Fetal Ventriculomegaly

[1]Ritsuko K Pooh, [2]Kyonghon Pooh

[1]CRIFM Clinical Research Institute of Fetal Medicine, PMC
[2]Department of Neurosurgery, Kagawa National Children's Hospital, Kagawa, Japan

Correspondence: Ritsuko K Pooh
CRIFM Clinical Research Institute of Fetal Medicine, PMC
Toricho 136, Marugame City, Kagawa #763-0043
Tel +81-877-58-0387, Fax +81-877-58-3235. e-mail address : rkpooh@guitar.ocn.ne.jp

Abstract: The causes of fetal ventriculomegaly vary. Ventriculomegaly can be caused by not only obstruction of cerebrospinal flow tract but also brain maldevelopment or other reasons. Recent advanced imaging technology and approaching technique of transvaginal sonography have contributed to an accurate prenatal diagnosis and clearly revealed fetal intracranial condition. However, management of the condition and counseling of parents are still difficult, because the initial cause, absolute risk, and degree of resulting neurological deficit cannot be determined with confidence. Ventriculomegaly is evaluated according to atrial width > 10 mm and mild ventriculomegaly is defined as an atrial width of 10 to 15 mm. In ventriculomegaly cases, accurate detection of intracranial structure and additional abnormalities is required. Furthermore, ventriculomegaly may resolve spontaneously or progress during pregnancy. Therefore, detailed neuroscan by advanced imaging technology, detailed extra-CNS scan, longitudinal serial scan during pregnancy are mandatory for proper counseling and management. Longitudinal observation study of not only short-term but also long-term neurological prognosis will be required.

Key words: Fetus, central nervous system, ventriculomegaly, prenatal diagnosis.

Learning objectives

- To know imaging technology for fetal CNS assessment.
- To know variety of causes of fetal ventriculomegaly.

INTRODUCTION

Enlargement of the ventricular system, the fluid filled spaces in the brain, can be caused by the obstruction of cerebrospinal fluid (CSF) tract, overproduction of CSF, absorption disorder, inadequate brain development or destruction of brain tissue. Modern imaging technologies such as transvaginal sonography,[1-3] three-dimensional (3D) ultrasound[4-15] and advanced magnetic resonance imaging (MRI)[16-17] have contributed to the prenatal assessment of congenital central nervous system (CNS) anomalies and acquired brain damage *in utero*. However, management of the condition and counseling of parents are still difficult, because the cause, absolute risk, and degree of resulting neurological deficit cannot be determined with confidence.

IMAGING TECHNOLOGY FOR FETAL CNS ASSESSMENT

Three-dimensional (3D) ultrasound is one of the most attractive modalities in the field of fetal ultrasound imaging. Recent advanced 3D ultrasound equipments have several useful functions which can be utilized for fetal CNS assessment; surface anatomy imaging,[4-8] bony structural imaging of the calvaria and vertebrae,[9] multiplanar imaging (three orthogonal view) of the intracranial structure,[4-11] tomographic ultrasound imaging of fetal brain in the any cutting section, thick slice imaging of the intracranial structure, simultaneous volume contrast imaging of the same section or vertical section of fetal brain structure,[11] volume calculation of target organs[11-14] such as intracranial cavity, ventricle, choroid plexus and intracranial lesions, and three-dimensional sonoangiography of the brain circulation (3D power Doppler, 3D color Doppler and 3D B-flow).[10,14,15] Combination of both transvaginal sonography and 3D ultrasound may be a great diagnostic tool for evaluation of three-dimensional structure of fetal CNS.

Recent advances in fast MRI technology has remarkably improved the T2-weighted image resolution despite a short acquisition time, and minimized artifacts due to fetal movement and/or maternal respiratory motion. Magnetic resonance imaging is not influenced by fetal location, fetal head position and ossification of fetal cranial bones, which sometimes obstruct ultrasound approach. It is playing an increasingly prominent role in depicting brain maturation, especially gyral formation that follows a temporospatial pattern, and in detecting developmental abnormalities of the cortex and other brain sectors.[16] It is a useful modality which can compensate for pitfalls of transvaginal 3D ultrasound.[17]

CNS ABNORMALITY AND OTHER COMPLICATIONS

There are two peaks of gestational weeks when patients are referred for further assessment of CNS abnormality; 13 to 21 weeks and 26 to 30 weeks (Fig. 1). Dysraphism such as acrania

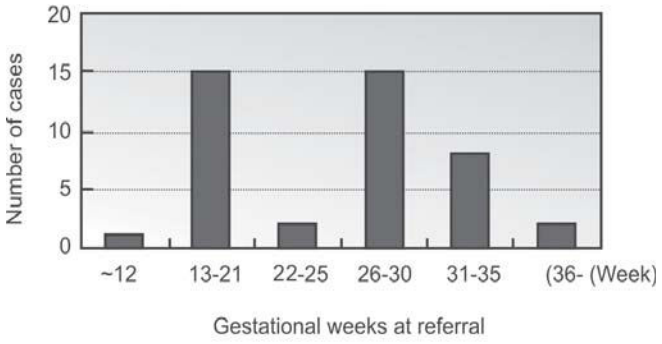

Fig. 1: Gestational weeks at referral of CNS diseases
Two peaks of gestational weeks of referral are seen; 13 to 21 weeks and 26 to 30 weeks

or myelomeningocele was seen in 50% of referral cases before 22 weeks (Table 1). In Japan, gestational limitation for termination of pregnancy (TOP) is the end of 21 weeks of gestation. The 68.7% of cases determined TOP while the rest 31.3% of parents decided to continue pregnancy after accepting fetal spina bifida or ventriculomegaly. Among cases diagnosed after the beginning of 22 weeks of gestation, a number of cases with simple ventriculomegaly/hydrocephalus are small (Table 2). As for associated abnormality and/or chromosomal aberration in cases of fetal CNS abnormality, cases without complication was 53.5% and the rest of 46.5% are complicated with extra-CNS abnormality or abnormal karyotype (Table 3).

Variety of Mild Ventriculomegaly with AW 10 to 15 mm

Mild ventriculomegaly is defined as a width of the atrium of the lateral cerebral ventricles of 10 to 15 mm. It has been reported that mild ventriculomegaly with atrial width 10 to 15 mm resolves in 29%, remains stable in 57%, progresses in 14% of the cases during pregnancy.[18] Figures 2 to 5 shows the prenatal diagnostic imaging of the cases with mild ventriculomegaly and associated abnormalities such as craniosynostosis, micrognathia, vein of Galen, aneurysmal malformation and multiple intracerebral bleeding. These cases were referred due to ventriculomegaly and atrial width was 10 to 13 mm at referral. Various outcomes and prognoses followed according to complicated abnormalities.

Table 4 summarizes 23 cases of ventriculomegaly with atrial width 10 to 15 mm; 13 cases with additional anomaly and 10 cases without other abnormality. More than 30% of cases with other abnormalities had chromosomal aberration or genetic disorder. However, among the cases with other complication, 30% of them have had no neurological deficit in short-term. It is difficult to estimate postnatal prognosis simply by intrauterine progression or resolution of ventricular enlargement during pregnancy. Normalization of ventricular enlargement during fetal period was seen in 70% of cases with no other complications. In our series, all cases with both no complications and spontaneous resolution of enlargement have had favorable prognosis in short-term.

Table 1: CNS abnormality in 16 referral cases before 22 weeks of gestation

Dysraphism	8 cases
Holoprosencephaly	2
Mild ventriculomegaly	2
Hydrocephalus	2
Huge Arachnoid cyst	1
Dandy-Walker malformation	1
Total	16
11 cases (68.7%)	Termination of pregnancy
5 cases (31.3%)	Continuing pregnancy

Table 2: CNS abnormality in 27 referral cases after 22 weeks of gestation

Dandy-Walker malformation	1*
Holoprosencephaly	4
Arachnoid cyst	1
Cerebellum hypoplasia	2*
Hydrocephalus	2
Mild ventriculomegaly	4**
Calcification	2
Multiple bleeding	1
Hydroanencephaly	1
Craniosynostosis	1
Agenesis of the corpus callosum	4
Cerebral hypoplasia	1*
Abnormal gyration	1
Lipoma	1
Leptocephaly	1
Total	27

Table 3: Chromosome and other abnormalities in 43 referral cases with CNS abnormality

Normal karyotype	*34*	*(79.1%)*
No associated abnormality	23	(53.5%)
Facial abnormality	4	(9.3%)
Limb abnormality	4	(9.3%)
Lung/heart abnormality	2	(4.7%)
Cytomegalo infection	1	(2.3%)
Abnormal karyotype	9	(20.9%)

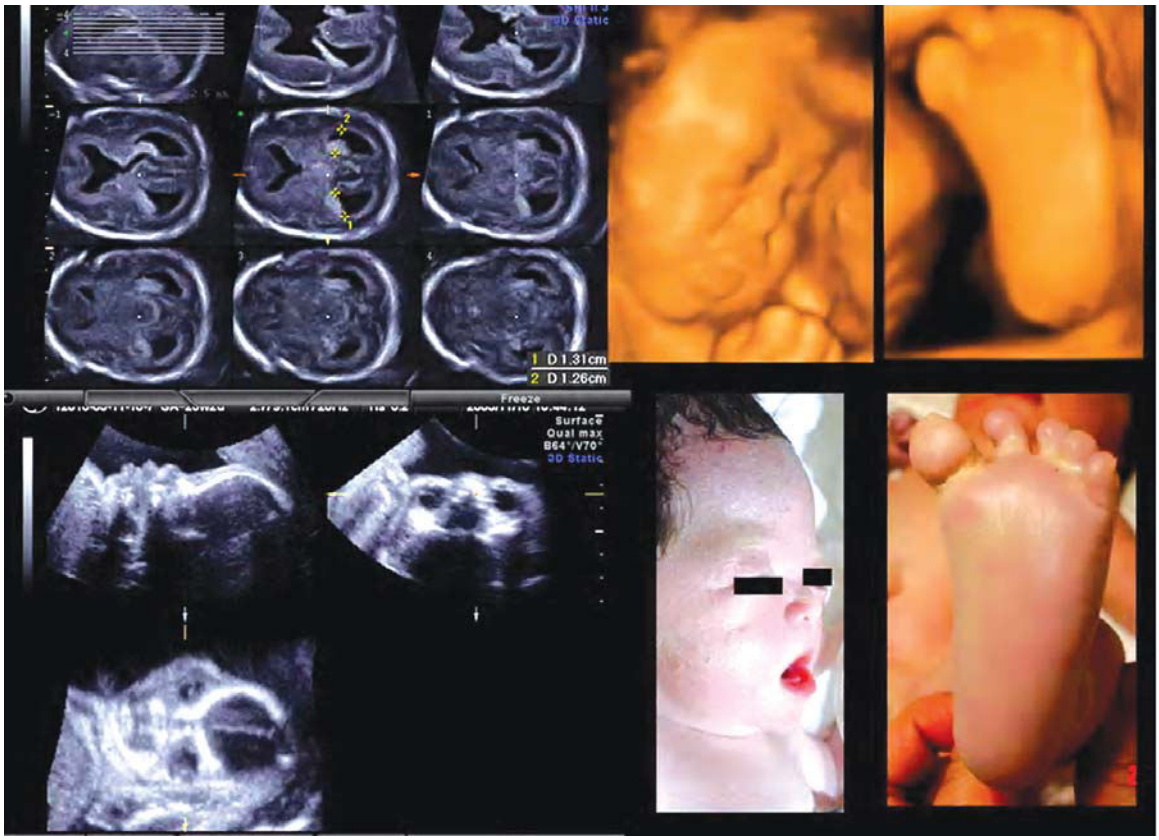

Fig. 2: Mild ventriculomegaly caused by craniosynostosis (26 weeks)
(Left upper) Tomographic ultrasound imaging of axial section of fetal brain. Atrial width was 12 to 13 mm. Fusion of bilateral ventricles were seen. (Left lower) Three orthogonal view of fetal face. Hypertelorism and ocular proptosis are seen. (Right upper) 3D surface reconstruction images of fetal face and big toe. (Right lower) Neonatal face and toe

Table 4: 23 cases of ventriculomegaly of atrial width 10 to 15 mm

With additional abnormality	*13/23 cases (56.5%)*
Chromosomal/genetic abnormality	31%
Other brain abnormality	69%
Extra-CNS abnormality	31%
MR, CP, neurological deficits	40%
No neurological deficit (< 2 years)	30%
IUFD, TOP	30%
Ventriculomegaly during pregnancy	
Resolved	31%
Remain stable	31%
Progressive	23%
Uncertain	15%
No other abnormality	*10/23 cases (43.5%)*
Cerebral palsy	10%
Epilepsy	10%
No neurological deficit (< 2 years)	80%
Ventriculomegaly during pregnancy	
Resolved	70%
Remain stable	20%
Progressive	10%

Generally, in cases of mild fetal ventriculomegaly with a normal karyotype and an absence of malformations, the outcome appears to be favorable.[19] Pilu and his colleagues[20] reviewed 234 cases of borderline ventriculomegaly including an abnormal outcome in 22.8% and concluded that borderline ventriculomegaly carries an increased risk of cerebral maldevelopment, delayed neurological development, and possibly, chromosomal aberrations. Isolated mild ventriculomegaly with atrial width of 10 to 12 mm may be normal variation. Signorelli and colleagues[21] described that their data of normal neurodevelopment between 18 months and 10 years after birth in cases of isolated mild ventriculomegaly (atrial width of 10 to 12 mm), should provide a basis for reassuring counseling. Ouahba and colleagues[22] recently reported the outcome of 167 cases of isolated mild ventriculomegaly and concluded that in addition to associated anomalies, three criteria are often associated with an unfavorable outcome: (i) atrial width greater than 12 mm, (ii) progression of the enlargement, and (iii) asymmetrical and bilateral ventriculomegaly.

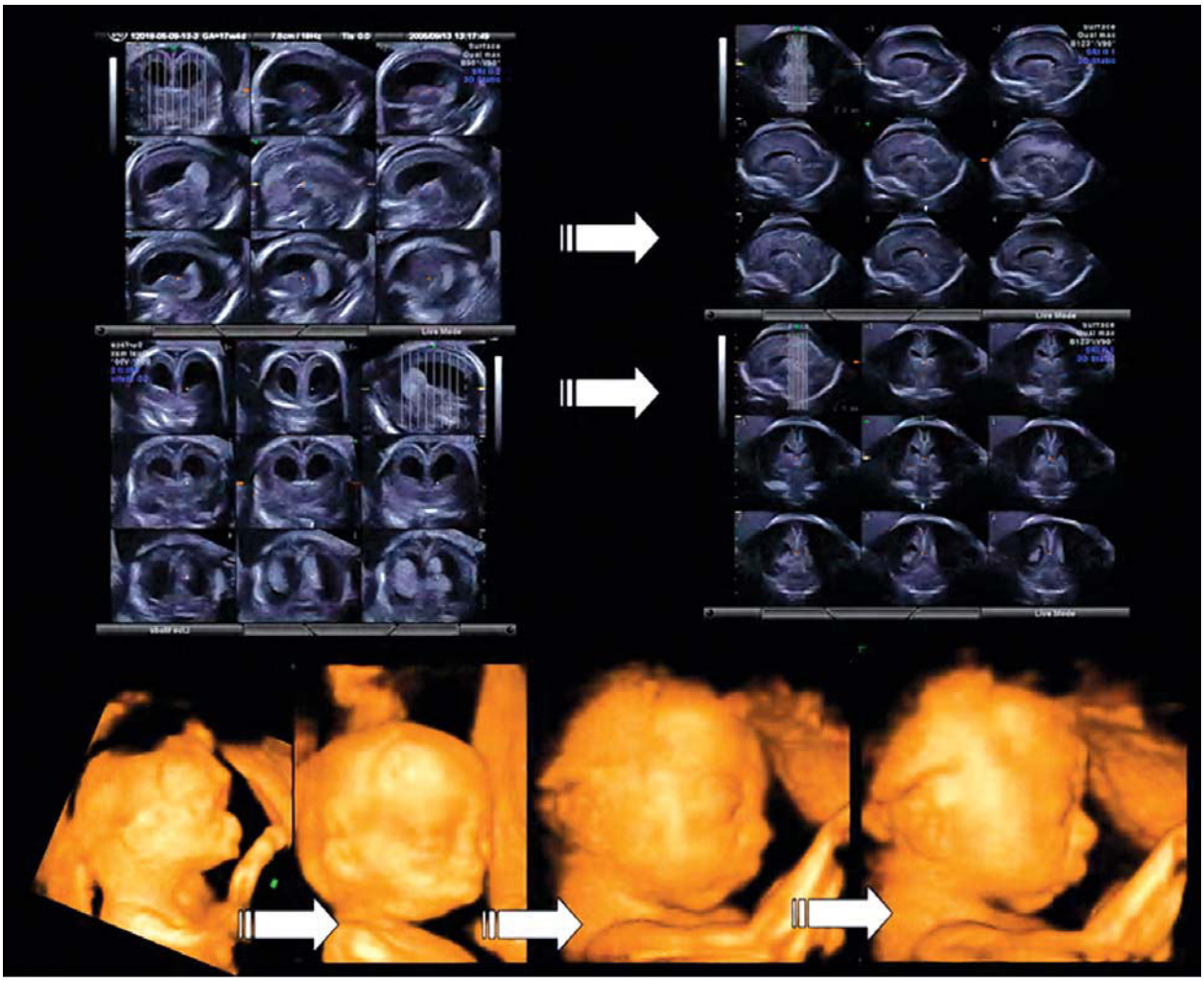

Fig. 3: Spontaneous resolution of ventriculomegaly and micrognathia (17 and 25 weeks)
On referral at 17 weeks, ventriculomegaly with atrial width 11 mm (Left upper) Tomographic ultrasound imaging) and micrognathia (Left lower) was demonstrated. Spontaneous resolution of ventriculomegaly (Right upper, 25 weeks) and slow jaw development was seen (Lower) during pregnancy. Final diagnosis was Pierre-Robin syndrome

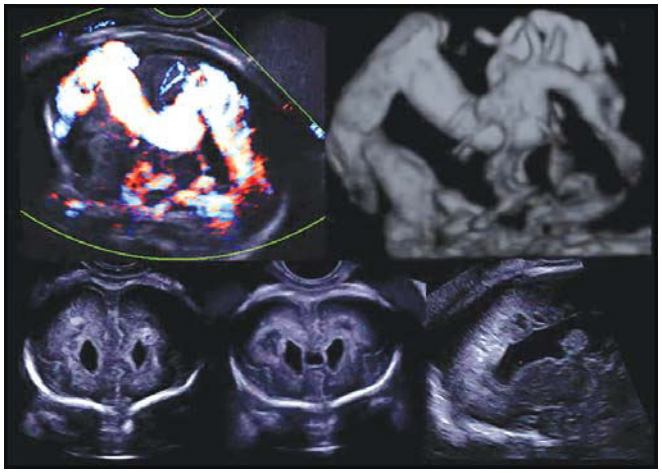

Fig. 4: Mild ventriculomegaly associated with vein of Galen aneurysmal malformation (VGAM) (28 weeks)
(Left upper) Intracranial angiogram by directional power Doppler. Huge blood vessels in the middle section were demonstrated. (Right upper) 3D B-flow angiography. Many arteries directly connected to aneurysmal sac are depicted. (Lower) Multiple brain damage due to hemorrhage or ischemic changes, and mild ventriculomegaly were demonstrated. At referral, atrial width was 10 mm

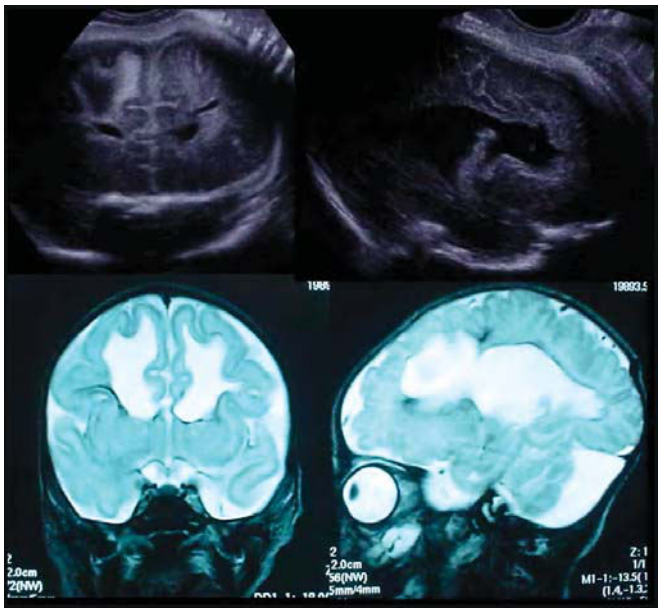

Fig. 5: Mild ventriculomegaly due to multiple intracranial bleeding (35 weeks and afterbirth)
(Upper) Ultrasound imaging in the coronal and parasagittal sections at 35 weeks. Brain hemorrhage was demonstrated as hypoechoic area within hyperechoic lesions, and porencephalic lesions. (Lower) MRI on 17th postnatal day. Clear porencephaly fused with lateral ventricles are seen

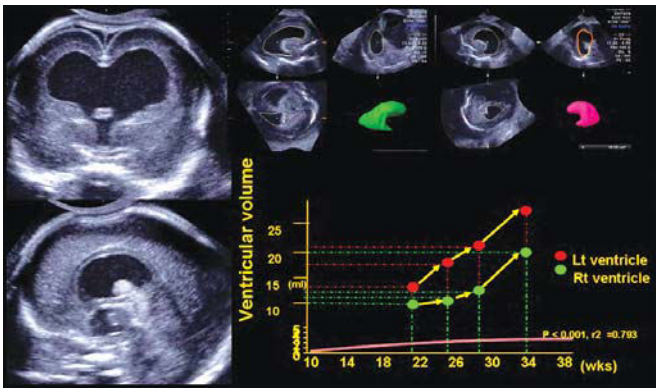

Fig. 6: Moderate ventriculomegaly (21 weeks)
(Left) Ultrasound images in the coronal and sagittal sections. Fused ventriculomegaly, enlarged foramen of Monro, mild IIIrd ventriculomegaly are demonstrated in the coronal section, and no enlargement of IVth ventricle was seen in the sagittal section. Therefore, aqueductal stenosis was suspected. (Right upper) 3D images with volume calculation of bilateral ventricles. (Right lower) Longitudinal study of ventricular size was on the graph. This case shows moderate increase of ventricular size during pregnancy

Table 5: 23 cases of ventriculomegaly of atrial width > 15 mm

Isolated ventriculomegaly	9
Normal karyotype	7
Abnormal karyotype	2
Holoprosencephaly	5
Myelomeningocele	5
Dandy-Walker syndrome	1
Agenesis of CC	1
ACC + IHC	1
Multiple porencephaly	1
Total	32

Moderate to Severe Ventriculomegaly with AW over 15 mm

Figures 6 and 7 shows prenatal sonographic imaging of fetal ventriculomegaly with atrial width of over 15 mm. In the case of Figure 6, the cause of ventriculomegaly was aqueductal stenosis and cerebral hypoplasia, while in the case of Figure 7, amniotic band attached to the scalp resulted in partial cranial bone defect and a small cephalocele, which may have caused Monro obstruction and enlarged ventricles. Table 5 shows the summary of 23 ventriculomegaly cases with atrial width > 15 mm. Nine cases (39.1%) had no other CNS abnormality but two, out of those 9, were complicated with chromosomal aberration. Among the rest of 14 cases, holoprosencephaly was detected in 5 cases and myelomeningocele in 5 cases. Four cases out of 7 without any complication had favorable postnatal prognosis after ventricular-peritoneal shunting procedure.

CONCLUSIONS

In cases of fetal ventriculomegaly, detailed neuroscan by advanced imaging technology, detailed extra-CNS scan, longitudinal serial scan during pregnancy, and longitudinal observation of short-term/long-term neurological prognosis are mandatory for proper counseling and management. We organized a Japanese committee team of *fetal hydrocephalus* including pediatric neurosurgeons and obstetrician specializing fetal neuron-diagnosis, and published a book of *Fetal Hydrocephalus Guideline for Diagnosis and Management* in 2005 (Fig. 8). The guideline committee has researched on 'Relations between CNS abnormalities with accurate prenatal diagnosis and neurological prognosis/outcome' for contributing proper diagnosis and management of fetal CNS diseases.

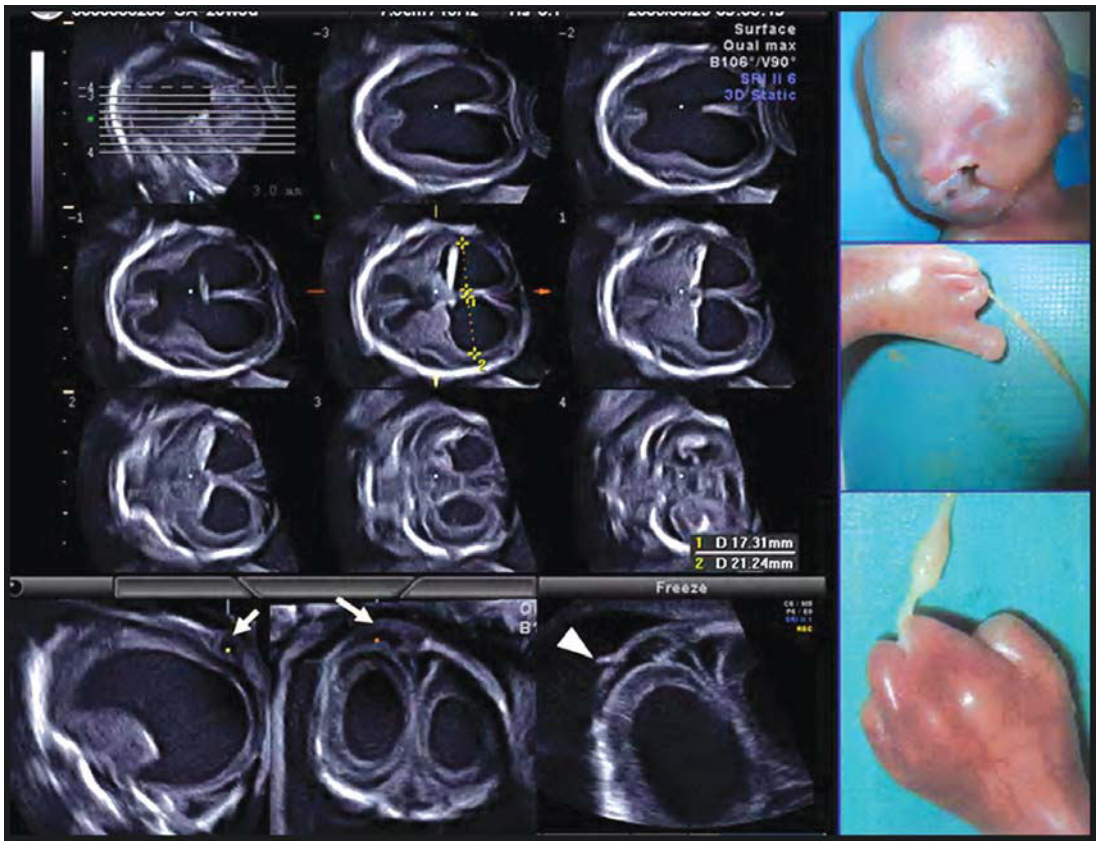

Fig. 7: Hydrocephalus due to amniotic band syndrome (20 weeks)
(Left upper) Tomographic ultrasound imaging in the axial section of fetal brain at referral. Bilateral atrial width was 17 and 21 mm respectively. From the observation of enlarged ventricles, simple hydrocephalus due to Monro obstruction was suspected. However, the fetus was complicated with cleft lip, amputation of fingers and amniotic band was detected by extra-CNS scan. (Lower) Small cephalocele (arrows) were seen with remnant of the amniotic band (arrowhead). (Right) Macroscopic view of the face and extremities after termination of pregnancy

Fig. 8: Fetal hydrocephalus guideline for diagnosis and management. A Japanese committee team of *fetal hydrocephalus* including pediatric neurosurgeons and obstetrician specializing fetal neuron-diagnosis, published a book of *fetal hydrocephalus guideline for diagnosis and management* in 2005. This book is not only for doctors and examiners but also for patients with fetal CNS abnormalities

REFERENCES

1. Timor-Tritsch IE, Monteagudo A. Transvaginal fetal neurosonography: standardization of the planes and sections by anatomic landmarks. Ultrasound Obstet Gynecol 1996;8:42-7.
2. Pooh RK, Nakagawa Y, Nagamachi N, Pooh KH, Nakagawa Y, Maeda K, et al. Transvaginal sonography of the fetal brain: detection of abnormal morphology and circulation. Croat Med J 1998;39:147-57.
3. Pooh RK, Maeda K, Pooh KH, Kurjak A. Sonographic assessment of the fetal brain morphology. Prenat Neonat Med 1999;4:18-38.
4. Pooh RK, Maeda K, Pooh KH. An Atlas of Fetal Central Nervous System Disease: Diagnosis and Management. Parthenon CRC Press: London, New York, 2003.
5. Pooh RK. Three-dimensional ultrasound of the fetal brain. In Kurjak A (Ed): Clinical Application of 3D Ultrasonography. Parthenon Publishing: Carnforth 2000;176-80.
6. Pooh RK, Pooh KH, Nakagawa Y, Nishida S, Ohno Y. Clinical application of three-dimensional ultrasound in fetal brain assessment. Croat Med J 2000;41:245-51.
7. Timor-Tritsch IE, Monteagudo A, Mayberry P. Three-dimensional ultrasound evaluation of the fetal brain: the three horn view. Ultrasound Obstet Gynecol 2000;16:302-6.
8. Monteagudo A, Timor-Tritsch IE, Mayberry P. Three-dimensional transvaginal neurosonography of the fetal brain: 'navigating' in the volume scan. Ultrasound Obstet Gynecol 2000;16:307-13.
9. Pooh RK, Pooh KH. Fetal vertebral structure detected by three-dimensional ultrasound. Ultrasound Review Obstet Gynecol 2005;5:29-33.
10. Pooh RK, Pooh KH. Transvaginal 3D and Doppler ultrasonography of the fetal brain. Semin Perinatol 2001;25:38-43.
11. Pooh RK, Pooh KH. Fetal neuroimaging with new technology. Ultrasound Review Obstet Gynecol 2002;2:178-81.
12. Endres LK, Cohen L. Reliability and validity of three-dimensional fetal brain volumes. J Ultrasound Med 2001;20:1265-9.
13. Roelfsema NM, Hop WC, Boito SM, Wladimiroff JW. Three-dimensional sonographic measurement of normal fetal brain volume during the second half of pregnancy. Am J Obstet Gynecol 2004;190(1):275-80.
14. Pooh RK, Pooh KH. The assessment of fetal brain morphology and circulation by transvaginal 3D sonography and power Doppler. J Perinat Med 2002;30:48-56.
15. Pooh RK. Two-dimensional and three-dimensional Doppler angiography in fetal brain circulation. In Kurjak A (Ed): 3D Power Doppler in Obstetrics and Gynecology. Parthenon Publishing: Carnforth 1999; pp 105-11.
16. Malinger G, Ben-Sira L, Lev D, Ben-Aroya Z, Kidron D, Lerman-Sagie T. Fetal brain imaging: a comparison between magnetic resonance imaging and dedicated neurosonography. Ultrasound Obstet Gynecol 2004;23:333-40.
17. Pooh RK, Nagao Y, Pooh KH. Fetal neuroimaging by transvaginal 3D ultrasound and MRI. Ultrasound Rev Obstet Gynecol 2006;6:123-34.
18. Kelly EN, Allen VM, Seaward G, Windrim R, Ryan G. Mild ventriculomegaly in the fetus, natural history, associated findings and outcome of isolated mild ventriculomegaly: a literature review. Prenat Diagn 2001;21:697-700.
19. Goldstein I, Copel JA, Makhoul IR. Mild cerebral ventriculomegaly in fetuses: characteristics and outcome. Fetal Diagn Ther 2005;20:281-4.
20. Pilu G, Falco P, Gabrielli S, Perolo A, Sandri F, Bovicelli L. The clinical significance of fetal isolated cerebral borderline ventriculomegaly: report of 31 cases and review of the literature. Ultrasound Obstet Gynecol 1999;14:320-6.
21. Signorelli M, Tiberti A, Valseriati D, Molin E, Cerri V, Groli C, Bianchi UA. Width of the fetal lateral ventricular atrium between 10 and 12 mm: a simple variation of the norm? Ultrasound Obstet Gynecol 2004;23:14-8.
22. Ouahba J, Luton D, Vuillard E, Garel C, Gressens P, Blanc N, Elmaleh M, Evrard P, Oury JF. Prenatal isolated mild ventriculomegaly: outcome in 167 cases. BJOG 2006;113:1072-9.