Seminars in Fetal & Neonatal Medicine 17 (2012) 330–335

Contents lists available at SciVerse ScienceDirect

Seminars in Fetal & Neonatal Medicine

journal homepage: www.elsevier.com/locate/siny

Diagnosis, treatment, and long-term outcomes of fetal hydrocephalus

Mami Yamasaki [a,b,*], Masahiro Nonaka [a], Yohei Bamba [b], Chika Teramoto [c], Chiaki Ban [d], Ritsuko K. Pooh [e]

[a] Department of Neurosurgery, Osaka National Hospital, National Hospital Organization, Osaka, Japan
[b] Institute for Clinical Research, Osaka National Hospital, National Hospital Organization, Osaka, Japan
[c] Department of Nursing, Osaka National Hospital, National Hospital Organization, Osaka, Japan
[d] Department of Obstetrics, Osaka National Hospital, National Hospital Organization, Osaka, Japan
[e] Division of Fetal Imaging Diagnosis, Clinical Research Institute of Fetal Medicine PMC, Osaka, Japan

Keywords:
Fetal hydrocephalus
Fetal magnetic resonance imaging
Long-term outcome
Prenatal diagnosis
Treatment

SUMMARY

This study analyzed 156 cases of fetal hydrocephalus treated at Osaka National Hospital from 1992 to 2011 to review current methods for diagnosing and treating fetal hydrocephalus, and for estimating its clinical outcome. This was a retrospective study of a single institute (Osaka National Hospital). Of 156 cases in total, 37% were diagnosed as isolated ventriculomegaly, 50% as another type of malformation (36 cases of myelomeningocele, six of holoprosencephaly, three of Dandy–Walker syndrome, one case of Joubert syndrome, 12 of arachnoid cyst, nine of encephalocele, three of atresia of Monro and eight of corpus callosum agenesis, and 13% as secondary hydrocephalus. Diagnoses were made between 13 and 40 weeks of gestation (average 27 weeks). Diagnosis was made before 21 weeks of gestation in 24% of cases, from the first day of 22 weeks to the sixth day of 27 weeks in 27%, and after the first day of 28 weeks in 49%. With the exclusion of 17 aborted cases and 40 cases in which the patients were too young to evaluate or lost during follow-up, the final outcome was analyzed for 90 cases. Of these, 17% of the patients died, 21% showed severe retardation, 13% moderate retardation, 26% mild retardation, and 23% showed a good outcome. The long-term outcome was mostly influenced by the basic disease and accompanying anomaly. The time of diagnosis showed no correlation with outcome. Hydrocephalus associated with arachnoid cyst, atresia of Monro, and corpus callosum agenesis, and hydrocephalus due to fetal intracranial hemorrhage, resulted in good outcomes. By contrast, holoprosencephaly, hydrocephalus associated with encephalocele, syndromic hydrocephalus, and hydrocephalus due to fetal virus infection led to poor outcomes. For accurate diagnosis and proper counseling, established protocols are important for the diagnosis and treatment of fetal hydrocephalus, including not only fetal sonography, fetal magnetic resonance imaging, and TORCH (toxoplasma, rubella, cytomegalovirus, herpes simplex) screening test, but also chromosomal and gene testing.

1. Introduction

Hydrocephalus is a condition in which cerebrospinal fluid (CSF) within the ventricles and/or subarachnoid space of the brain accumulates abnormally, causing dilatation of the ventricles and increased intracranial pressure, at the time of diagnosis or previously. Fetal hydrocephalus is diagnosed prenatally. It includes primary (congenital) hydrocephalus due to maldevelopment and secondary (acquired) hydrocephalus originating from intracranial bleeding, infection, or accompanying brain tumors in the fetal period. Congenital hydrocephalus is often used synonymously with primary hydrocephalus, but strictly speaking, congenital hydrocephalus includes fetal secondary hydrocephalus.[1]

Hydrocephalus has been increasingly diagnosed prenatally as ventriculomegaly (VM), due to the development of diagnostic technology. However, the long-term prognosis and clinical course are still unclear. Those factors most responsible for the outcome such as time of diagnosis, the severity of VM, the original disease, the etiology of the VM, the accompanying anomaly and the treatment course, are the subject of debate. In this paper, we analyze the clinical course and long-term outcome of fetal hydrocephalus and clarify the risk factors.

2. Clinical materials and methods

This was a retrospective study of cases from a single institute. The medical records for 156 cases of fetal hydrocephalus managed

* Corresponding author. Department of Neurosurgery, Osaka National Hospital, National Hospital Organization, 2-1-14 Hoenzaka, Chuo-ku, Osaka City, Osaka 540-0006, Japan. Tel.: +81 6 6942 1331; fax: +81 6 6943 6467.
E-mail address: myamasaki@ajk.takatsuki-hp.or.jp (M. Yamasaki).

1744-165X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.siny.2012.07.004

at the Department of Neurosurgery of Osaka National Hospital, National Hospital Organization from 1992 to 2011 were analyzed. In all cases, fetal VM was diagnosed in utero using ultrasonography, and the cases were then examined in detail using fetal magnetic resonance imaging (MRI).

Of the 156 cases, 32 in which the patients were born after November 2009 were excluded because the patients were too young for their developmental status to be evaluated. Seventeen cases were terminated during pregnancy, and 17 cases were lost during follow-up. Therefore, 90 cases were evaluated for long-term outcome in this paper.

In the cases with surviving patients, the child's developmental status was evaluated after age 2 years. Of the original 90 patients, 75 survived for >2 years and were evaluated. The other 15 died before age 2 years.

Neurodevelopmental data were analyzed using a modified version of the mental and physical handicap assessment method of Hamamoto.[2] This method has been used in the epidemic survey conducted by the research committee of intractable hydrocephalus granted by Japanese Ministry of Health, Labor and Warfare for 20 years. These scores of 1–25 are applied in combination with the grades (1–5) for physical and locomotor activities and the grades (1–5) for mental and psychological conditions (Table 1). The grades for physical and locomotor activities are defined as follows: 0; 1, no physical deficit; 2, minor deficit but able to perform daily tasks and walk alone; 3, mild deficit but able to perform useful tasks with some limitation and to walk with some handicap; 4, moderate deficit with limited performance of useful tasks, for example, able to sit but unable to stand alone; 5, severe deficit with an inability to perform activities of daily living, e.g. being bedridden. The subscores for mental and psychological conditions are as follows: 0; 1, normal (developmental quotient, DQ > 85); 2, slightly delayed (DQ 84–75); 3, education and rehabilitation possible (DQ 74–50); 4, difficult to educate, but rehabilitation possible (DQ 49–25); 5, total support needed (DQ < 24). A final score of 1 is defined as normal, 2–12 as slightly retarded, 13–18 as moderately retarded, and 19–25 as severely retarded (Table 1). For the evaluation of mental and psychomotor assessments, the Kyoto Scale of Psychological Development or the Wechsler Intelligence Scale for Children was used by trained examiners. Fisher's exact test was used to analyze the relationship between the original disease and developmental delay. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Classification of fetal ventriculomegaly and its incidence

Fetal hydrocephalus is divided into primary and secondary (acquired) VM. Acquired VM originates from intracranial bleeding, infection, or associated tumors. Primary hydrocephalus is divided into isolated ventriculomegaly (IVM) and VM accompanied by an anomaly, such as myelomeningocele, Dandy–Walker malformation, holoprosencephaly (HPE), encephalocele, or agenesis of corpus callosum (ACC). In this study, IVM is classified as true IVM and syndromic IVM. Syndromic IVM includes hydrocephalus due a genetic anomaly, such as X-linked hydrocephalus, chromosomal defects such as 6p deletion, and syndromes such as Walker–Warburg syndrome.

Of the total of 156 cases, 57 (37%) were classified as IVM, including 39 (25%) cases of true IVM and 18 (12%) of syndromic IVM. The syndromic IVM cases included six cases of X-linked hydrocephalus, four cases of other types of hereditary hydrocephalus, four cases of IVM accompanied by a chromosomal anomaly, and one case of ectrodactyly–ectodermal dysplasia–cleft (EEC) syndrome. VM accompanied by anomaly represented 78 (50%) of the cases, and included myelomeningocele (MMC, 36 cases), Dandy–Walker cyst (three cases), Joubert syndrome (one case), HPE (six cases), encephalocele (nine cases), arachnoid cyst (12 cases), atresia of Monro (three cases), and ACC (eight cases). The final group of diagnoses was secondary hydrocephalus, comprising 21 cases (13%), including four cases of virus infection, nine of fetal intracranial hemorrhage, and eight cases with accompanying fetal brain tumor (Table 2).

3.2. Time of diagnosis

The gestational age at the time of VM diagnosis in 154 cases (two were excluded because the time of diagnosis was unknown) was 13–40 weeks (average 27 weeks). The population was divided into three groups according to the time of diagnosis: group A (37 cases; 24%), earlier than 21 weeks; group B (42 cases; 27%), from

Table 1
Method of developmental evaluation.

Physical and locomotor activities	Mental and psychological conditions				
	Grade 0 DQ > 85 Normal	Grade 1 DQ 84–75 Slight delay	Grade 2 DQ 74–50 Education and rehabilitation possible	Grade 3 DQ 49–25 Difficult to educate, but education possible	Grade 4 DQ < 24 Total support needed
Grade 0: no physical deficit	1[a]	2[b]	3[b]	4[c]	5[d]
Grade 1: minor deficit but able to perform daily tasks and walk alone	6[b]	7[b]	8[b]	9[c]	10[d]
Grade 2: mild deficit but able to perform useful tasks with some limitation and to walk with some handicap	11[b]	12[b]	13[c]	14[c]	15[d]
Grade 3: moderate deficit with limited performance of useful tasks, e.g. able to sit but unable to stand alone	16[c]	17[c]	18[c]	19[d]	20[d]
Grade 4: severe deficit with an inability to perform activities of daily living, e.g. being bedridden	21[d]	22[d]	23[d]	24[d]	25[d]

DQ, developmental quotient.
[a] Normal.
[b] Mild retardation.
[c] Moderate retardation.
[d] Severe retardation.

Table 2
Classification of fetal hydrocephalus and occurrence rate.

Classification of hydrocephalus	*n*	%
Primary hydrocephalus		
Isolated ventriculomegaly (IVM)		
True IVM	39	25
Syndromic hydrocephalus	18	12
Hydrocephalus associated with myelomeningocele	36	23
Dandy–Walker syndrome and Jobert syndrome	4	3
Holoprosencephaly	6	4
Cranial bifida (encephalocele)	9	6
Hydrocephalus associated with arachnoid cyst	12	8
Hydrocephalus associated with atresia of Monro	3	2
Corpus callosum agenesis	8	5
Fetal secondary hydrocephalus		13
Post-intracranial hemorrhage	9	
Hydrocephalus associated with brain tumor	8	
Post-infectious hydrocephalus	4	

the first day of 22 weeks to the sixth day of 27 weeks; and group C (75 cases; 49%), after the first day of 28 weeks.

3.3. Methods of diagnosis

In all cases, fetal VM was diagnosed in utero using fetal ultrasonography. Fetal MRI was performed in 135 cases. Prenatal karyotype testing or gene analysis was performed in 38 cases.

For hydrocephalus accompanied with MMC, a fetal diagnosis was made in 36 cases, which accounted for 80% of the total cases recorded in that period. The gestational age at the time of MMC diagnosis was between 13 and 39 weeks (average 27 weeks): group A, 11 cases (30%); group B, six cases (17%); group C, 19 cases (53%). All the cases encountered before 2005 were categorized as group C. Of the cases after 2006, 41% were in group A, 22% in group B, and 37% in group C. Over time, diagnoses have been made earlier in gestation. Of the 11 cases in group A, seven were terminations of pregnancy (TOP) and the other four resulted in live births.

3.4. Treatment and management

The gestational age at time of delivery was between 34 and 43 weeks (average 37 weeks) in 121 cases, excluding cases of TOP and insufficient data for unknown reasons. Elective cesarean section was performed in 74 cases at 34–40 weeks of gestation (average 37 weeks), and vaginal delivery was performed in 41 cases.

Neurosurgical intervention was performed in 85 cases (63%). The patients in 64 cases were treated with ventriculo-peritoneal (VP) shunt placement, and in 14 cases the patients underwent endoscopic third ventriculostomy or septostomy. In 27 cases of MMC and seven of encephalocele the patients were treated by repair of the anomaly. In five cases with symptomatic Chiari malformation, the patients underwent foramen magnum decompression, and five patients with fetal brain tumor were treated by surgical resection of the tumor.

3.5. Long-term outcome

Of the 139 fetal cases that resulted in live birth, 32 were too young to evaluate and 17 were lost during follow-up; therefore, 90 cases were used to evaluate long-term outcomes. Overall, the outcome was death before age 2 years in 15 cases (17%), severe retardation in 19 (21%), moderate retardation in 12 (13%), mild retardation in 23 (26%), and normal development in 21 (23%).

3.6. Factors related to prognosis

Normal development and mild retardation were defined as good outcomes; severe retardation and death were defined as poor outcomes. Patients in the 'good outcomes' group included 100% of those with hydrocephalus accompanied by arachnoid cyst, ACC, and atresia of Monro, 80% of those with post-hemorrhagic hydrocephalus, 52% of those with hydrocephalus with MMC, 50% of those with Dandy–Walker cyst, and 45% of those with true IVM. By contrast, there were no cases with good outcomes among the patients with HPE, hydrocephalus accompanied by encephalocele, syndromic hydrocephalus, or post-infectious hydrocephalus (Table 3). Therefore, the outcome was strongly correlated with the basic disease and accompanying anomaly ($P = 0.00026$).

For the 88 cases for which the time of VM diagnosis was known, we examined the correlation between outcome and gestational weeks at the time of diagnosis. Patients showing normal development accounted for 23% of group A, 24% of group B, and 30% of group C. Cases of normal development and mild retardation together comprised 31% of group A, 52% of group B, and 66% of group C. Therefore, the time of gestation at diagnosis showed no correlation with outcome (Fig. 1).

Table 3
Outcome variation between diseases.

Classification of hydrocephalus	*a*	*b*	*c*: good outcome			*d*: poor outcome		*c*/*b* (%)
			Normal	Mild	Moderate	Severe	Dead	
Primary hydrocephalus								
Isolated ventriculomegaly (IVM)								
True IVM	39	22	4	6	0	7	5	45
Syndromic hydrocephalus	18	6	0	0	0	5	1	0
Hydrocephalus associated with myelomeningocele	36	23	5	7	8	0	3	52
Dandy–Walker syndrome and Jobert syndrome	4	4	1	1	1	1	0	50
Holoprosencephaly	6	3	0	0	0	0	3	0
Cranial bifida (encephalocele)	9	4	0	0	1	2	1	0
Hydrocephalus associated with arachnoid cyst	12	9	5	4	0	0	0	100
Hydrocephalus associated with atresia of Monro	3	3	2	1	0	0	0	100
Corpus callosum agenesis	8	3	2	1	0	0	0	100
Fetal secondary hydrocephalus								
Post-intracranial hemorrhage	9	5	1	3	1	0	0	80
Hydrocephalus associated with brain tumor	8	5	1	0	1	1	2	25
Post-infectious hydrocephalus	4	3	0	0	0	3	0	0
Totals	156	90	21	23	12	19	15	

a: total numbers; *b*: numbers evaluated for long-term outcome.

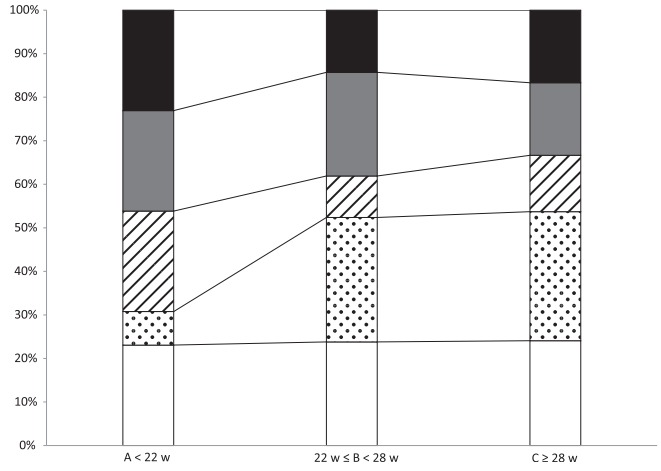

Fig. 1. Outcome and time of diagnosis. Bars: black: dead; grey: severe; hatched: moderate; stippled: mild; white: normal.

4. Discussion

Fetal ventricular dilatation is diagnosed as atrial width (AW) of the lateral ventricle ≥10 mm, regardless of the pregnancy week. When VM is diagnosed in a fetus and the case is referred to a neurosurgical department, it is essential to obtain an accurate diagnosis and counseling for the parents, to decide the time and method of delivery, and to determine the treatment for the hydrocephalus and accompanying anomaly.

For an accurate diagnosis, fetal MRI is performed to detect brain anomalies, in addition to fetal ultrasonography (to detect general complications), a karyotype test, and TORCH (toxoplasma, rubella, cytomegalovirus, herpes simplex) testing. Nicolaides et al. reported that only 3% of fetuses with IVM had chromosomal defects, compared with 36% of those with additional malformations. This emphasizes the need for karyotype testing to obtain an accurate diagnosis.[3]

In data obtained from Hungary, 306 cases of spina bifida were diagnosed prenatally from 1976 to 2002; 74% were diagnosed before 24 weeks of gestation.[4] This is earlier than the gestational age at the time of diagnosis in Japan. In Hungary, four screening ultrasound examinations are offered for low-risk pregnant woman, at gestational weeks 7–8, 18–20, 28–30, and 36–37. In addition, during the 16th gestational week, a maternal serum α-fetoprotein examination is performed to screen for fetal neural tube defects (NTDs). Boyd et al.[5] surveyed the national screening policies in 2004 for 18 European countries. There is a formal national ultrasound screening policy for structural anomalies in 14 countries, and the overall prenatal detection rate for NTDs was 88% (range: 25–94%). The detection rate was highest in countries with national standards.

4.1. Time and method of delivery

In-utero surgical intervention for myelomeningocele and hydrocephalus has been tried in the USA and Brazil.[6,7] This approach is based on the findings that the neural placode appears to suffer additional damage from the pressure and exposure to amniotic fluid or that there can be progressive VM damage to the brain mantle. It was recently reported that the incidence of shunt-dependent hydrocephalus with Chiari malformation is lower after in-utero repair compared with postnatal repair. However, the indication for shunt replacement to treat hydrocephalus with MMC is controversial. Symptomatic Chiari malformations represent <10% of MMC cases. In fetal hydrocephalus, progressive VM is very rare. The type of fetal hydrocephalus depends on the original cause or accompanying anomaly, which determines the long-term prognosis. Patients with several different kinds of hydrocephalus showed normal development after receiving postnatal treatment. The long-term benefit of in-utero surgery has not yet been confirmed.

Early delivery at 32 weeks of gestation was recommended for fetal hydrocephalus in the 1990s. However, there is no evidence that this practice improves the outcome, so we recommend delivery at term, after 37 gestational weeks.[8] The cases in which VM are progressive represent <2% of the total in our data, and 5% in the literature. These patients were treated after delivery at 37 weeks of gestation, but time of treatment does not seem to influence their developmental outcome.[8]

There has been debate about the relative merits of cesarean section versus vaginal delivery for MMC. Luthy et al.[9] found that labor was associated with an increased risk of additional deficit and concluded that delivery by cesarean section before the onset of labor may result in better motor function than vaginal delivery or cesarean section after a period of labor. From a practical standpoint, planning the delivery early in the morning and subsequently performing simultaneous repair and VP shunt replacement the same day seems to yield a better prognosis. Therefore, we select cesarean section for cases of MMC, large encephalocele, post-hemorrhagic hydrocephalus, and cephalic–pelvic disproportion, due to the large head.

4.2. Treatment and management

The first choice for pediatric hydrocephalus remains VP shunt. Programmable shunt systems are widely used, because they enable the optimal intracranial pressure for skull and brain-matter development. We use a programmable shunt system to avoid over-drainage. We recommended that the body weight be >2000 g when the shunt is placed. Intermittent CSF aspiration from the CSF reservoir is temporarily performed for patients with low body weight or cloudy CSF.

Endoscopic third ventriculostomy (ETV) is another method for treating pediatric hydrocephalus; however, the indication for ETV is limited to cases of obvious non-communicating hydrocephalus. Another opinion is that there is no indication for ETV in a hydrocephalus patient aged <1 year.[10,11]

We perform endoscopic cyst fenestration for arachnoid cysts, and septostomy for atresia of Monro. We recently began performing ETV instead of shunt replacement, when the first shunts are not functional in the patients with hydrocephalus with MMC. It is still necessary to evaluate the long-term mental and psychological outcomes when determining the indication for ETV.

4.3. Long-term outcome

Renier et al.[12] reviewed the long-term outcome of 108 prenatal hydrocephalus patients treated surgically from 1971 to 1981 at Hôpital des Enfants Malades. Eighty-four percent of the infants underwent surgery before the age of 3 months, and the survival rate was 62% at 10 years. Of the 75 surviving children, 28% had IQ > 80, 21% had a score of 60–80, and for 51% it was 60. The mean IQ was 54 (range: 0–130). Head enlargement at birth, ventricular size, and time of surgery were not found to be related to the late functional results. The outcomes were best when there was no associated malformation or shunt infection, when the hydrocephalus was due to aqueduct stenosis (excluding X-linked hydrocephalus and toxoplasmosis), or when the first DQ measured at 6 months was >80. The authors concluded that the basic disease,

associated malformations, and surgical complications were related to the long-term outcome.

HPE leads to very poor outcomes. In a study of 61 children with HPE surviving beyond 1 year, only 50% of those with the lobar type HPE, which is less severe than the semilobar and alobar types, were able to walk with assistance, had useful hand function, and could say one or more words.[13] Patients with the alobar type of HPE usually die within their first year.

Dandy–Walker syndrome patients are divided into those with or without other anomalies. In the former group, the anomalies can be CNS anomalies, such as corpus callosum agenesis, occipital encephalocele, polymicrogyria, and ectopic gray matter, or extra-CNS anomalies such as chromosome abnormalities, facial anomalies, and cardiac defects. An IQ > 80 was found in 12–65% of the DWS patients with other anomalies, and in 60–100% of those without other anomalies.[14,15]

ACC is often accompanied by associated structural defects and/or chromosomal abnormalities. In one report of 117 cases of prenatally diagnosed ACC, 30% were isolated ACC, 42% were complicated by associated structural defects, and 28% had chromosomal abnormalities. Of the isolated ACC cases, 64% showed normal development.[16] In our cases, isolated ACC showed a good outcome. It is very important to check for anomalies and to perform karyotype testing in evaluating the prognosis for DWS and ACC.

By contrast with the above-described situations, the outcomes in IVM vary widely. IVM here is classified into true IVM and syndromic IVM. Syndromic IVM includes hydrocephalus due to genetic anomaly, associated with chromosomal defects, and syndromic hydrocephalus. Regarding congenital hydrocephalus, the genetics in X-linked hydrocephalus (XLH) have been elucidated over the last 20 years, since the first family with XLH was reported to have a neural cell adhesion molecule L1CAM (L1) gene mutation, in 1992. We identified 51 different *L1* gene mutations in 56 families with XLH.[17] In our clinical evaluation of XLH, all the cases showed a very poor outcome. Renier et al. reported that no case with XLH showed normal development and the average IQ was 17. Of the 56 families we studied, nine obligate carriers have requested prenatal gene mutation analysis for the fetal *L1* gene in 14 pregnancies.[18] From a mother carrying an *L1* mutation, 50% of the male fetuses could have severe hydrocephalus; therefore, for a family with XLH, prenatal molecular genetics diagnosis with genetic counseling is important.

Most *L1* mutations are private, occurring within a single family. Within the 56 families in which we identified *L1* gene mutations, only four specific mutations were found in more than one family: three mutations were each found in two unrelated families, and one was found in three unrelated families. Only half of the 56 families had a family history of hydrocephalus; the others were sporadic cases. Novel mutations were found in 70% of the cases. In other words, *L1* mutations have no hot point. The *L1* gene is composed of 28 exons, and a 3825 bp open reading frame. Therefore, direct sequencing of the entire gene requires at least 4 weeks. For families in which the *L1* gene mutation has previously been detected and analyzed, it only takes a week to analyze the few exons known to be involved. Prenatal gene analysis is thus limited to carriers already diagnosed with an *L1* mutation. In the male cases with severe ventricle dilatations and no family history of XLH, it is helpful to look for adducted thumbs, a characteristic feature of *L1* mutations, by fetal ultrasonography.

By contrast with syndromic IVM, true IVM has wide variations in outcome. Several papers on correlations of IVM with AW and prognosis have recently been published. Falip et al.[19] reported a prospective study of 101 fetuses with IVM. The percentage of patients with IQ > 90 represented 94% of the cases in which the AW was 10–11.9 mm and 85% of the cases in which the AW was 12–15 mm. Gaglioti et al.[20] reported that 93% of a mild group (AW 10–12 mm), 75% of a moderate group (AW 12.1–14.9 mm), and 62.5% of a severe group (AW > 15 mm) showed a normal neurodevelopmental outcome in 176 IVM cases. In all these series, associated anomalies were excluded by fetal ultrasonography, fetal MRI, karyotype testing, and TORCH screening.

5. Conclusion

Fetal VM is one of the most common cerebral abnormalities detected with ultrasonography. However, it is still difficult to diagnose accurately. Prenatal counseling and support for families is very important, but precise diagnoses are required for this. The detection of IVM may cause a dilemma, because the outcomes can vary so widely. It is important to establish guidelines for the diagnosis and treatment of fetal hydrocephalus.

Practice points

- Around 50% of fetal VM shows mild retardation or a good outcome.
- The long-term outcome is mostly influenced by the basic disease and accompanying anomaly.
- The time of diagnosis shows no correlation with outcome.
- Hydrocephalus associated with arachnoid cyst, atresia of Monro, corpus callosum agenesis, and hydrocephalus due to fetal intracranial hemorrhage, results in good outcomes.
- Holoprosencephaly, hydrocephalus associated with encephalocele, syndromic hydrocephalus, and hydrocephalus due to fetal virus infection led to poor outcomes.
- It is important to check for associated anomalies by fetal ultrasonography, fetal MRI and to perform karyotype testing by TORCH screening in evaluating the prognosis for fetal hydrocephalus.

Conflict of interest statement

None declared.

Funding source

Health Sciences Research Grants for Research of Intractable Disease (2010-ID-131) from the Ministry of Health, Labor and Welfare in Japan (M.Y.).

References

1. Yamasaki M. Hydrocephalus. In: Yamasaki M, editor. *Guidelines for diagnosis and management of fetal hydrocephalus*. 2nd ed. Kyoto: Kimpodo; 2011. p. 13–21 [in Japanese].
2. Kumagai K. Scales for motor and mental retardation. In: Arima M, Kumagai K, Awai H, editors. *Fundamentals of developmental delay*. Tokyo: Nihon Bunka Kagakusya; 2008. p. 33–7 [in Japanese].
3. Nicolaides KH, Berry S, Snijders RJM, Thorpe-Beeston JG, Gosden C. Fetal lateral cerebral ventriculomegaly: associated malformations and chromosomal defects. *Fetal Diagn Ther* 1990;**5**:5–14.
4. Joo JG, Beke A, Papp C, et al. Neural tube defects in the sample of genetic counseling. *Prenat Diagn* 2007;**27**:912–21.
5. Boyd PA, Devigan C, Khoshnood B, Loane M, Garne E, Dolk H. EUROCAT working group: 2008 Survey of prenatal screening policies in Europe for structural malformations and chromosome anomalies, and their impact on detection and termination rate for neural tube defects and Down's syndrome. *BLOG* 2008;**115**:689–96.
6. Adzick NS, Thom EA, Spong CY, et al. A randomized trial of prenatal versus postnatal repair of myelomeningocele. *N Engl J Med* 2011;**364**:993–1004.

7. Cavalheiro S, Moron AF, Almodin CG, et al. Fetal hydrocephalus. *Child's Nerv Syst* 2011;**27**:1575–83.
8. Sakamoto H. Treatment of fetal hydrocephalus. In: Yamasaki M, editor. *Guidelines for diagnosis and management of fetal hydrocephalus*. 2nd ed. Kyoto: Kimpodo; 2011. p. 25–34 [in Japanese].
9. Luthy DA, Wardinsky T, Shurtleff DB, et al. Cesarean section before the onset of labor and subsequent motor function in infants with myelomeningocele diagnosed antenatally. *N Engl J Med* 1991;**324**:662–6.
10. Rekate HL. Selecting patients for endoscopic third ventriculostomy. *Neurosurg Clin N Am* 2004;**15**:39–49.
11. Nishiyama K, Mori H, Tanaka R. Changes in cerebrospinal fluid hydrodynamics following endoscopic third ventriculostomy for shunt-dependent noncommunicating hydrocephalus. *J Neurosurg* 2003;**98**:1027–31.
12. Renier D, Sainte-Rose C, Pierre-Kahn A, Hirsch JF. Prenatal hydrocephalus: outcome and prognosis. *Child's Nerv Syst* 1988;**4**:213–22.
13. Hahn JS, Plawner LL. Evaluation and management of children with holoprosencephaly. *Pediatr Neurol* 2004;**31**:79–88.
14. Hirsch JF, Pierre-Kahn A, Renier D, Sainte-Rose C, Hoppe-Hirsch E. The Dandy–Walker malformation. A review of 40 cases. *J Neurosurg* 1984;**61**:515–22.
15. Sato N. Dandy Walker syndrome. In: Yamasaki M, editor. *Guideline for diagnosis and management of fetal hydrocephalus*. 2nd ed. Kyoto: Kimpodo; 2011. p. 120–7.
16. Fratelli N, Papageorghiou AT, Prefumo F, Bakalis S, Homfray T, Thilaganathan B. Outcome of prenatally diagnosed agenesis of the corpus callosum. *Prenat Diagn* 2007;**27**:512–7.
17. Kanemura Y, Okamoto N, Sakamoto H, Shofuda T, Kamiguchi H, Yamasaki M. Molecular mechanisms and neuroimaging criteria for severe L1 syndrome with X-linked hydrocephalus. *J Neurosurg* 2006;**105**(5 Suppl.): 403–12.
18. Yamasaki M, Nonaka M, Suzumori N, et al. Prenatal molecular diagnosis of a severe type of L1CAM syndrome (X-linked hydrocephalus). *J Neurosurg Pediatr* 2011;**8**:411–6.
19. Falip C, Blanc N, Maes E, et al. Postnatal clinical and imaging follow-up of infant with prenatal isolated mild ventriculomegaly. *Prenatal Radiol* 2007; **37**:981–9.
20. Gaglioti P, Danelson D, Bontempo S, Mombro M, Cardaropoli S, Todros T. Fetal cerebral ventriculomegaly: outcome in 176 cases. *Ultrasound Obstet Gynecol* 2005;**25**:372–7.