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Original Article

Assessment of placental volume and vascularization at 11−14 weeks of gestation in a Taiwanese population using three-dimensional power Doppler ultrasound

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Abstract

Background: The placental volume and vascular indices are crucial in helping doctors to evaluate early fetal growth and development. Inadequate placental volume or vascularity might indicate poor fetal growth or gestational complications. This study aimed to evaluate the placental volume and vascular indices during the period of 11−14 weeks of gestation in a Taiwanese population.
Methods: From June 2006 to September 2009, three-dimensional power Doppler ultrasound was performed in 222 normal pregnancies from 11−14 weeks of gestation. Power Doppler ultrasound was applied to the placenta and the placental volume was obtained by a rotational technique (VOCAL). The three-dimensional power histogram was used to assess the placental vascular indices, including the mean gray value, the vascularization index, the flow index, and the vascularization flow index. The placental vascular indices were then plotted against gestational age (GA) and placental volume.
Results: Our results showed that the linear regression equation for placental volume using gestational week as the independent variable was placental volume $= 18.852 \times GA - 180.89$ ($r = 0.481$, $p < 0.05$). All the placental vascular indices showed a constant distribution throughout the period 11−14 weeks of gestation. A tendency for a reduction in the placental mean gray value with gestational week was observed, but without statistical significance.
Conclusion: All the placental vascular indices estimated by three-dimensional power Doppler ultrasonography showed a constant distribution throughout gestation.

Keywords: gestational week; placental volume; three-dimensional power Doppler ultrasound; VOCAL

1. Introduction

The size of the placenta is significant in the assessment of problems in pregnancy, such as pre-eclampsia, small-for-gestational-age fetuses, placental abruption, maternal diabetes, hydrops fetalis, chromosomal abnormalities, placental insufficiency, and congenital viral infection.[1] The ultrasonographic appearance of both thick heterogeneous and small placentas

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

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can give information about possible adverse outcomes in pregnancy. Recent advances in ultrasonography allow the combination of three-dimensional (3D) ultrasound with power Doppler ultrasound, making it possible to quantify Doppler signals in a volume obtained by 3D scanning and therefore to assess the whole placental circulation.[2,3] A few placental volume nomograms and vascular indices have been described and these reference values were obtained in pregnancies at early gestational ages, generally in the first trimester. Shaw et al[4] used 3D ultrasound to measure the nuchal volume in the first trimester screening for Down's syndrome. This was the first study to use a 3D technique during the first trimester of pregnancy in a Taiwanese population. However, there are no reports on the placental volume (PV) and vascular indices in relation to gestational age (GA) between the late first trimester and early second trimester in a Taiwanese population. Therefore the objective of this study was to prospectively evaluate the distribution of the PV and vascular indices using 3D power Doppler ultrasonography in normal pregnancies in relation to GA at 11^{+}−14^{+} weeks in a Taiwanese population.

2. Methods

Patients were recruited from the low-risk prenatal care unit of Department of Obstetrics and Gynecology, Taipei Veterans General Hospital, Taipei, Taiwan from June 2006 to September 2009. All the women received a nuchal translucency measurement and volunteered to undergo 3D power Doppler ultrasound examination after being fully familiarized with the study protocol and the technique. The inclusion criteria were healthy women with singleton normal pregnancies, normal fetal morphological ultrasound examinations, reliable pregnancy dating as established by the date of the last menstrual period and sonographic measurement of the crown−rump length in the first trimester, and GA from 11 weeks to 14 weeks. The exclusion criteria were fetal congenital abnormalities, abnormal nuchal translucency, absence of a nasal bone, reverse A-wave of the ductus venosus, and patient absence during follow up. Patients with a history of any medical disease or with a history of smoking were excluded from the study. Each patient was scanned once during pregnancy with informed consent. Every patient recruited into this study had a good postnatal outcome and no neonatal disease was noted. The prospective study protocol was approved by the hospital's Institutional Review Board and Ethics Committee (IRB number 98-01-64A).

2.1. Acquisition and measurement of PV and vascular indices

A Voluson 730 ultrasound machine (GE Medical Systems, Milwaukee, WI, USA) equipped with a 4−8 MHz transducer was used for the 3D power Doppler scanning. Using the same pre-established instrument power settings (angio mode, cent; smooth, 4/5; FRQ, low; quality, 16; density, 6; enhance, 16; balance, GO150; filter, 2; actual power, 2 dB; pulse repetition frequency, 0.9) for all patients, independent of GA, 3D power Doppler was applied to obtain images of the PV and vasculature. The longest view of the placenta was identified by 2D ultrasound and the volume box was adjusted to scan the entire placenta. After scanning the entire volume, the longest view of the placenta on the A plane of the three orthogonal ultrasound sections was chosen as the reference image. The volume was then measured by the rotational technique using VOCAL software (GE Medical Systems), which consists of outlining the contour of the placenta repeatedly after rotating its image six times by 30°. After finishing the complete 360° rotation, the PV was automatically provided by the software (Fig. 1A). After estimation of the PV, the 3D-power Doppler histogram was used to determine the vascular indices from computer algorithms (Fig. 1B). The mean gray value (MGV) represents the placental echogenicity, which may be interpreted as placental density. The vascular indices determined were: (1) vascularization index (VI), which refers to the color voxel/total voxel ratio (vascularity); (2) the flow index (FI), which refers to the weighted color voxel (on a scale of 0−100) divided by the total color voxel ratio and provides an amplitude value for the color signal; and (3) the vascularization flow index (VFI), which refers to the weighted color voxel/total voxel ratio, combining the information of the presence of vessels (vascularity) and amount of transported blood cells (blood flow). For each patient, the placental vascular indices were measured by a single doctor (C.Y.C.).

2.2. Statistical analysis

The placental vascular indices (VI, FI, and VFI) were plotted against GA and PV. The distributions were evaluated by regression modes. The Pearson correlation coefficient test was used to evaluate the correlation between the placental vascular indices and GA. All calculations were performed using Excel and SPSS 15.0 programs (Microsoft, Redmond, WA, USA). Differences were considered to be significant at $p < 0.05$.

3. Results

A total of 222 women with a normal singleton pregnancy between 11 weeks and 13^{+6} weeks of gestation were examined. All the measurements were completed during examinations and were also reviewed from the Taipei Veterans General Hospital (Taipei, Taiwan) picture archiving and communication system by one obstetrician (C.Y.C.). Poor quality images were excluded. The birth records of each fetus were reviewed. No small (or large) for GA or neonatal anomaly was identified. After reviewing by one obstetrician (C.Y.C.), the data for the PV and vascular indices were analyzed. The mean maternal age was 31 (range 19−45) years, corresponding to a gestational age of 12^{+4} (range 11^{+0}−13^{+6}) weeks. Linear correlation exists between GA and PV ($p < 0.05$, $r = 0.481$, $PV = 18.852 \times GA - 180.89$; Fig. 2). However, other flow indices showed no significant correlation with GA (p for MGV, VI, FI, and VFI were 0.668, 0.297, 0.864, and 0.474, respectively; Figs. 3−6).

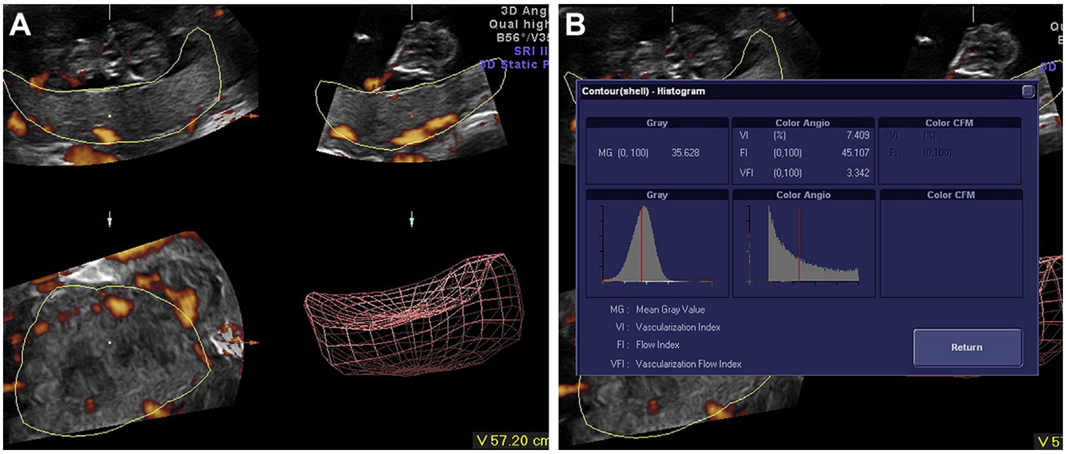

Fig. 1. (A) Three-dimensional structure of the placenta at 12 weeks of gestation generated using the VOCAL technique. (B) Histogram analysis of the placenta.

4. Discussion

For the past decade, first trimester screening for Down's syndrome, mainly by measuring nuchal translucency, has become mainstream. Many biochemical markers as well as functional Doppler ultrasonographic parameters have been developed to assist obstetricians to evaluate the wellbeing of fetuses.[5–7] These parameters and formulae can be used to calculate the risks for Down's syndrome, Edward's syndrome, Patau's syndrome, pre-eclampsia prior to 34 weeks of gestation, fetal growth restriction prior to 37 weeks of gestation, and even the risks of intrauterine fetal growth restriction or intrauterine fetal death. We evaluated the fetuses directly by detailed morphological examination and the measurement of fetal Doppler indices. We calculated the probability of a high-risk pregnancy – for example, early or late pre-eclampsia and preterm labor – by testing maternal serum biochemical markers and uterine arterial Doppler indices. Some fetal chromosomal or genetic abnormalities cause placental disorders – for example, women who are carrying a trisomy 13 fetus are prone to have a small placental volume and to develop pre-eclampsia in the second and third trimesters.[8] It is well known that the pathophysiological mechanism of pre-eclampsia and intrauterine fetal growth restriction are highly associated with early placental development, mainly focused on the vascular remodeling of the endometrium and sub-endometrial myometrium by cytotrophoblasts.[9,10] A small PV during the first trimester has also been shown to be a predictor of pregnancy complications, including placental abruption.[11] The identification of a smaller PV in most aneuploid fetuses at the end of the first trimester could lead to an improvement in first trimester screening for chromosomal anomalies.[12] Furthermore, it has recently been reported that pregnancies ending in miscarriage have smaller trophoblast volumes as well as reduced trophoblast growth compared with those that result in live births.[13]

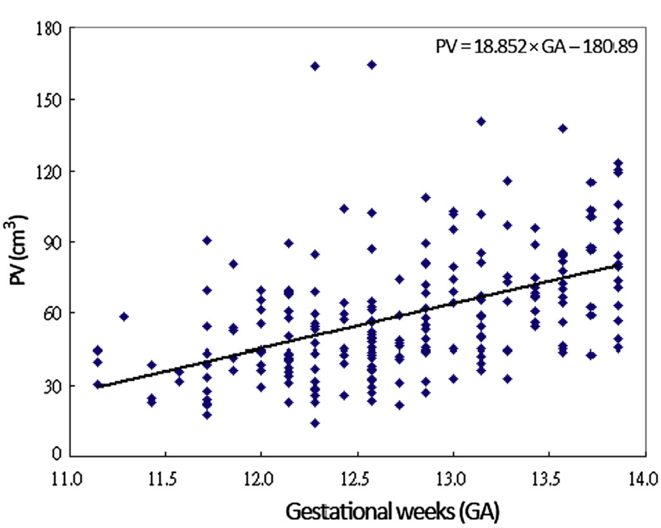

Fig. 2. Correlation between gestational age (GA) and placental volume (PV) (cm^3); $r = 0.481$, $p < 0.05$.

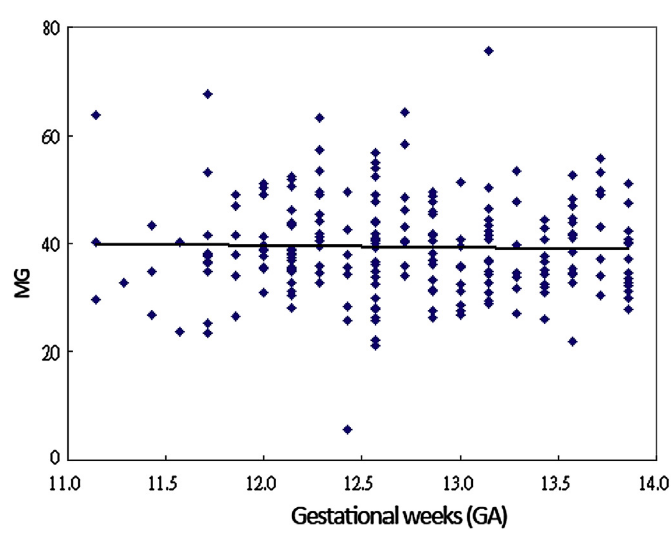

Fig. 3. Correlation between gestational age (GA) and mean gray value (MG); $r = -0.029$, $p = 0.668$.

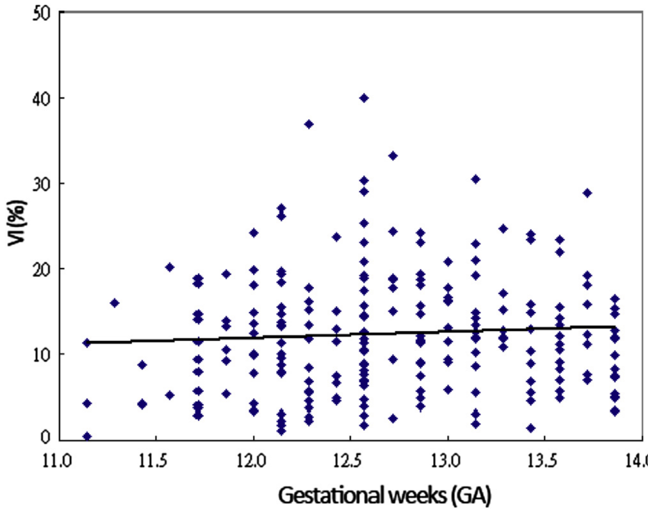

Fig. 4. Correlation between gestational age (GA) and vascularization index (VI) (%); $r = 0.07$, $p = 0.297$.

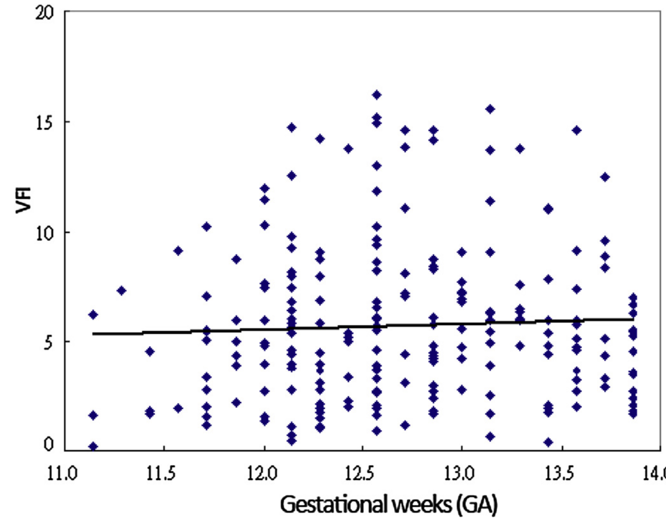

Fig. 6. Correlation between gestational age (GA) and vascularization flow index (VFI); $r = 0.048$, $p = 0.474$.

Many papers have been published on the volumes and vascular indices of the placenta (Table 1). The PV and vascular indices have been shown to correlate highly with GA.[1−3] These studies covered a wide range of GA, which could explain the positive correlation between the vascular indices and GA. After 20 weeks of gestation, the body mass of the fetus, the PV, and the placental blood supply increase significantly. Other studies have only analyzed the relationship between PV and GA, but not vascular indices.[14−17] Our study is the first published paper to compile statistics for MGV as well as vascular indices. All the indices, including the MGV, showed no significant change between 11 weeks and 14 weeks of gestation. The placental density (MGV) and blood supply (flow indices) during this stage is relatively constant, which could be crucial for the early development of the organ and cardiovascular systems of the fetus.

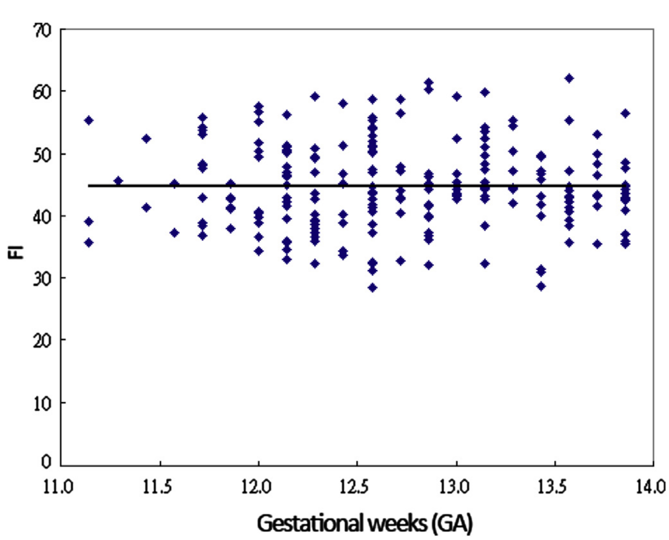

Fig. 5. Correlation between gestational age (GA) and flow index (FI); $r = -0.012$, $p = 0.864$.

Table 1
Studies on the volumes and vascular indices of the placenta.

Study	GA (weeks)	N	PV (cm^3)	MG	VI	FI	VFI
Yu et al[2]	20−40	100	+	NA	+	+	+
de Paula et al[1,3]	12−40	295	+	NA	+	+	+
Nardozza et al[14]	7−11	70	+	NA	NA	NA	NA
Metzenbauer et al[15]	10−13	1462	+	NA	NA	NA	NA
Zalud and Shaha[16]	14−25	199	+	NA	NA	NA	NA
Hafner et al[17]	15−17	356	+	NA	NA	NA	NA
This study	11−14	222	+	NS	NS	NS	NS

FI = flow index; GA = gestational age; MG = mean gray value; NA = no analysis; NS = no significant correlation; PV = placental volume; VFI = vascularization flow index; VI = vascularization index; + = positive correlation with GA.

In conclusion, this work focused on placental development in the first trimester in a Taiwanese population. Any deviation in placental growth at this stage might indicate abnormal fetal growth or anomalies. However, it is worth collecting more data to compare normal and abnormal pregnancies.

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