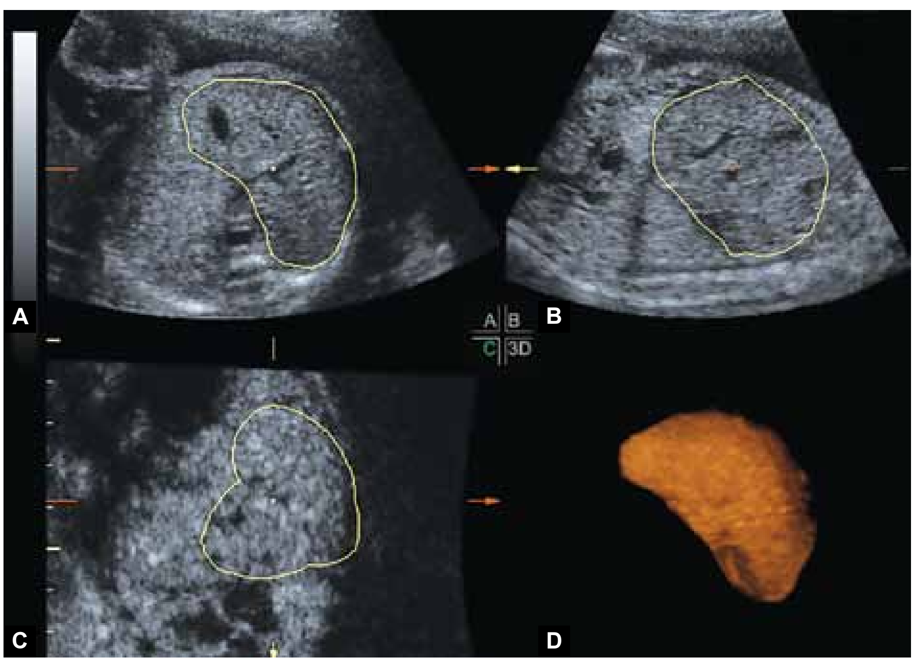

**Figs 7A to D:** Fetal heart volume: (A) Transverse section, (B) sagittal section, (C) coronal section and (D) rendered imaging

from adult liver studies, to estimate fetal liver weight. Currently, fetal liver volume is measured using its longest diameter, which may be less reproducible. With the advent of 3DUS and the improvement of its technology, fetal liver volume assessment becomes possible, easier and more reproducible (Figs 8A to D).[40-47] Besides, it has become an easy and noninvasive approach to obtain precise measurement of fetal liver volumes, and good correlation has been established between liver volume and other fetal growth parameters.

There have been very few studies reporting on normal ranges of fetal liver volumes assessed by 3DUS. Fetal liver volumes range from 11.73 $cm^3$ at 20 weeks to 131.51 $cm^3$ at 40 weeks (Table 5).[42,47]

### Fetal Renal Volume

Renal diseases are not uncommon in fetal life, and some of them might be treatable or carry a better outcome if detected earlier. Evaluating fetal renal size may be a valuable tool in the detection and monitoring of renal conditions, including nephromegaly, hypoplasia and other anomalies. Besides, assessing fetal renal size may be useful to evaluate renal function. Konje et al[48] demonstrated that fetal renin concentration is related to




**Figs 8A to D:** Fetal liver volume: (A) Transverse section, (B) sagittal section, (C) coronal section and (D) rendered imaging

**Table 4:** Percentiles of fetal heart volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Fetal heart volume ($cm^3$)* | | |
|---|---|---|---|
| | *Percentiles* | | |
| *GA* | *2.50%* | *50%* | *97.50%* |
| 12 | 0.40 | 0.63 | 0.86 |
| 14 | 0.17 | 0.53 | 0.88 |
| 16 | 0.46 | 1.14 | 1.81 |
| 18 | 1.24 | 2.42 | 3.61 |
| 20 | 2.44 | 4.33 | 6.23 |
| 22 | 4.04 | 6.83 | 9.62 |
| 24 | 5.99 | 9.87 | 13.80 |
| 26 | 8.24 | 13.40 | 18.60 |
| 28 | 10.80 | 17.40 | 24.00 |
| 30 | 13.50 | 21.80 | 30.10 |
| 32 | 16.40 | 26.60 | 36.80 |

Modified from Peralta, et al. Ultrasound in Obstetrics and Gynecology 2006[39]

**Table 5:** Percentiles of fetal liver volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Fetal liver volume ($cm^3$)* | | |
|---|---|---|---|
| | *Percentiles* | | |
| *GA* | *10%* | *50%* | *90%* |
| 20 | 5.05 | 11.84 | 18.63 |
| 22 | 11.82 | 19.17 | 26.51 |
| 24 | 17.00 | 24.90 | 32.80 |
| 26 | 21.73 | 30.18 | 38.63 |
| 28 | 27.18 | 36.13 | 45.13 |
| 30 | 34.32 | 43.38 | 53.44 |
| 32 | 44.46 | 54.57 | 64.69 |
| 34 | 58.67 | 69.34 | 80.00 |
| 36 | 78.08 | 83.30 | 100.53 |
| 38 | 103.83 | 115.61 | 127.38 |
| 40 | 137.05 | 149.38 | 161.71 |

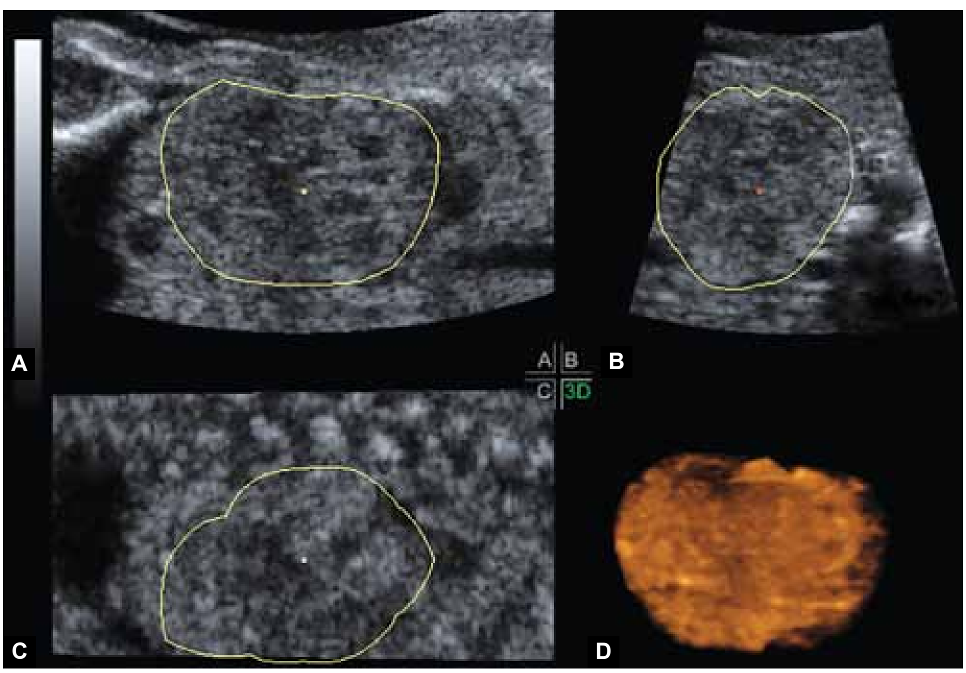
Modified from Chang et al. Ultrasound in Medicine and Biology 2003[42]

fetal size. The classical way of measuring fetal renal size using 2DUS is not precise. With the application of 3DUS, it becomes feasible and more accurate by estimating fetal renal volumes (Figs 9A to D).

There have been very few reports on the distribution of fetal renal volumes throughout gestational age. Hsieh et al[49] described good correlation between fetal renal volumes and gestational age, suggesting the following mathematical formulas: right fetal renal volume = 0.4032 × gestational age – 6.2097; left fetal renal volume = 0.3954 × gestational age – 6.3068. Yu et al[50] reported the following mathematical formulas: right fetal renal volume = 0.74053 × gestational week – 13.318; left fetal renal volume = 0.76093 × gestational age – 13.421. More recently, Yoshizaki et al[51] reported the following mathematical formulas: expected right kidney volume = exp [–1.01 + (0.12 × gestational age)], and expected left kidney volume = exp [–0.90 + (0.12 × gestational age)] (Table 6).

## Fetal Adrenal Gland Volume

The fetal adrenal glands are important organs to fetal growth. *In utero*, the normal fetal adrenal glands can be scanned using 2DUS as hypoechogenic structures located immediately above the fetal kidneys bilaterally. Some pathologic conditions of fetal adrenal glands, such as adrenoblastomas or neuroblastomas, can be diagnosed on ultrasound examinations. These fetal adrenal tumors




**Figs 9A to D:** Fetal renal volume: (A) Sagittal section, (B) transverse section, (C) coronal section and (D) rendered imaging

**Table 6:** Percentiles of fetal renal volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Right fetal renal volume ($cm^3$)* | | | *Left fetal renal volume ($cm^3$)* | | |
|---|---|---|---|---|---|---|
| | *Percentiles* | | | *Percentiles* | | |
| *GA* | *10%* | *50%* | *90%* | *10%* | *50%* | *90%* |
| 20 | 2.4 | 4.0 | 6.9 | 2.4 | 4.2 | 7.4 |
| 22 | 3.0 | 5.1 | 8.7 | 3.1 | 5.4 | 9.4 |
| 24 | 3.9 | 6.5 | 11.1 | 3.9 | 6.8 | 11.8 |
| 26 | 4.9 | 8.3 | 14.1 | 4.9 | 8.6 | 15.0 |
| 28 | 6.3 | 10.6 | 18.0 | 6.2 | 10.8 | 18.9 |
| 30 | 8.0 | 13.5 | 22.9 | 7.9 | 13.7 | 23.9 |
| 32 | 10.1 | 17.2 | 29.1 | 9.9 | 17.3 | 30.2 |
| 34 | 12.9 | 21.8 | 37.0 | 12.6 | 21.9 | 38.2 |
| 36 | 14.1 | 27.8 | 47.1 | 15.9 | 27.7 | 48.4 |
| 38 | 20.8 | 35.3 | 59.9 | 20.1 | 35.1 | 61.2 |
| 40 | 26.5 | 45.0 | 76.2 | 25.4 | 44.3 | 77.3 |

Modified from Yoshizaki, et al. J Ultrasound Med 2013[51]

may have abnormal sizes. Therefore, measuring this gland volume may be useful for the early diagnosis of this condition.

The irregular shape of fetal adrenal glands makes difficult to evaluate its volume using 2DUS. With the advent of 3DUS, using the rotational technique, it becomes feasible and noninvasive method to evaluate its volumes (Figs 10A to D).[52-57] Reference values may vary according to the following equation: adrenal gland volume = $-0.2683 \times$ gestational age + $0.0082 \times$ (gestational age)$^2$ + 3.1927 (Table 7).[52]

Other interest in assessing fetal adrenal gland volumes can be related to a potential use in predicting labor, especially preterm labor.[53,55] Several mechanisms have been implicated in triggering preterm labor, like genetic predisposition, decidual hemorrhage, fetal stress and inflammation/infections. In most animal species, the fetal hypothalamic-pituitary-adrenal axis plays a special role in the initiation of parturition.

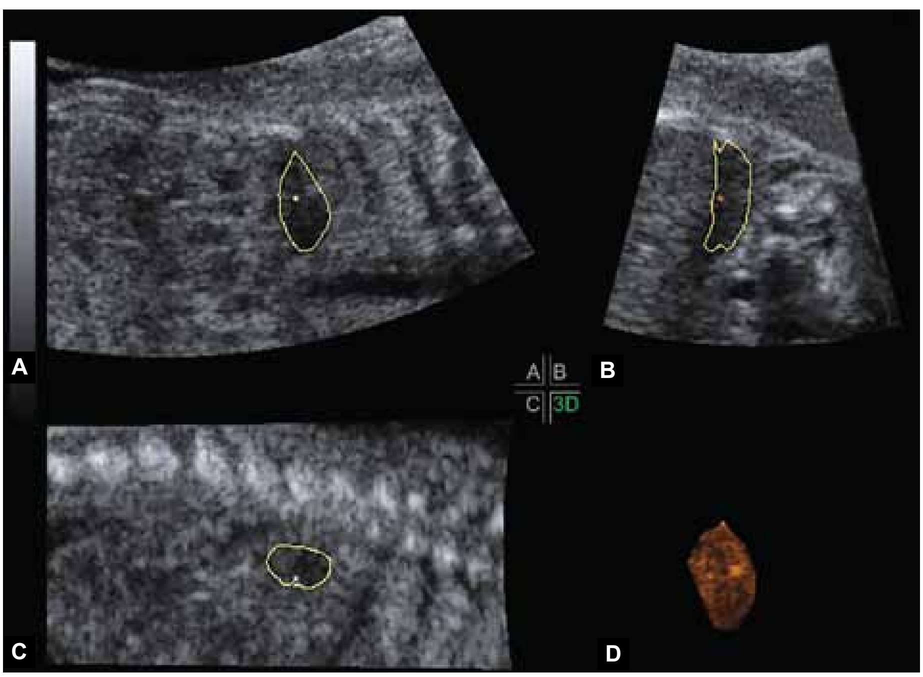
**Table 7:** Percentiles of fetal adrenal gland volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Fetal adrenal gland volume ($cm^3$)* | | |
|---|---|---|---|
| | *Percentiles* | | |
| *GA* | *10%* | *50%* | *90%* |
| 22 | 0.86 | 1.24 | 1.63 |
| 24 | 1.01 | 1.45 | 1.90 |
| 26 | 1.22 | 1.73 | 2.25 |
| 28 | 1.50 | 2.08 | 2.65 |
| 30 | 1.85 | 2.49 | 3.13 |
| 32 | 2.26 | 2.96 | 3.67 |
| 34 | 2.74 | 3.51 | 4.27 |
| 36 | 3.28 | 4.11 | 4.94 |
| 38 | 3.89 | 4.78 | 5.68 |
| 40 | 4.56 | 5.52 | 6.48 |

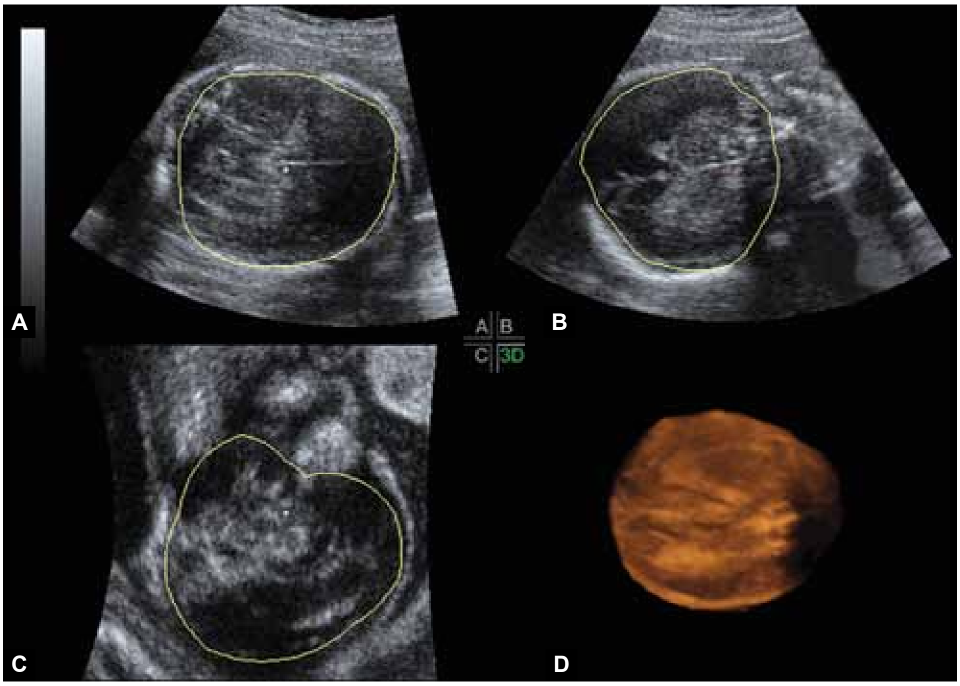
Modified from Chang et al. Ultrasound in Medicine and Biology 2002[52]

## Fetal Brain Volume

Both fetal BPD and fetal HC are standard parameters in establishing normal and abnormal fetal biometry and growth. Fetal brain volume measurement in conjunction with fetal liver volume determination could provide insight into the nature of abnormal fetal growth.[43] Up-to-date, there have been few studies reporting on the use of 3DUS to assess fetal brain volume (Figs 11A to D). Fetal brain volumes vary from 53 $cm^3$ at 20 weeks to 316 $cm^3$




**Figs 10A to D:** Fetal adrenal gland volume: (A) Sagittal section, (B) transverse section, (C) coronal section and (D) rendered imaging




**Figs 11A to D:** Fetal brain volume: (A) Transverse section, (B) sagittal section, (C) coronal section and (D) rendered imaging

**Table 8:** Percentiles of fetal brain volume ($cm^3$) estimated by 3DUS using the rotational technique (VOCAL™) in accordance to gestational age in weeks

| | *Fetal brain volume ($cm^3$)* | | |
|---|---|---|---|
| | *Percentiles* | | |
| *GA* | *5%* | *50%* | *95%* |
| 20 | 38 | 53 | 71 |
| 22 | 58 | 77 | 100 |
| 24 | 82 | 116 | 133 |
| 26 | 109 | 139 | 173 |
| 28 | 140 | 177 | 218 |
| 30 | 174 | 219 | 269 |
| 32 | 211 | 265 | 326 |
| 34 | 252 | 316 | 389 |

Modified from Roelfsema et al. American Journal of Obstetrics and Gynecology 2004[58]

at 34 weeks according to the following equation: fetal brain volume = 0.75 × gestational age – 7.71 (Table 8).[58]

In addition to the entire fetal brain volume, it is possible to measure the fetal hippocampus, cerebellum, thalamus and ventricles.[59-66] Recent studies have demonstrated that fetuses with particular diseases, such as congenital heart diseases have not only smaller brain, but reduced volumes of intracranial structures.[67] Three-dimensional ultrasound is an important prenatal diagnostic tool in fetal neurosonography, which can be used to predict adequate neurodevelopment.[68,69]

## CONCLUSION

Nowadays, it is possible to evaluate the fetal organ volumes using 3DUS technology. The main advantage of using 3DUS over 2DUS technology in measuring the organ volume is related to the fact that the first method permits evaluation of the entire organ instead of part of it. Using the rotational technique, the process of measuring the fetal organ volumes has become more feasible and reproducible. There is still a need to standardize and generalize the methods of measuring the fetal organ volumes. However, several clinical applications of 3DUS fetal organ measurements have been demonstrated.

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