

Outcome of antenatally diagnosed intracranial hemorrhage: case series and review of the literature

T. GHI*, G. SIMONAZZI*, A. PEROLO*, L. SAVELLI*, F. SANDRI†, B. BERNARDI‡, D. SANTINI§, L. BOVICELLI* and G. PILU*

*Department of Obstetrics and Gynecology, †Department of Paediatrics, ‡Department of Radiology, MRI Section and §Department of Pathology, Policlinico S. Orsola-Malpighi, University of Bologna, Bologna, Italy

KEYWORDS: fetus; intracranial hemorrhage; *in utero* magnetic resonance imaging; prenatal diagnosis; rhesus alloimmunization; ultrasound; ventriculomegaly

ABSTRACT

Objectives Prenatal diagnosis of intracranial hemorrhage (ICH) has been widely reported. Hemorrhages may occur either within the cerebral ventricles, subdural space or infratentorial fossa. The aim of this study was to determine the sonographic criteria for the diagnosis of fetal ICH, the role of *in utero* magnetic resonance imaging (MRI) and the outcome of this condition.

Methods The archives of our ultrasound laboratory and the literature were searched for all cases of antenatally diagnosed ICH. A grading system was used to classify the intraventricular lesions as suggested in postnatal sonographic studies.

Results Adding our series of 16 fetuses to the 93 cases identified in the literature, a group of 109 fetal ICHs was obtained: 89 were intracerebral (79 intraventricular and 10 infratentorial) and 20 were subdural hemorrhages. Intraventricular lesions were mostly classified as severe (32 each for Grades III and IV). In 27 cases antenatal MRI was performed additionally to ultrasound and confirmed the sonographic findings. Of the entire group, 65 infants (59%) were reported to be alive 1 month after birth (51 intraventricular hemorrhages, three infratentorial hemorrhages, 11 subdural hematomas). At 12 months, of the 48 infants whose follow-up was available, 25 or 52% were judged neurologically normal (17/36 or 47% among the intraventricular hemorrhages, 6/9 or 66% among the hematomas, and 2/3 or 66% among the infratentorial hemorrhages).

Conclusions Fetal ICH may be accurately identified and categorized by antenatal sonography. The outcome is usually poor, especially for those fetuses affected by

higher-grade intraventricular hemorrhages. Copyright © 2003 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

Intracranial hemorrhage (ICH) is a common event in premature infants^{1,2}. It may occur *in utero* also, and prenatal diagnosis by either sonography or magnetic resonance imaging (MRI) has been reported^{3–64}. Factors predisposing to *in utero* ICH include a variety of conditions, mostly maternal trauma and fetal coagulation disorders⁵⁵. In many cases, however, the cause is not identified. The incidence is unclear, although an estimate of 1 in 10 000 pregnancies has been suggested⁶³.

Sonographic findings of fetal ICH are variable and at times subtle. In general, this condition is considered difficult both to identify and to differentiate from other intracranial lesions. However, with continuous improvement of ultrasound equipment, the number of fetal diagnoses is likely to increase.

The aim of our study was to determine from our own series of 16 fetuses and from a review of the available literature the sonographic criteria for the diagnosis of fetal ICH, the role of MRI, the clinical implications and outcome of this condition.

METHODS

The archives of our ultrasound laboratory were searched retrospectively from 1981 for all cases of antenatally diagnosed ICH. No attempt was made to look for false negatives.

Ultrasound examinations were always performed transabdominally using a multiplanar approach as

Correspondence to: Dr T. Ghi, Medicina Età Prenatale, Clinica Ostetrica e Ginecologica dell'Università di Bologna, Policlinico S. Orsola-Malpighi, Via Massarenti 13, 40100 Bologna, Italy (e-mail: tullighi@yahoo.com)

Accepted: 19 May 2003

previously described⁶⁵, with 3.5–7.5-MHz probes. Since 1987, when permitted by a low position of the fetal head, neurosonography was performed transvaginally using 5–10-MHz probes. From 1999, all cases with suspected fetal ICH were offered MRI. ICHs were subdivided into intracerebral and extracerebral (subdural hematomas). Intracerebral hemorrhages were further subdivided into intraventricular and infratentorial (occurring within the posterior fossa).

Intraventricular hemorrhages were categorized following the classification commonly used in neonates¹ as follows:

- Grade I: limited to subependymal matrix;
- Grade II: clear spill-over to ventricles, but filling less than 50% of the lateral ventricle and without ventriculomegaly;
- Grade III: spill-over to the ventricle, with flooding of 50% or more of one or both lateral ventricles and ventriculomegaly; and
- Grade IV: Grades I, II or III with hemorrhage in a large part of the periventricular parenchyma.

In our own series we decided to classify intraventricular hemorrhages associated with a transverse diameter of the lateral ventricular atrium of < 15 mm as Grade II, and those with a diameter > 15 mm as Grade III.

The clinical data of the pregnancies, in addition to a detailed follow-up of all cases, were obtained in all instances through medical records and/or telephonic

interviews with the physicians and/or parents of the affected infants.

A literature search was performed through MEDLINE using the following keywords: intracranial hemorrhage; intracerebral hemorrhage, subdural hematoma, infratentorial or cerebellar hemorrhage and fetus; prenatal diagnosis. Additional sources were identified through cross-referencing.

Only reports where the diagnosis of ICH had been achieved antenatally and confirmed at follow-up were considered. When available, pregnancy outcome and neurological follow-up of the reported cases were derived. When indicated by the authors, maternal or fetal predisposing conditions were considered.

RESULTS

In our center, 16 cases of fetal ICHs including 14 intracerebral hemorrhages and two subdural hematomas were detected antenatally from 1981 to 2001 (Table 1). Two of these cases had been previously reported⁶⁶.

Intracerebral hemorrhages included 12 intraventricular and two infratentorial hemorrhages. Intraventricular hemorrhages included four cases each of Grade II, Grade III and Grade IV.

Intraventricular hemorrhages were diagnosed by the demonstration of findings suggestive of blood clots within the ventricles (Figure 1). Similarly to neonatal sonographic studies, fresh blood clots appeared as homogeneously echogenic areas, separate from the choroid plexus.

Table 1 Details of cases comprising present series

Case	Weeks	Type of hemorrhage	Possible etiology	Outcome
1	32	IVH Grade II	None	Mild ventriculomegaly, normal at birth, lost at follow-up
2	22	IVH Grade II	None	Normal neonatal neurosonogram
3	21	IVH Grade II	None	Normal neonatal neurosonogram
4	24	IVH Grade II	Hydrops	Overt ventriculomegaly at birth, ventriculoperitoneal shunting
5	29	IVH Grade III	None	Pregnancy termination, pathology confirmation
6	28	IVH Grade III	None	Intrauterine death, pathology not available
7	29	IVH Grade III	Car accident at 25 weeks	Live birth, porencephalic cyst, ventriculoperitoneal shunting, DQ < 50 at 4 years
8	33	IVH Grade III	None	Live birth, ventriculoperitoneal shunting, neurologically normal at 2 months
9	24	IVH Grade IV	<i>In utero</i> death of the co-twin in a twin-to-twin transfusion	Live birth, ventriculomegaly, neurologically normal at 2 months
10	32	IVH Grade IV	Alloimmune thrombocytopenia	Live birth, porencephalic cyst, ventriculoperitoneal shunting, DQ < 50 at 4 years*
11	29	IVH Grade IV	None	Live birth, porencephalic cyst, ventriculoperitoneal shunting, DQ < 50 at 2 years*
12	22	IVH Grade IV	None	Pregnancy termination, pathology confirmation
13	22	Infratentorial	Hydrops, anemia, Rh alloimmunization	Pregnancy termination, pathology confirmation
14	22	Infratentorial	Hydrops, anemia, Rh alloimmunization	Live birth, cerebellar hypoplasia, neurologically normal at 12 months
15	23	Subdural hematoma	Maternal trauma	Live birth, surgical drainage, neurologically normal at 10 months
16	24	Subdural hematoma	<i>In utero</i> death of the co-twin, possible twin-to-twin transfusion	Pregnancy termination, pathology confirmation

*Previously reported case⁶⁶. DQ, developmental quotient; IVH, intraventricular hemorrhage; Rh, rhesus.

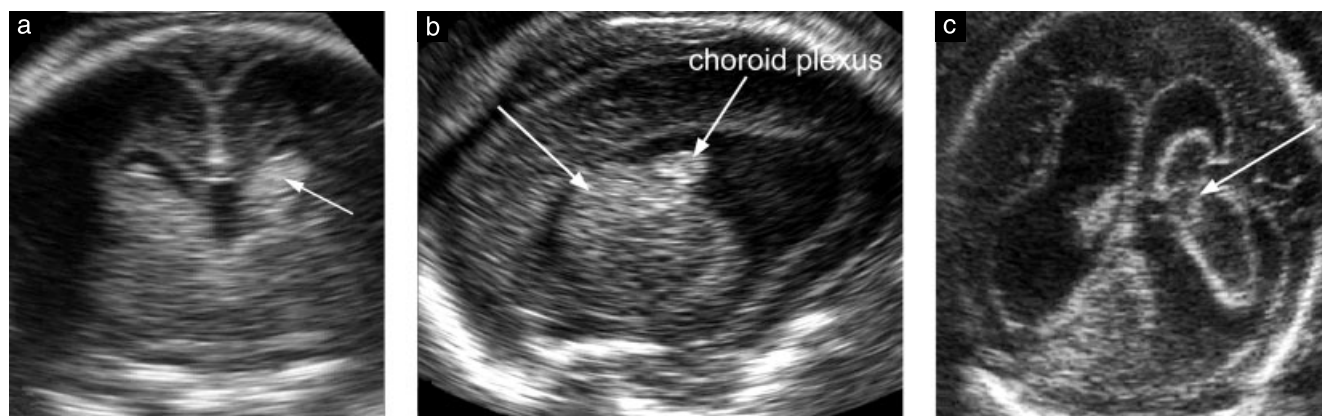


Figure 1 Sonographic demonstration of intraventricular hemorrhage. (a) Coronal and (b) sagittal views in a mid-trimester fetus (21 weeks) with a recent Grade II hemorrhage; the blood clot (arrows) appears as a uniformly echogenic collection close to the choroid plexus; the lateral ventricle is mildly enlarged. (c) Coronal scan in a third-trimester fetus (33 weeks) with an old Grade III intraventricular hemorrhage; the blood clot has developed an anechoic core.

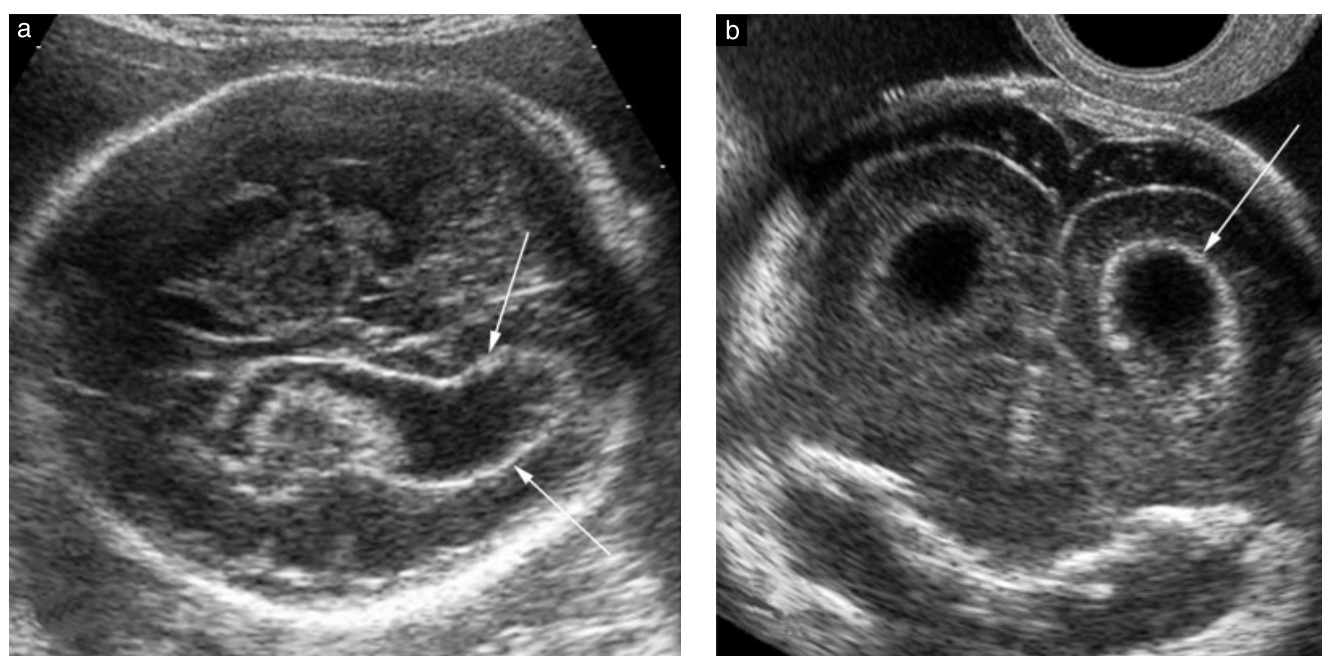


Figure 2 Grade III intraventricular hemorrhage in a 34-week fetus in an axial view (a) and a posterior coronal view (b). The lateral ventricle containing the blood clot has a bright echogenic lining (arrows) presumably representing ventriculitis.

In the following weeks blood clots developed a complex appearance, with an external echogenic lining and an internal sonolucent core (Figure 1). Of four fetuses with a Grade II intraventricular hemorrhage, three had borderline enlargement of the ventricles. In two of these cases the images interpreted as clots disappeared and ventriculomegaly resolved throughout gestation. The infants had negative neurosonograms at birth and appeared clinically normal at a short-term follow-up. In one case, associated with non-immune hydrops, the ventricles were normal at the first scan but progression of ventriculomegaly was noted and after birth the infant underwent a ventriculo-peritoneal shunt.

In four cases a Grade III hemorrhage was diagnosed following the demonstration of images suggestive of blood clots within very enlarged lateral ventricles, with

seemingly normal cerebral parenchyma. In two of these fetuses, at the first observation the dilated lateral ventricle had an echogenic lining, and the contralateral ventricle was either normal in size or mildly enlarged (Figure 2). In the former case, serial examinations were performed demonstrating a progressive decrease in size of the clot, disappearance of the echogenic lining of the ventricle and progressive dilatation of the contralateral ventricle. In the latter case, severe hydrocephalus due to aqueductal obstruction was demonstrated after birth and the infant underwent shunting. Intrauterine MRI was performed in two cases within 7 days of sonographic diagnosis and this confirmed the ultrasound findings (Figure 3).

In four cases a Grade IV hemorrhage was suspected following the demonstration of diffuse intracerebral echogenicity obscuring one or both lateral ventricles and



Figure 3 Grade III intraventricular hemorrhage. (a,b) Intrauterine T2-weighted magnetic resonance images (MRI) demonstrating ventriculomegaly and a blood clot (arrows) within one of the lateral ventricles in a 34-week fetus. (c) Postnatal MRI in the same case demonstrating considerable regression of the blood clot (arrow) and worsening of the ventriculomegaly; aqueductal stenosis was present and the infant underwent ventriculoperitoneal shunting soon after birth.

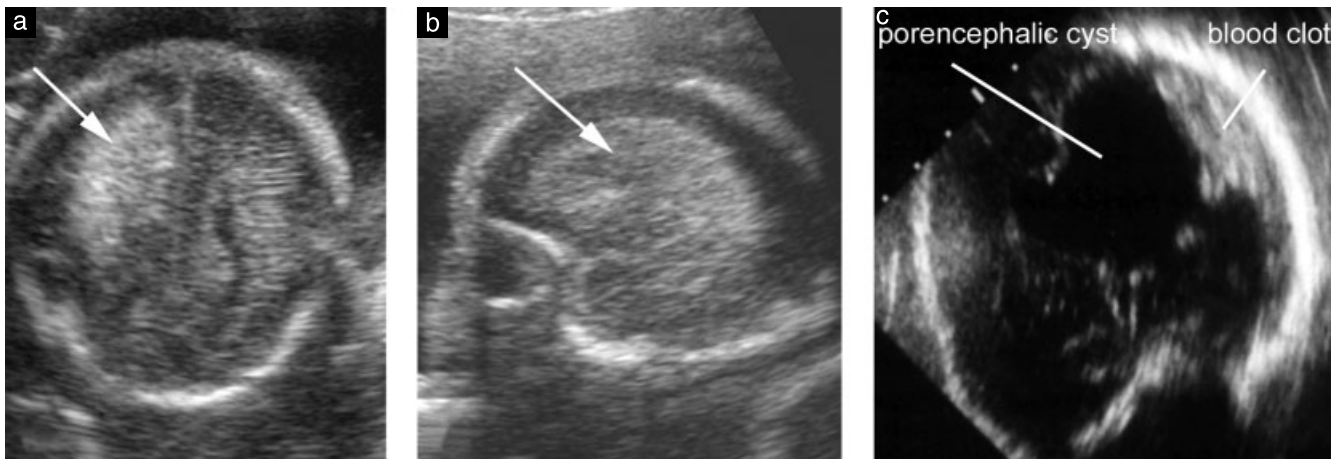


Figure 4 Grade IV intraventricular hemorrhages. (a) Coronal and (b) sagittal views in a mid-trimester fetus (24 weeks) the day after the death of a monochorionic co-twin in the context of twin transfusion. There is a large echogenic collection involving one entire lateral ventricle and extending to the surrounding parenchyma. A porencephalic cyst and hypertensive hydrocephalus developed subsequently. (c) A large fetal porencephalic cyst in a 30-week pregnancy that was later found to be complicated by alloimmune thrombocytopenia. A blood clot is visible within the cyst.

projecting into the surrounding cerebral parenchyma. In one case, serial examinations were performed. Ten days after the first examination, severe ventriculomegaly, intraventricular images suggestive of blood clots and irregular cerebral parenchyma surrounding the ventricles were seen. The diagnosis was confirmed by *in utero* MRI and by pathology after termination of pregnancy. In the remaining three cases a Grade IV hemorrhage was diagnosed because of the demonstration of a porencephalic cyst containing an image suggestive of a blood clot (Figure 4).

Finally, infratentorial lesions were demonstrated in two mid-trimester fetuses. One pregnancy was electively terminated and pathology confirmed the presence of a hemorrhage within the cisterna magna and involving the cerebellum (Figure 5). In the latter case the couple opted

to continue the pregnancy: progressive hypoplasia of the cerebellar hemisphere affected by the hemorrhage was demonstrated either by subsequent ultrasound scans that were serially performed throughout the pregnancy or by *in utero* MRI at 32 weeks of gestation (Figure 6). At birth, neuroimaging showed a hemispheric hypotrophy with no apparent clinical or neurological compromise of the infant who is now 1 year old.

In two fetuses a subdural hematoma was diagnosed. In both cases ventriculomegaly of variable degree was associated with distension of the subarachnoid space that appeared densely corpusculated (Figure 7).

A plausible cause for the fetal ICH could be clearly identified in 7/16 cases (43%). One fetus with Grade IV hemorrhage was found after birth to have severe alloimmune thrombocytopenia. A Grade III hemorrhage

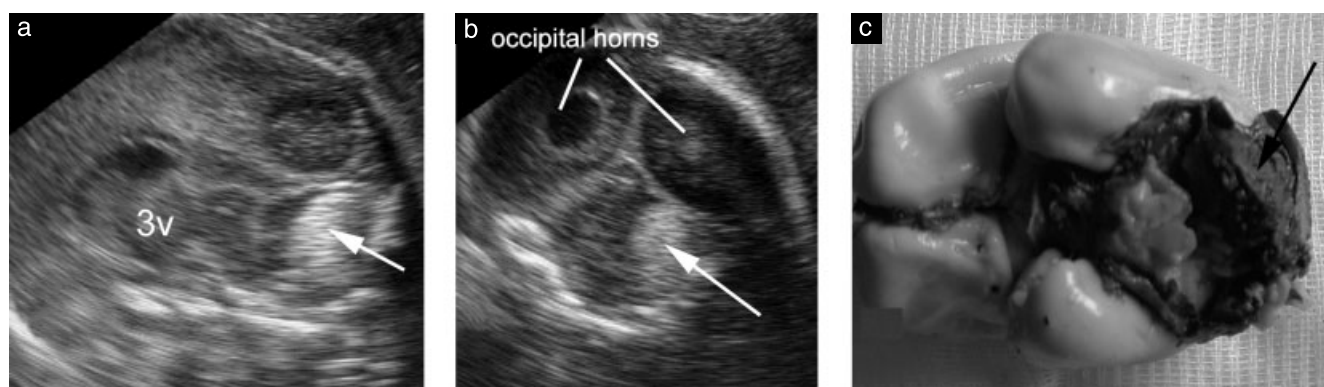


Figure 5 This mid-trimester fetus (22 weeks) was referred with hydrops and severe anemia (hemoglobin concentration 1.5 g/dL) due to severe Rh alloimmunization. The first intrauterine transfusion was successful. However, a few days later, ultrasound demonstrated the presence of an echogenic collection in the posterior fossa involving part of the cerebellum and the cisterna magna (arrows in a and b). The couple opted for pregnancy termination and pathology confirmed the presence of an infratentorial hemorrhage (arrow in c). 3v, third ventricle.

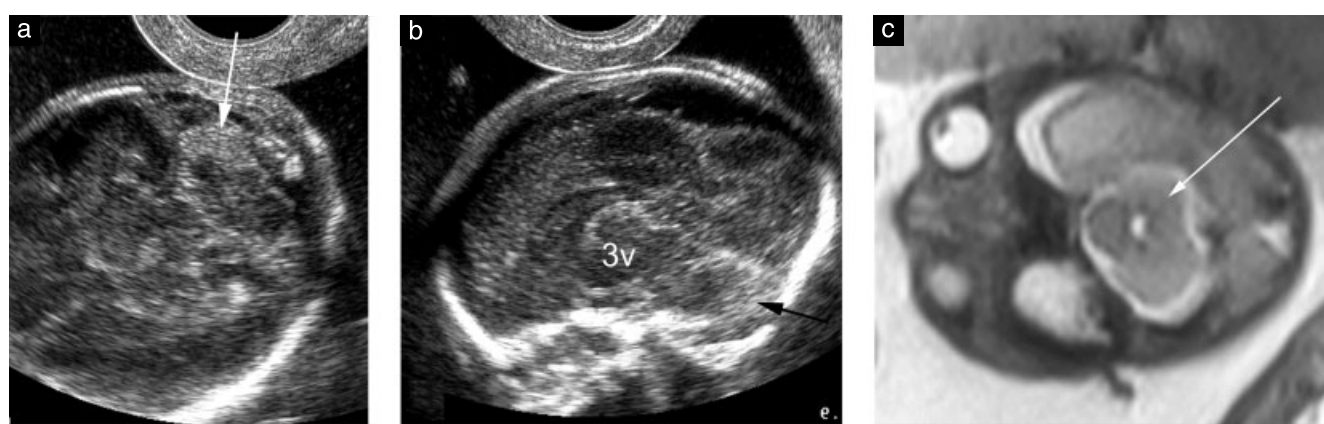


Figure 6 Similarly to the case illustrated in Figure 5, this 22-week fetus was referred because of hydrops and severe anemia (hemoglobin concentration 1.8 g/dL) due to severe Rh alloimmunization. After the first successful intrauterine transfusion, an echogenic area was noted in one of the cerebellar hemispheres (arrows in a and b). The couple opted to continue the pregnancy. At 32 weeks *in utero* magnetic resonance imaging demonstrated progressive hypoplasia of the affected cerebellar hemisphere (arrow in c). This was confirmed after birth. 3v, third ventricle.

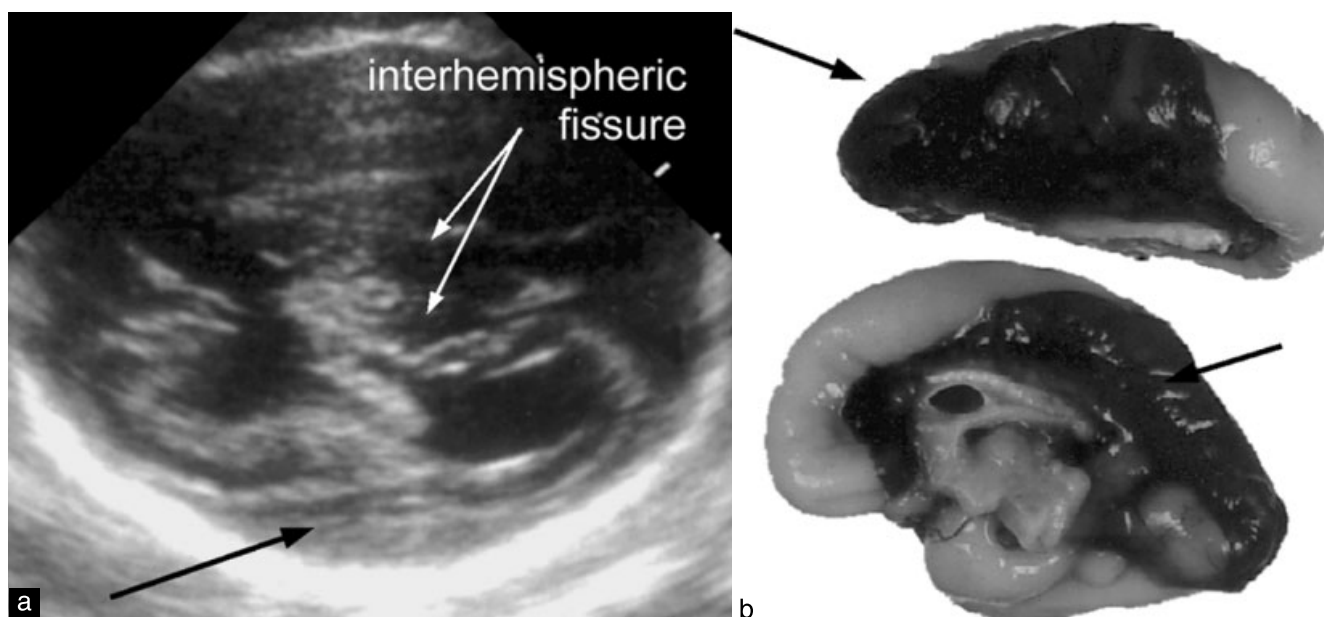


Figure 7 This 24-week fetus was referred after the death of a monochorionic co-twin presumably affected by twin–twin transfusion syndrome. (a) Sonography revealed mild ventriculomegaly and distension of the subarachnoid space both at the level of the Sylvian fossa and interhemispheric fissure (arrows). The subarachnoid space also had a densely corpusculated appearance. (b) After termination of pregnancy, subdural hemorrhage was confirmed (arrows).

was identified following a car accident involving the mother, and a subdural hematoma after a maternal trauma due to a domestic accident. A subdural hematoma as a Grade IV intraventricular hemorrhage occurred after the death of a co-twin with a monochorionic placentation. Both cases of intratentorial hemorrhage occurred in mid-trimester fetuses with severe anemia (1.5 and 1.8 g/dL) and hydrops as a consequence of severe rhesus (Rh) alloimmunization. Images suggestive of hemorrhage were documented a few days after the first successful intrauterine transfusion.

Reviewing the literature, 93 cases with antenatal ultrasonographic diagnosis of ICH were found, including 75 cases of intracerebral hemorrhage, 17 cases of subdural hematoma and one case of both³⁻⁶⁴. Of the 75 cases of intracerebral hemorrhage the vast majority were classified as being of intraventricular origin ($n = 67$), the remaining cases having a pericerebellar or intratentorial location ($n = 8$).

By adding our own series, the total number of cases was 109. The mean gestational age at diagnosis was 30 (range, 20–37) weeks. In 27 fetuses MRI was performed in addition to ultrasound and confirmed the cranial findings. A maternal or fetal predisposing condition was identified in 48/109 cases (44%), and more precisely in 36 intracerebral and 12 subdural hematomas. A history of maternal trauma was present in 10 cases while a hemorrhagic diathesis was present in 19 fetuses (including nine with alloimmune thrombocytopenia). Only in two fetuses with antenatal diagnosis of subdural hematoma was an antecedent maternal trauma reported. The majority of ICHs were classified prenatally as intraventricular hemorrhages of either Grade III or IV (32 cases in each group).

Prenatal data and pregnancy outcome of the whole series are presented in Table 2. Intrauterine death occurred in 17 cases (15 intraventricular hemorrhages, of which 14 were classified as Grade III or greater, one combined intracerebral and subdural hemorrhage and one subdural hemorrhage).

Table 2 Prenatal data and pregnancy outcome (total)

	Total	Pregnancy outcome		
		TOP	IUD*	LB
Cases	109	11	17	81
Intracerebral	89	9	15	65
IVH I	6	0	1	5
IVH II*	9	1	0	8
IVH III	32	0	2	30
IVH IV	32	3	12*	17
Intratentorial	10	5	0	5
Subdural hematoma	19	2	1	16
Both	1	0	1	0

*Including one case of death in partum. IVH, intraventricular hemorrhage; IUD, intrauterine death; LB, live birth; TOP, termination of pregnancy.

Table 3 Follow-up at 11.6 (range, 1–48) months of the available cases

	Total	Normal	Mild handicap	Severe handicap	Dead
Cases	48	25	6	13	4
Intracerebral	39	19	5	12	3
IVH I	4	4	0	0	0
IVH II	7	4	0	3	0
IVH III	18	8	5	5	0
IVH IV	7	1	0	3	3
Intratentorial	3	2	0	1	0
Subdural hematoma	9	6	1	1	1
Both	0	0	0	0	0

IVH, intraventricular hemorrhage.

Of the 81 fetuses (65 with intracerebral and 16 with extracerebral hemorrhage) that were liveborn, 16 died in the neonatal period. No losses were reported in fetuses with intracerebral hemorrhages of low grade (Grades I and II) whereas two deaths were registered in the subgroup with an intratentorial lesion.

Postnatal and neurological follow-up data were available for only 48/65 infants who survived the neonatal period (Table 3). At a mean age of 11.6 (range, 1–48 months) 25 infants were reported to be neurologically normal, while in 19 infants there was evidence of neurodevelopmental delay, either severe ($n = 13$) or mild ($n = 6$). Infantile death was described in four cases.

Two-thirds of the neonates (6/9) who had had an antenatal diagnosis of subdural hematomas were judged neurologically normal. In the 36 cases of intraventricular hemorrhage, outcome and neurological development at 13.3 months was found to depend upon the grade of the hemorrhagic lesion. All eleven infants whose intracranial hemorrhage had been prenatally staged as Grade I or II were alive, eight of them being neurologically normal (72%). Conversely, of the infants with Grade III and IV hemorrhage, 22/25 survived. Of these, 13 were handicapped and only nine (41%) were considered neurodevelopmentally normal. Finally, two of the three infants with a prenatal diagnosis of cerebellar hemorrhage were apparently normal, although their follow-up was short.

DISCUSSION

Our results suggest that antenatal ultrasound allows an accurate diagnosis of fetal ICH. The findings are variable and change with time. A new hemorrhage appears as a brightly echogenic collection without posterior shadowing. Over the following days blood clots develop a complex echogenic texture with an external echogenic lining and an internal sonolucent core. Intraventricular blood clots are usually associated with distension of the ventricles, which initially demonstrate a typical echogenic lining. Intraventricular hemorrhages may undergo spontaneous resolution or may obstruct the cerebrospinal fluid

circulation, usually at the level of the aqueduct of Sylvius, resulting in ventriculomegaly. Involvement of the cortex can be predicted by demonstration of extension of the echogenic collection to the periventricular parenchyma in the early stages and formation of a porencephalic cyst usually about 2 weeks after the hemorrhagic event. A bright area around the cerebellum may prompt the diagnosis of an infratentorial hemorrhage.

In our hands ultrasound correlated well with the postnatal diagnosis, with the exception of only two cases in which resolution occurred *in utero*. Such evolution is, however, compatible with the natural history of these lesions and has been reported previously⁴⁹.

The role of MRI in the evaluation of fetal cerebral anomalies is controversial⁶⁷. Most of the cases from both review of the literature and our own experience were examined antenatally only with ultrasound. Our study therefore does not allow us to draw definitive conclusions on the relative role of ultrasound versus MRI. In our own experience the sonograms were always diagnostic, and MRI, when performed, did not add further information. Conversely, MRI always proved accurate. It also has the additional advantage that in T1-weighted sequences blood collections appear as areas of typically increased intensity⁶⁸. It is clear that there is certainly a role for this technology, at least in those cases where antenatal sonography is inconclusive.

Our results and the review of the literature suggest that prenatally diagnosed ICHs have a poor outcome. About 40% of fetuses die either *in utero* or within the first month after birth. Among the survivors, less than half appear neurodevelopmentally normal at short-term follow up.

The survival rate is similar for subdural hematomas and intracerebral hemorrhage. At a follow-up of 1 year a slightly better outcome was observed with subdural hematomas than with intracerebral hemorrhage (normal development in 67% vs. 48% cases). Similarly to postnatal studies, the outcome of fetal intraventricular hemorrhage was strongly related to the grade of the lesion. Perinatal mortality with Grades I–II was 1/14 (7.1%) vs. 27/61 (44%) with Grades III–IV.

However, experience with Grade I and II hemorrhages was limited to a small number of cases, and was probably inadequate to provide firm prognostic figures. Indeed, complete regression of this lesion is possible. In two fetuses in our series and in a further case previously reported⁴⁹ progressive disappearance of abnormal sonographic findings was observed, always in association with a normal postnatal outcome. Conversely, intrauterine progression of hemorrhage from a low to high grade is also possible as observed in our series and in previously reported cases¹¹.

It is noteworthy that in three of our cases, unilateral borderline ventricles were identified in association with sonographic findings suggestive of an intraventricular hemorrhage. In two of these fetuses the signs of intraventricular hemorrhage disappeared during the course of the pregnancy, followed later on by restoration of

normal ventricular size. We postulate that an intraventricular hemorrhage of low grade may be responsible for at least some cases of borderline ventriculomegaly, particularly the unilateral ones. The pathophysiological mechanism underlying transient ventricular dilatation is unclear. We speculate that this may be the consequence of obstruction to cerebrospinal fluid at the level of the foramina of Monro (in both of our cases blood clots were seen at the level of the bodies of the lateral ventricles). This may provide an explanation for the puzzling cases in which a transient fetal cerebral ventriculomegaly was identified⁶⁹.

A predisposing condition to the *in utero* occurrence of ICH was identified or suspected in 47% of the cases, most frequently hematological disorder of the fetus and maternal trauma. An association with these risk factors has been noted either for intracerebral hemorrhage (12 coagulation disorders and eight trauma) or extracerebral hemorrhage (six coagulation disorders and two trauma). On the basis of these results, prenatally diagnosed subdural hematomas do not seem to be strictly related to a traumatic cause, as reported for those with perinatal onset⁴⁸. Intrauterine hypoxia is commonly recognized as another possible cause of antenatal hemorrhage^{3,63}.

In four of the cases herein reported, the development of the hemorrhage was related to the presence of fetal anemia (two immune hydrops, two deaths of the co-twin with monochorionic placentation) as previously described^{22,38,54}. The pathophysiology is unclear. We speculate that the hyperdynamic circulation that is well documented in severely anemic fetuses may have been the cause of the disruption of intracranial vessels. The documentation of a cerebral (in both cases infratentorial) hemorrhage in two severely anemic fetuses because of Rh alloimmunization is noteworthy. The occurrence of abnormal neurodevelopment in survivors after intrauterine transfusion has been previously documented⁷⁰. The pathophysiology of brain damage in such cases is debated. We provide evidence that in some cases at least brain injury may occur prenatally. We believe that our observation suggests a role for fetal neurosonography in pregnancies with severe Rh alloimmunization undergoing intrauterine transfusion.

In some cases with Grade III hemorrhages, intraventricular clots disappeared during intrauterine life and only obstructive hydrocephalus was documented after birth. This observation may help to explain at least some cases in which severe hydrocephalus only appears in late gestation.

To the best of our knowledge this is the largest review on antenatally diagnosed ICHs. Most lesions occur sporadically and, apart from the cases in which a specific fetomaternal condition may be identified, the risk of recurrence is very low. According to the available data, the parents of affected fetuses must be counseled about a poor outcome following the diagnosis of either a Grade III or IV intraventricular hemorrhage or a subdural hemorrhage. Whether the unfavorable prognosis is entirely the consequence of the cerebral lesion or is

influenced by the underlying disease causing the hemorrhage remains unclear. However, half of the fetuses will die within the first month of postnatal life and only half of these will be neurologically normal at short-term follow-up.

The outcome of fetuses with Grade I–II intraventricular hemorrhages or infratentorial hemorrhages is less clear given the limited number of cases reported thus far. As the sonographic findings in these cases are very subtle we also expect that many cases will escape antenatal detection. A correlation may exist between borderline ventriculomegaly, particularly when unilateral, and low-grade intraventricular hemorrhages.

The diagnostic work-up of a pregnancy complicated by sonographic evidence of an intracranial hemorrhage should include an interview focusing on drug use or recent trauma (motor vehicle accident, fall onto the abdomen, others) and laboratory tests for the possible presence of a fetal platelet disorder. This should include maternal platelet count and testing for both maternal alloimmunity and isoimmunity. Antenatal hemorrhage is possible with isoimmune thrombocytopenia but is exceedingly rare⁷¹. Conversely, it is frequently associated with the alloimmune type⁷². Treatment of alloimmune thrombocytopenia is still a matter of debate and the interested reader is referred to specific publications on this topic^{73–75}. Whether treatment would be indicated in the presence of an established fetal intracranial lesion is uncertain. The optimal mode of delivery of an infant with sonographic evidence of an ICH is equally uncertain. Severe lesions usually have a poor prognosis and conservative management may be offered to the couples. There are no data to indicate that a Cesarean delivery may ameliorate the outcome of those infants with less severe lesions⁷¹.

REFERENCES

- Burstein J, Papile LA, Burstein R. Intraventricular hemorrhage and hydrocephalus in the preterm newborn: a prospective study with CT. *AJR Am J Roentgenol* 1978; **132**: 631–635.
- Papile LA, Burstein J, Burstein R, Koffler H. Incidence and evolution of subependymal and intraventricular hemorrhage: a study of infants with birth weights less than 1,500 gm. *J Pediatr* 1978; **92**: 529–534.
- Achiron R, Pinchas OH, Reichman B, Heyman Z, Schimmel M, Eidelman A, Mashiach S. Fetal intracranial haemorrhage: clinical significance of *in utero* ultrasonographic diagnosis. *Br J Obstet Gynaecol* 1993; **100**: 995–999.
- Anderson MW, McGahan JP. Sonographic detection of an *in utero* intracranial hemorrhage in the second trimester. *J Ultrasound Med* 1994; **13**: 315–318.
- Barozzino T, Sgro M, Toi A, Akouri H, Wilson S, Yeo E, Blaser S, Chitayat D. Fetal bilateral subdural haemorrhages. Prenatal diagnosis and spontaneous resolution by time of delivery. *Prenat Diagn* 1998; **18**: 496–503.
- Batukan C, Holzgreve W, Bubl R, Visca E, Radu EW, Tercanli S. Prenatal diagnosis of an infratentorial subdural hemorrhage: case report. *Ultrasound Obstet Gynecol* 2002; **19**: 407–409.
- Becroft DM, Gunn TR. Prenatal cranial haemorrhages in 47 Pacific Islander infants: is traditional massage the cause? *N Z Med J* 1989; **102**(867): 207–210.
- Ben-Chetrit A, Anteby E, Lavy Y, Zucut D, Yagel S. Increased middle cerebral artery blood flow impedance in fetal subdural hematoma. *Ultrasound Obstet Gynecol* 1991; **1**: 357–358.
- Bondurant S, Boehm FH, Fleischer AC, Machin JE. Antepartum diagnosis of fetal intracranial hemorrhage by ultrasound. *Obstet Gynecol* 1984; **63**(Suppl.): 25S–27S.
- Catanzarite VA, Schrimmer DB, Maida C, Mendoza A. Prenatal sonographic diagnosis of intracranial haemorrhage: report of a case with a sinusoidal fetal heart rate tracing, and review of the literature. *Prenat Diagn* 1995; **15**: 229–235.
- Chambers SE, Johnstone FD, Laing LA. Ultrasound *in-utero* diagnosis of choroid plexus haemorrhage. *Br J Obstet Gynaecol* 1988; **95**: 1317–1320.
- De Sousa C, Clark T, Bradshaw A. Antenatally diagnosed subdural haemorrhage in congenital factor X deficiency. *Arch Dis Child* 1988; **63**(10 Spec. No.): 1168–1170.
- De Vries LS, Connell J, Bydder GM, Dubowitz LM, Rodeck CH, Mibashan RS, Waters AH. Recurrent intracranial haemorrhages *in utero* in an infant with alloimmune thrombocytopenia. Case report. *Br J Obstet Gynaecol* 1988; **95**: 299–302.
- Dean LM, McLeary M, Taylor GA. Cerebral hemorrhage in alloimmune thrombocytopenia. *Pediatr Radiol* 1995; **25**: 444–445.
- DeVore G. *In-utero* cerebral vascular accident prior to external cephalic version. *J Clin Ultrasound* 1991; **19**: 227–229.
- Donn SM, Barr M Jr, McLeary RD. Massive intracerebral hemorrhage *in utero*: sonographic appearance and pathologic correlation. *Obstet Gynecol* 1984; **63**(Suppl.): 28S–30S.
- Edmondson SR, Hallak M, Carpenter RJ Jr, Cotton DB. Evolution of hydranencephaly following intracerebral hemorrhage. *Obstet Gynecol* 1992; **79**(5 Pt 2): 870–871.
- Fogarty K, Cohen HL, Haller JO. Sonography of fetal intracranial hemorrhage: unusual causes and a review of the literature. *J Clin Ultrasound* 1989; **17**: 366–370.
- Folkerth RD, McLaughlin ME, Levine D. Organizing posterior fossa hematomas simulating developmental cysts on prenatal imaging: report of 3 cases. *J Ultrasound Med* 2001; **20**: 1233–1240.
- Fusch C, Ozdoba C, Kuhn P, Durig P, Remonda L, Muller C, Kaiser G, Schroth G, Moessinger AC. Perinatal ultrasonography and magnetic resonance imaging findings in congenital hydrocephalus associated with fetal intraventricular hemorrhage. *Am J Obstet Gynecol* 1997; **177**: 512–518.
- Giovangrandi Y, Daffos F, Kaplan C, Forestier F, Mac Aleese J, Moirrot M. Very early intracranial haemorrhage in alloimmune fetal thrombocytopenia. *Lancet* 1990; **336**(8710): 310.
- Green PM, Wilson H, Romaniuk C, May P, Welch CR. Idiopathic intracranial haemorrhage in the fetus. *Fetal Diagn Ther* 1999; **14**: 275–278.
- Guerriero S, Ajossa S, Mais V, Risalvato A, Angiolucci M, Labate F, Lai MP, Melis GB. Color Doppler energy imaging in the diagnosis of fetal intracranial hemorrhage in the second trimester. *Ultrasound Obstet Gynecol* 1997; **10**: 205–208.
- Gunn TR, Mok PM, Becroft DM. Subdural hemorrhage *in utero*. *Pediatrics* 1985; **76**: 605–610.
- Gunn TR, Mora JD, Becroft DM. Congenital hydrocephalus secondary to prenatal intracranial haemorrhage. *Aust N Z J Obstet Gynaecol* 1988; **28**: 197–200.
- Hadi HA, Finley J, Mallette JQ, Strickland D. Prenatal diagnosis of cerebellar hemorrhage: medicolegal implications. *Am J Obstet Gynecol* 1994; **170**(5 Pt 1): 1392–1395.
- Hanigan WC, Ali MB, Cusack TJ, Miller TC, Shah JJ. Diagnosis of subdural hemorrhage *in utero*. Case report. *J Neurosurg* 1985; **63**: 977–979.
- Hashimoto I, Tada K, Nakatsuka M, Nakata T, Inoue N, Takata M, Kudo T, Joja I. Fetal hydrocephalus secondary to intraventricular haemorrhage diagnosed by ultrasonography

- and *in utero* fast magnetic resonance imaging. A case report. *Fetal Diagn Ther* 1999; 14: 248–253.
29. Huang CC, Shen EY. Tentorial subdural hemorrhage in term newborns: ultrasonographic diagnosis and clinical correlates. *Pediatr Neurol* 1991; 7: 171–177.
 30. Hurst RW, Abbitt PL. Fetal intracranial hemorrhage and periventricular leukomalacia: complications of twin–twin transfusion. *AJNR Am J Neuroradiol* 1989; 10(5 Suppl.): S62–S63.
 31. Jennett RJ, Daily WJ, Tarby TJ, Manwaring KH. Prenatal diagnosis of intracerebellar hemorrhage: case report. *Am J Obstet Gynecol* 1990; 162: 1472–1474; discussion 4–5.
 32. Kawabata I, Imai A, Tamaya T. Antenatal subdural hemorrhage causing fetal death before labor. *Int J Gynaecol Obstet* 1993; 43: 57–60.
 33. Kim MS, Elyaderani MK. Sonographic diagnosis of cerebroventricular hemorrhage *in utero*. *Radiology* 1982; 142: 479–480.
 34. Kirkinen P, Partanen K, Ryyanen M, Orden MR. Fetal intracranial hemorrhage. Imaging by ultrasound and magnetic resonance imaging. *J Reprod Med* 1997; 42: 467–472.
 35. Kirkinen P, Orden MR, Partanen K. Cerebral blood flow changes associated with fetal intracranial hemorrhages. *Acta Obstet Gynecol Scand* 1997; 76: 308–312.
 36. Kuhn MJ, Couch SM, Binstadt DH, Rightmire DA, Morales A, Khanna NN, Long SD. Prenatal recognition of central nervous system complications of alloimmune thrombocytopenia. *Comput Med Imaging Graph* 1992; 16: 137–142.
 37. Lebbi I, de Rochambeau B, Claris O, Mellier G. Cerebral hemorrhage *in utero*. Diagnosis and management. A case report [in French]. *J Gynecol Obstet Biol Reprod* 1992; 21: 671–675.
 38. Leidig E, Dannecker G, Pfeiffer KH, Salinas R, Peiffer J. Intrauterine development of posthaemorrhagic hydrocephalus. *Eur J Pediatr* 1988; 147: 26–29.
 39. Lionnet C, Body G, Gold F, Paillet C, Vaillant MC, Alle C, Berger C. Fetal cerebral accident due to massive fetomaternal hemorrhage. A case report [in French]. *J Gynecol Obstet Biol Reprod* 1995; 24: 553–556.
 40. Lustig-Gillman I, Young BK, Silverman F, Raghavendra BN, Wan L, Reitz ME, Aleksic S, Greco A, Snyder JR. Fetal intraventricular hemorrhage: sonographic diagnosis and clinical implications. *J Clin Ultrasound* 1983; 11: 277–280.
 41. Malinger G, Katz R, Amsel S, Gewurtz G, Zakut H. Brain, hemorrhage, germinal matrix. *The fetus* 1992; 2: 1–4.
 42. Malinger G, Lerman-Sagie T, Watemberg N, Rotmensh S, Lev D, Glezerman M. A normal second-trimester ultrasound does not exclude intracranial structural pathology. *Ultrasound Obstet Gynecol* 2002; 20: 51–56.
 43. Mateos F, Estaban J, Ramos JT, Martin-Puerto M, Miralles M, Ozaita G, Martinez-Portillo J. Fetal subdural hematoma: diagnosis *in utero*. *Pediatr Neurol* 1987; 13: 125–128.
 44. McGahan JP, Haesslein HC, Meyers M, Ford KB. Sonographic recognition of *in utero* intraventricular hemorrhage. *AJR Am J Roentgenol* 1984; 142: 171–173.
 45. Minkoff H, Schaffer RM, Delke I, Grunebaum AN. Diagnosis of intracranial hemorrhage *in utero* after a maternal seizure. *Obstet Gynecol* 1985; 65(3 Suppl.): 22S–24S.
 46. Mintz MC, Arger PH, Coleman BG. *In utero* sonographic diagnosis of intracerebral hemorrhage. *J Ultrasound Med* 1985; 4: 375–376.
 47. Mullaart RA, Van Dongen P, Gabreels FJ, van Oostrom C. Fetal periventricular hemorrhage in von Willebrand's disease: short review and first case presentation. *Am J Perinatol* 1991; 8: 190–192.
 48. Pierre-Kahn A, Renier D, Sainte-Rose C, Hirsch JF. Acute intracranial hematomas in term neonates. *Childs Nerv Syst* 1986; 2: 191–194.
 49. Pretorius DH, Singh S, Manco-Johnson ML, Rumack CM. *In utero* diagnosis of intracranial hemorrhage resulting in fetal hydrocephalus. A case report. *J Reprod Med* 1986; 31: 136–138.
 50. Ranzini AC, Shen-Schwarz S, Guzman ER, Fisher AJ, White M, Vintzileos AM. Prenatal sonographic appearance of hemorrhagic cerebellar infarction. *J Ultrasound Med* 1998; 17: 725–727.
 51. Reiss I, Gortner L, Moller J, Gehl HB, Baschat AA, Gembruch U. Fetal intracerebral hemorrhage in the second trimester: diagnosis by sonography and magnetic resonance imaging. *Ultrasound Obstet Gynecol* 1996; 7: 49–51.
 52. Rotmensh S, Grannum PA, Nores JA, Hall C, Keller MS, McCarthy S, Hobbins JC. *In utero* diagnosis and management of fetal subdural hematoma. *Am J Obstet Gynecol* 1991; 164(5 Pt 1): 1246–1248.
 53. Sadler LC, Lane M, North R. Severe fetal intracranial haemorrhage during treatment with cholestyramine for intrahepatic cholestasis of pregnancy. *Br J Obstet Gynaecol* 1995; 102: 169–170.
 54. Sherer DM, Abramowicz JS, Jaffe R, Smith SA, Metlay LA, Woods JR Jr. Twin–twin transfusion with abrupt onset of microcephaly in the surviving recipient following spontaneous death of the donor twin. *Am J Obstet Gynecol* 1993; 169: 85–88.
 55. Sherer DM, Anyaegbunam A, Onyeije C. Antepartum fetal intracranial hemorrhage, predisposing factors and prenatal sonography: a review. *Am J Perinatol* 1998; 15: 431–441.
 56. Sibony O, Fondacci C, Oury JF, Benard C, Vuillard E, Blot P. *In utero* fetal cerebral intraparenchymal hemorrhage associated with an abnormal cerebral Doppler. *Fetal Diagn Ther* 1993; 8: 126–128.
 57. Sims M, Mann E. Communicating hydrocephalus secondary to fetal intracranial haemorrhage. *J Perinatol* 1988; 8: 371–373.
 58. Sohda S, Hamada H, Trakanami Y, Kubo T. Prenatal diagnosis of fetal subdural hematomas. *Br J Obstet Gynaecol* 1996; 103: 89–90.
 59. Stirling HF, Hendry M, Brown JK. Prenatal intracranial haemorrhage. *Dev Med Child Neurol* 1989; 31: 807–811.
 60. Stoddard RA, Clark SL, Minton SD. *In utero* ischemic injury: sonographic diagnosis and medicolegal implications. *Am J Obstet Gynecol* 1988; 159: 23–25.
 61. Strigini FA, Cioni G, Canapicchi R, Nardini V, Capriello P, Carmignani A. Fetal intracranial hemorrhage: is minor maternal trauma a possible pathogenetic factor? *Ultrasound Obstet Gynecol* 2001; 18: 335–342.
 62. Tampakoudis P, Bili H, Lazaridis E, Anastasiadou E, Andreou A, Mantalenakis S. Prenatal diagnosis of intracranial hemorrhage secondary to maternal idiopathic thrombocytopenic purpura: a case report. *Am J Perinatol* 1995; 12: 268–270.
 63. Vergani P, Strobelt N, Locatelli A, Paterlini G, Tagliabue P, Parravicini E, Ghidini A. Clinical significance of fetal intracranial hemorrhage. *Am J Obstet Gynecol* 1996; 175(3 Pt 1): 536–543.
 64. Ville Y, Jenkins E, Shearer MJ, Hemley H, Vasey DP, Layton M, Nicolaides KH. Fetal intraventricular haemorrhage and maternal warfarin. *Lancet* 1993; 341(8854): 1211.
 65. Timor-Tritsch IE, Monteagudo A. Transvaginal fetal neurosonography: standardization of the planes and sections by anatomic landmarks. *Ultrasound Obstet Gynecol* 1996; 8: 42–47.
 66. Pilu G, Falco P, Perolo A, Sandri F, Cocchi G, Ancora G, Bovicelli L. Differential diagnosis and outcome of fetal intracranial hypoechoic lesions: report of 21 cases. *Ultrasound Obstet Gynecol* 1997; 9: 229–236.
 67. Malinger G, Lev D, Lerman-Sagie T. Is fetal magnetic resonance imaging superior to neurosonography for detection of brain anomalies? *Ultrasound Obstet Gynecol* 2002; 20: 317–321.

68. Levine D, Barnes PD, Madsen JR, Abbott J, Mehta T, Edelman RR. Central nervous system abnormalities assessed with prenatal magnetic resonance imaging. *Obstet Gynecol* 1999; **94**: 1011–1019.
69. Goldstein RB, La Pidus AS, Filly RA, Cardoza J. Mild lateral cerebral ventricular dilatation *in utero*: clinical significance and prognosis. *Radiology* 1990; **176**: 237–242.
70. Doyle LW, Kelly EA, Rickards AL, Ford GW, Callanan C. Sensorineural outcome at 2 years for survivors of erythroblastosis treated with fetal intravascular transfusions. *Obstet Gynecol* 1993; **81**: 931–935.
71. American College of Obstetricians and Gynecologists (ACOG) practice bulletin. Thrombocytopenia in pregnancy. Number 6, September 1999. Clinical management guidelines for obstetrician–gynecologists. *Int J Gynaecol Obstet* 1999; **67**: 117–128.
72. Burrows RF, Caco CC, Kelton JG. Neonatal alloimmune thrombocytopenia: spontaneous *in utero* intracranial hemorrhage. *Am J Hematol* 1988; **28**: 98–102.
73. Bussel JB, Berkowitz RL, Lynch L, Lesser ML, Paidas MJ, Huang CL, McFarland JG. Antenatal management of alloimmune thrombocytopenia with intravenous gamma-globulin: a randomized trial of the addition of low-dose steroid to intravenous gamma-globulin. *Am J Obstet Gynecol* 1996; **174**: 1414–1423.
74. Bussel JB, Berkowitz RL, McFarland JG, Lynch L, Chitkara U. Antenatal treatment of neonatal alloimmune thrombocytopenia. *N Engl J Med* 1988; **319**(21): 1374–1378.
75. Nicolini U, Rodeck CH, Kochenour NK, Greco P, Fisk NM, Letsky E, Lubenko A. *In-utero* platelet transfusion for alloimmune thrombocytopenia. *Lancet* 1988; **2**(8609): 506.