



# Prenatal diagnosis of arachnoid cysts: MRI features and neurodevelopmental outcome

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## ABSTRACT

**Objective:** Arachnoid cysts (AC) are congenital lesions comprising 1% of all intracranial mass lesions. The aim of this study was to characterize arachnoid cysts and their neurodevelopmental outcome and to compare it with the outcome of children without AC.

**Methods:** This is a retrospective cohort study of arachnoid cysts detected prenatally by fetal MRI in 29 fetuses compared to a control group of 59 fetuses without arachnoid cyst who were examined by MRI. The cohort was divided into 2 groups by the arachnoid cyst anatomical location: group A (n = 9), which included cases with supratentorial cyst, and group B (n = 20), which included cases with infratentorial cyst. Developmental analysis, the cohort was divided into 2 groups by the neurodevelopmental outcome: group  $\gamma$  (n = 5) which included cases that were affected by arachnoid cyst presence, and group  $\delta$  (n = 17) which included cases that had neurodevelopmental outcome within the normal range.

Data collected included prenatal history, MRI features, sonographic follow up, and neurodevelopmental outcome.

**Results:** In 22/29 cases we achieved a long-term follow up, by evaluation of children development in a range of ages from 6 months to 6 years. In group A (n = 9), 4 infants had normal outcome, 2 had abnormal outcome, 1 pregnancy was terminated, and 2 cases were not cooperative with the study. In group B (n = 20), 13 infants had normal outcome, 3 had abnormal outcome, and 4 cases were not cooperative with the study.

**Conclusions:** From all cases with AC detected by fetal MRI, 77.3% had normal neurodevelopmental outcome and 22.7% had abnormal neurodevelopment.

## 1. Introduction

Arachnoid cysts (AC) are rare congenital lesions of the arachnoid membrane that expands by Cerebrospinal Fluid (CSF) secretion. [1] AC comprise 1% of all intracranial space-occupying lesions and are rarely associated with other central nervous system malformations [2–5]. Although AC usually occur sporadically, it appears that they have a higher incidence in individuals with autosomal dominant polycystic kidney disease [6,7]. The etiology of AC is not well established; the

leading theory is splitting of the arachnoid membrane to two leaves with CSF where it is able to fill the potential space and produce a cyst whose capsule is composed of the same cells as the remainder of the arachnoid. [5,8,9] The natural history of AC is mostly benign and does not require any treatment, although in some patients rupture of AC into subdural space can occur spontaneously or due to head injury. [9,10] The incidence of hydrocephalus associated with AC is low, currently estimated as less than 10%, and is usually due to large supratentorial cysts. [11] Symptomatic AC can be treated either by fenestration or by

**Abbreviations:** AC, arachnoid cyst; CSF, cerebrospinal fluid; US, ultrasound; MRI, magnetic resonance imaging; CNS, central nervous system; VABS, Vineland II Adaptive Behavior Scale; TOP, termination of pregnancy; VSD, ventricular septal defect; FOV, field of view

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cyst peritoneal shunting. After the procedure the cyst is decompressed and the associated symptoms are usually improved or resolved [6,7,12,13].

Data regarding the neurodevelopmental outcome of infants with AC is scarce. Previous studies are of small cohorts and describe mostly neonates and premature infants. They have suggested that the vast majority of AC that were not related with other anomalies remain asymptomatic. [6] The prognosis of fetal intracranial cysts depends on the brain integrity rather than the cyst volume or location [14].

The growing use of prenatal imaging such as ultrasound (US) and magnetic resonance imaging (MRI) has led to an increase in prenatal detection and accuracy of the diagnosis of AC. [15,16] However, the clinical meaning of these findings is not well established.

The objectives of this study were to characterize the sizes, locations, and pressures caused by the AC and to establish reliable data regarding the outcome of fetuses with AC in comparison to fetuses with normal MRI.

## 2. Materials and methods

### 2.1. Population and setting

This is a retrospective cohort study. All the participants in the study had a standard sonographic screening during pregnancy consisting of nuchal translucency at the end of the 1<sup>st</sup> trimester and US survey during the 2<sup>nd</sup> trimester. Consequently, fetuses that had brain anomalies during the 2<sup>nd</sup> trimester survey were referred to a tertiary medical center for MRI examination. The study group included all pregnant women who underwent fetal brain MRI in which AC were detected between 2011 and 2016, in a single tertiary medical center.

The control group included pregnant women who underwent fetal brain MRI due to different maternal reasons, without detection of AC or any other brain structural anomalies. The indications for MRI for the control group included suspected pathologic findings on ultrasonographic evaluation, extracranial pathologic findings and a family member with an intracranial pathology.

Data obtained from the records include the following: maternal history (age, medical history, previous pregnancy outcome), abnormal pregnancy events, prenatal history (gender, prenatal testing, US and MRI features of AC, associated findings), perinatal history (gestational age, birth weight, Apgar score, and mode of delivery), US follow up, and clinical follow up. To establish reliable data concerning the AC characteristics, we investigated our cohort from two different angles: Anatomical and neurodevelopmental: Anatomical analyzation, the cohort was divided into 2 groups by the arachnoid cyst anatomical location: group A (n = 9), which included cases with supratentorial cyst, and group B (n = 20), which included cases with infratentorial cyst. Developmental analyzation, the cohort was divided into 2 groups by the neurodevelopmental outcome: group  $\gamma$  (n = 5) which included cases that were affected by arachnoid cyst presence, and group  $\delta$  (n = 17) which included cases that had neurodevelopmental outcome within the normal range.

### 2.2. MR imaging

All patients were referred to fetal MRI due to a specific suspected anomaly demonstrated by US. The preferred timing for fetal brain MRI at our institution is in the 32<sup>nd</sup> week of gestation, due to the ability to assess brain maturation (sulcation, gyration and parenchyma), in addition to comprehensive brain structure scanning. [17,18] Comparing to US, fetal MRI has a major advantage during the 3<sup>rd</sup> trimester of pregnancy regarding maternal obesity, inappropriate fetal position, decreased amniotic fluid [18].

Fetal MRI was performed and evaluated by an interdisciplinary team composed of an obstetrician who specializes in fetal US and MR imaging (E.K.), an expert MRI neuroradiologist (C.H.), and an

experienced pediatric neurologist (O.B.Y.) in a group analysis. A 1.5 T MR imaging system (Optima 1.5 T; GE Healthcare, Milwaukee, Wisconsin) was used. Single shot fast spin-echo T2 weighted sequences in 3 orthogonal planes were used with section thickness of 3–4 mm, no gap, and a flexible coil (8-channel cardiac coil). The field of view (FOV) was determined by the size of the fetal head, 24 cm for smaller fetuses and up to 30 cm for larger ones. Other parameters were a matrix of 320/224, TE of 90 ms, and TR of 1298 ms. The fast spoiled gradient-echo T1 sequence was performed only in the axial plane with a larger FOV of 40 cm, 4 mm section thickness, 0/5-mm gap, a TR of 160 ms, and a TE of 2.3 ms [19].

### 2.3. AC imaging features

AC were defined according to Barkovich et al., [6] as sharply margined and homogenous mass with an identical signal to CSF on MRI. Fetal MRI demonstrates the cyst as a CSF-intensity mass that displaces adjacent parenchyma [6]. The prenatal MRI helps to demonstrate the anatomic details of other central nervous system abnormalities, such as compression of the aqueduct, communication between the cyst and the ventricles, corpus callosum dysgenesis, and other brain malformations [16].

### 2.4. Neurodevelopmental outcome

Children were evaluated using Vineland II Adaptive Behavior Scale (VABS), [20] which examines 4 areas of development: communication, daily living skills, socialization, and motor skills. The score derived from this instrument has a mean of  $100 \pm 15$ . The published Israeli version of the VABS was administered, although no Israeli norms are available for the full age range. Since there was no reason to believe that children from Israel and the United States would develop mental and motor skills differently, we used the United States norms. Scores of children were considered abnormal if the standard score was < 70. The children in our study were evaluated in a range of ages from 6 months to 6 years. [19,21,22]. VABS was conducted by three medical students trained and supervised by a pediatric neurologist and child development expert experienced in conducting VABS (O.B.Y.). Inter-rater reliability was assessed by validation of VABS scores in 30 cases (performed by O.B.Y.). This validation demonstrated high concordance in VABS scores (Pearson correlation coefficient 0.87, B = 1.35). In addition, records of neurologic clinical follow-up were collected retrospectively.

### 2.5. Statistical analysis

Statistical analyses were conducted using the IBM Statistical Package for the Social Sciences (IBM SPSS v.23; IBM Corporation Inc., Armonk, NY, USA). Continuous variables were described as mean (STD) or median (IQR) as appropriate.

Analysis of variance (ANOVA) was used to examine the differences among the different groups and subgroups. Nominal variables were compared by Pearson chi-square test.

Significance was accepted at  $p < 0.05$ .

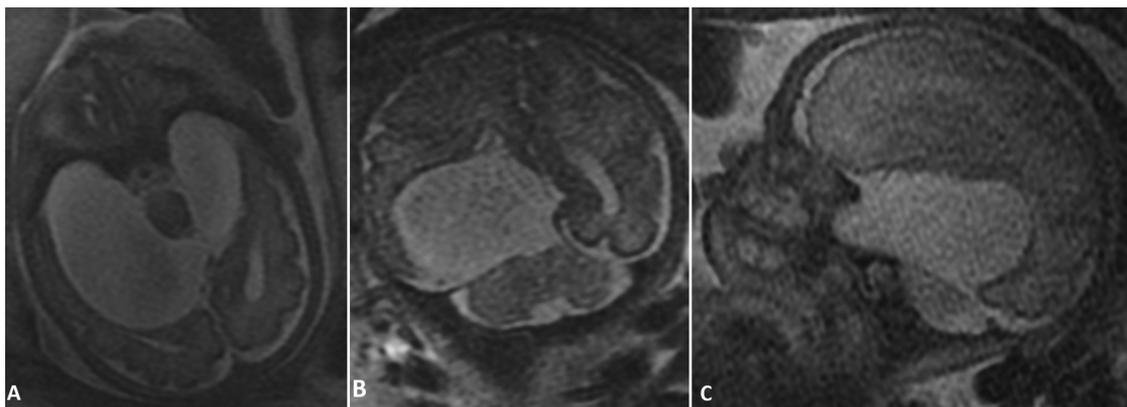
## 3. Results

### 3.1. Population

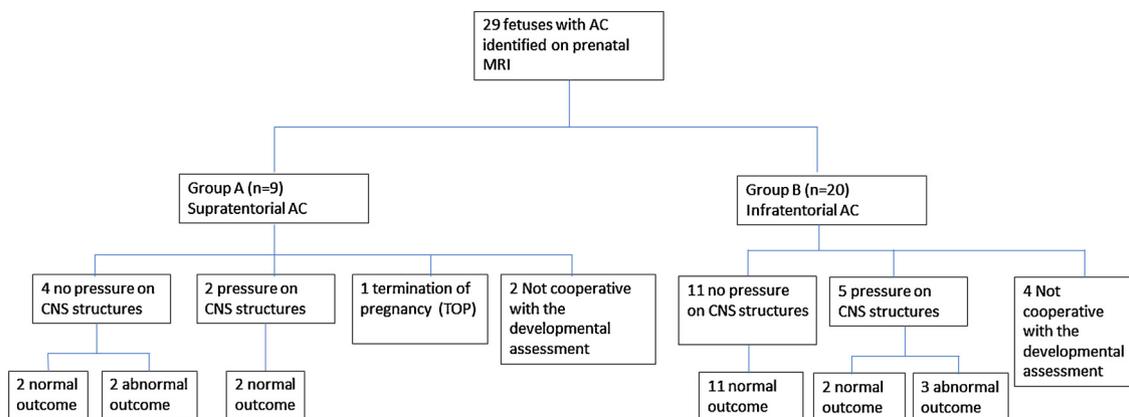
Between 2011 and 2016, 2717 patients underwent a fetal brain MRI examination due to suspected brain anomalies detected by fetal US. In 29 cases (1.06%) AC were detected. In addition, 59 cases without AC or any other structural anomaly were randomly chosen as a control group (as described in Methods). The pregnancy and neonatal characteristics of the cohort and control groups (88 cases) are described in Table 1. Concerning the cohort group, males were 2.6 times more likely to be

**Table 1**  
Study population, neonatal and delivery characteristics.

Pregnancy and maternal	γ Cohort group affected (n = 5)		δ Cohort group unaffected (n = 17)		Control group (n = 59)		significance
Maternal age (year)	31.60	(SD 1.14)	33.12	(SD 4.27)	32.34	(SD 5.27)	0.785
<i>In vitro</i> fertilization	1/5	(20%)	2/17	(11.8%)	12/59	(20.3%)	
<b>Fetal and neonatal</b>							
Male/female ratio	3/2	1.5:1	13/4	3.25:1	32/27	1.185:1	0.259
Fetal abnormalities in other organs	3/5	(60%)	1/17	(5.9%)	18/59	(30.5%)	0.031
Gestational age at MRI (week)	33.00	(SD 1.87)	34.12	(SD 2.93)	31.53	(SD 3.33)	0.014
Birth gestational age (week)	38.00	(SD 0.00)	38.69	(SD 1.19)	38.54	(SD 2.09)	0.812
Birth weight (grams)	3430	(SD 497)	3326	(SD 273)	3196	(SD 483)	0.401
Apgar score							
at 1 min	8.00	(SD 2.00)	8.93	(SD 0.27)	8.7	(SD 1.10)	0.303
at 5 min	9.75	(SD 0.50)	10	(SD 0.00)	9.89	(SD 0.38)	0.382
<b>Mode of delivery (n = 21)</b>							
Vaginal delivery	1/4	(25%)	10/17	(58.8%)	36/59	(61%)	0.546
Cesarean delivery	3/4	(75%)	7/17	(41.2%)	21/59	(35.6%)	
Vacuum delivery	0/4	(0%)	0/17	(0%)	2/59	(3.4%)	
<b>VABS</b>							
Communication skills	87.80	(SD 10.26)	103.88	(SD 9.23)	107.58	(SD 9.06)	< 0.001
Daily living skills	88.40	(SD 14.31)	103.35	(SD 7.16)	110.56	(SD 10.29)	< 0.001
Socialization skills	82.40	(SD 12.90)	93.29	(SD 9.25)	113.25	(SD 10.78)	< 0.001
Motor skills	63.60	(SD 24.84)	96.76	(SD 13.06)	104.62	(SD 10.15)	< 0.001
Total VABS score	77.20	(SD 5.54)	98.94	(SD 8.01)	110.73	(SD 9.63)	< 0.001
Percentile %	7.40	(SD 5.18)	47.35	(SD 19.87)	72.72	(SD 18.02)	< 0.001
Moderately low adaptive level	5/5	(100%)	0/17	(0%)	0/59	(0%)	



**Fig. 1.** Case 11: Axial (A), Coronal (B), Sagittal (C) T2-MR fetal brain images at 31 weeks of gestation. Supratentorial AC with major influence on the following structures: pressure on the temporal lobes bilaterally and over the posterior fossa-cerebellum and vermis.



**Chart 1.** Flowchart illustrating the study design and outcome of the cohort. Cases are divided to 2 groups: fetuses in group A had supratentorial AC, while fetuses in group B had infratentorial AC. The groups were further subdivided by the pressure that the AC caused over brain structures and by the neurodevelopmental outcome of the patients.

**Table 2**  
Description of abnormal cases of the cohort.

Case number	Gender	Relation to tentorium	Volume of the AC in ml	Specific location of AC	Pressure on other brain structures	Age at the time of the study in months	VABS total standardized score	Neurodevelopmental percentile %	Notes
3	Male	supratentorial	51	ambient cistern	no pressure	28	83	13	At the age of 4 months, mild hypotony and mild left torticollis TOP (Fig. 1)
6	Male	supratentorial	23.1	ambient cistern	no pressure	18	72	3	
11	Female	supratentorial	64	middle cranial fossa	suppression of posterior fossa and temporal lobes bilaterally	-	-	-	
15	Female	infratentorial	127.68	posterior fossa	mild tentorial elevation	49	83	13	1 sibling with enlarged cistern magna is diagnosed as high functioning pervasive developmental disorder
17	Male	infratentorial	77	posterior fossa	mild tentorial elevation	41	76	5	AC increased in size, blocked CSF drainage and caused hydrocephalus which forced neurosurgery (Fig. 2)
26	Female	infratentorial	41.6	posterior fossa	suppression of vermis and cerebellum	19	72	3	

diagnosed with AC than females (2.6:1). Four fetuses of the cohort (group  $\delta$ ) with neurodevelopmental outcome in the normal range, had additional fetal extracranial abnormalities: 2 had cardiac Ventricular Septal Defect, 1 had left kidney double collecting system, and 1 had dilatation of umbilical vein. One fetus had additional intracranial abnormality of lateral and third ventricles dilation.

The median birth gestational age of the cohort was 38 weeks (range 37–41 weeks), the median birth weight was 3347 g (range 2930–4160 g). There was no statistically significant difference between the cohort ( $\gamma$  and  $\delta$ ) and control groups concerning maternal, pregnancy, fetal, and labor data.

Termination of pregnancy (TOP) was performed only in 1 case, in which 2 MRI examinations were conducted during gestational weeks 25 and 31. The first MRI presented a relatively large AC, 47 ml in the quadrigeminal cistern without any pressure on nearby brain structures. The second MRI (Fig. 1) presented an even bigger AC, 64 ml with influence on the following structures: pressure over the posterior fossa, concave and compressed vermis, small cerebellomedullaris cistern (cisterna magna) as an expression of high pressure over posterior fossa and temporal lobes bilaterally. The decision to terminate the pregnancy and the procedure itself took place in a different medical center.

### 3.2. Anatomical features of AC on MRI

Nine cases of AC were supratentorial (group A), 20 cases of AC were infratentorial (group B). Chart 1 demonstrates the characteristics of the AC concerning anatomical location, pressure over brain structures, and neurodevelopmental outcome. In group A the mean volume of supratentorial AC was 20.00 ml (SD 29.26). For group B the mean volume of infratentorial AC was 12.05 ml (SD 10.88).

### 3.3. Postnatal sonographic follow up

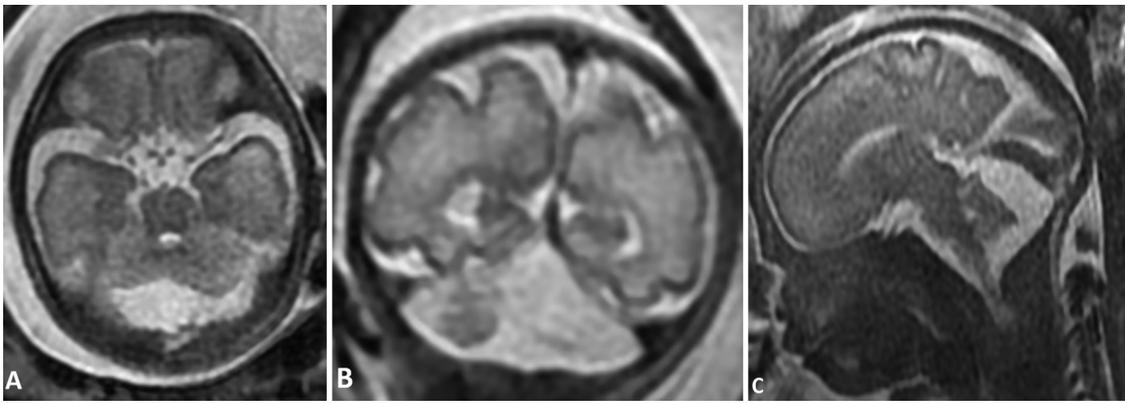
During the first month of life, postnatal cranial sonographic follow up was performed in 18/22 neonates (81%). In 7 cases out of the 18 (38.9%) examinations neither AC nor other abnormalities were demonstrated. 1 of those cases was supratentorial without any pressure, the other 6 were all infratentorial, half of them with minor elevation of tentorium and the other half without any pressure. None of the epidemiological or clinical characteristics were significantly associated with spontaneous resolution of AC. The remaining 11 cases (61.1%) of postnatal US demonstrated AC as it was described in the prenatal MRI.

### 3.4. Neurodevelopmental outcome

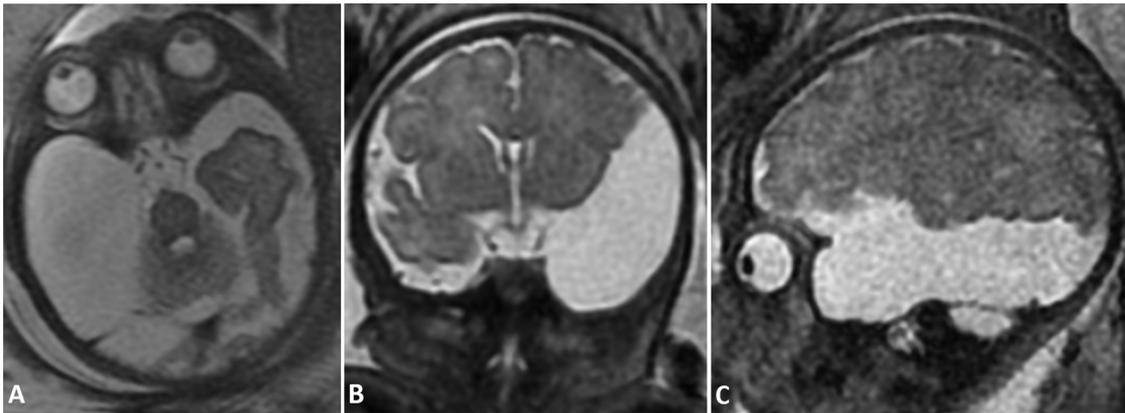
Long-term follow up was performed by VABS in 81/88 cases. A significant differences were found between group  $\gamma$  of the cohort comparing with group  $\delta$  and the control group. The statistical significance  $p < 0.05$  is presented in Table 1. It is important to note that the mean and the percentile of VABS of group  $\delta$  are lower than the control but still in the normal range. In the cohort group  $\delta$  17/22 (77.3%) of infants had normal neurodevelopmental outcome and group  $\gamma$  5/22 (22.7%) were moderately low developed according to the VABS. [20] In the control group all infants had at least normal neurodevelopment: 41/59 (69.4%) had normal development, 17/59 (28.8%) had moderately high development, and 1/59 (1.7%) had high neurodevelopmental outcome according to the same standardized scale. The five cases of group  $\gamma$  with abnormal neurodevelopmental outcome are described in Table 2, important notion is that all of them had isolated AC. One example of abnormal neurodevelopment is demonstrated in case 26 (Fig. 2).

## 4. Discussion

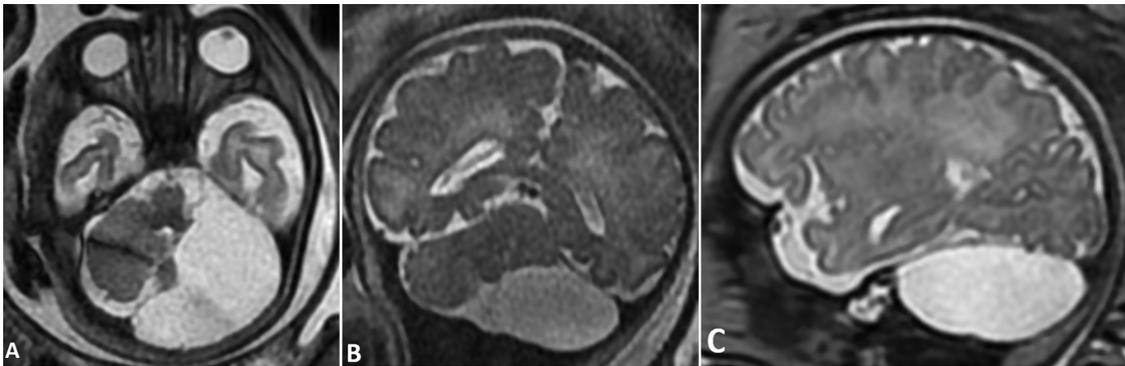
The aim of this study was to describe the anatomical characteristics of prenatally diagnosed AC demonstrated by MRI and to determine



**Fig. 2.** Case 26: Axial (A), Coronal (B), Sagittal (C) T2-MR fetal brain images at 31 weeks of gestation. Infratentorial AC caused anatomical disruption of the vermis and cerebellum. The tentorium cerebelli is slightly elevated.



**Fig. 3.** Case 1: Axial (A), Coronal (B), Sagittal (C) T2-MR fetal brain images at 32 weeks of gestation. Large supratentorial AC caused unilateral upward rotation of the temporal lobe. The cortical development in this region is adequate to the gestational age.



**Fig. 4.** Case 24: Axial (A), Coronal (B), Sagittal (C) T2-MR fetal brain images at 38 weeks of gestation. infratentorial AC caused tentorial elevation and local pressure on the left lobes of cerebellum and vermis.

their association with neurodevelopmental outcome. Although we compared maternal, anatomical and neurodevelopmental outcome of the supratentorial AC and infratentorial AC, we could not demonstrate any parameter with statistical significance. Current literature suggests that AC have been associated with variable outcomes. Most of the studies reported good neurodevelopmental outcomes in the presence of isolated AC, without hydrocephalus or additional anatomical abnormalities. [6,23] An example of isolated AC with good neurodevelopmental outcome is presented in case 1 (Fig. 3).

In our study most of the AC were located infratentorial, 69% (20/29), and only 31% (9/29) were located supratentorially. Our data differ from the current literature in which supratentorial AC are the vast majority of AC. [24] Examples from recent studies are the Linliang et al.

[23] study, which demonstrated only 15% infratentorial AC and 85% supratentorial AC [23], as well as different from the De Keersmaecker et al. [25] study, which presented 25% infratentorial and 75% supratentorial. In the current literature we could not find any explanation for this difference concerning the anatomical location in the different populations.

The prognosis of fetal intracranial cysts has been shown to rely on the brain integrity rather than the cyst volume or location. [14,26] In our cohort 2/22 (9.1%) children suffered from hydrocephalus due to pressure caused by AC over brain structure and compression toward the foramen magnum; this follows the literature regarding hydrocephalus due to AC [11]. Both children suffered from hydrocephalus had infratentorial AC and underwent ventricular-peritoneal shunt after birth:

Case 26 (Fig. 2, Table 2) suffered from AC of 41 ml with suppression of vermis and cerebellum demonstrated by fetal MRI. Following birth additional enlargement of the AC to 50 ml. By VABS case 26 had moderately low neurodevelopment.

On the other hand, Case 24 (Fig. 4) had AC of 48.75 ml with suppression of left lobe of vermis and cerebellum as well as elevation of tentorium. In this case also neurosurgery was obligatory. Following the procedure, the child had normal neurodevelopment by VABS.

Postnatal cranial sonographic follow up during the first month of life was performed in 81% of the cohort. In 39% of them complete resolution was demonstrated. 6 out of 7 were infratentorial AC and considered as isolated AC cases.

In our cohort, group  $\delta$ , 77.3% (17/22) of the children exhibited normal neurodevelopment. The rest of the children, group  $\gamma$ , 22.7% (5/22) presented moderately low neurodevelopment, we did not find any correlation or similarity between the AC of the affected children. These percentages are slightly lower than the reported results of Linliang et al.'s [23] study in which 80% of the children exhibited normal neurodevelopment.

Prenatal counseling concerning AC is challenging due to the relatively small number of studies in this specific field, although the outcome is relatively good. [23] An interesting observation is that there is a major difference in percentage of TOP from the fetuses diagnosed with AC in different countries. While in the Linliang et al. [23] study, which was conducted in China, more than half of the pregnancies were terminated [23], in De Keersmaecker et al.'s [25] study, which took place in Belgium, only 8% (1/12), and in our study only 4% (1/22) underwent TOP. We assume that the reason for the differences in TOP rate is due to cultural differences between the different societies.

The strengths of our study are: First, its relatively large number of cases ( $n = 29$ ) and high follow-up rate ( $n = 22$ ), which is the largest study of its kind. Second, the high rate of live birth fetuses diagnosed with arachnoid cyst prenatally. Third, the wide range of parameters recorded, including clinical prenatal and perinatal factors, morphologic characteristics of fetal MRI, and the long-term follow up of the infants.

There are limitations to our study: First, our study was retrospective and there was a group of women that was lost for follow up. This may cause a bias of the study results. The characteristic of the study group and the group lost for follow up were compared and there was no significant difference between the groups.

Second, half of the children participating in this study were under the age of 3 years when the VABS [20] was performed; it may therefore be possible that a longer follow-up period would reveal slightly different neurodevelopmental results.

## 5. Conclusions

AC diagnosis during pregnancy has a favorable outcome. Only a small group of children (5/22) had moderate neurodevelopmental delay and even a smaller group of children (2/22) needed a surgical intervention to resolve the complications of an expanding AC.

## Ethics approval

The study was approved by the local institutional ethics board.

## Conflict of interest

The authors declare that there were no conflicts of interest in the

drafting of this article.

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## References

- [1] I. Spalova, T. Belsan, M. Cihar, et al., Arachnoid cysts: prenatal diagnosis and Management, *Ultrasound Obstet. Gynecol.* 24 (3) (2004) 369–372.
- [2] R. Ibarra, P. Kesava, Role of MR imaging in the diagnosis of complicated arachnoid cyst, *Pediatr. Radiol.* 30 (2000) 329–331.
- [3] M. Epelman, A. Daneman, S. Blaser, et al., Differential diagnosis of intracranial cystic lesions at head US: correlation with CT and MR imaging, *Radiographics* 26 (1) (2006) 173–196.
- [4] J. Nelson, D. Marvin, K. Maher, et al., A different approach to cysts of the posterior fossa, *Pediatr. Radiol.* 34 (9) (2004) 720–732.
- [5] P. Rafferty, J. Britton, L. Penna, et al., Prenatal diagnosis of a large fetal arachnoid cyst, *Ultrasound Obstet. Gynecol.* 12 (5) (1998) 358–361.
- [6] A. Barkovich, C. Raybaud, *Pediatric Neuroimaging*, fifth ed., Wolters Kluwer Health/Lippincott Williams & Wilkins, Philadelphia, 2012, pp. 524–528.
- [7] S. Pomeranz, S. Constantini, I. Lubetzki-Korn, et al., Familial intracranial arachnoid cyst, *Childs Nerv. Syst.* 7 (2) (1991) 100–102.
- [8] F. Bretelle, M. Senat, J. Bernard, et al., First-trimester diagnosis of fetal arachnoid cyst: prenatal implication, *Ultrasound Obstet. Gynecol.* 20 (4) (2002) 400–402.
- [9] R. Hayward, Prenatal diagnosis of neural tube defects, *Prenat. Diagn.* 29 (2009) 396–401.
- [10] S. Elbers, M. Furness, Resolution of presumed arachnoid cyst in utero, *Ultrasound Obstet. Gynecol.* 14 (5) (1999) 353–355.
- [11] A. Pierre-Kahn, L. Capelle, R. Brauner, et al., Presentation and management of suprasellar arachnoid cysts, *J. Neurosurg.* 73 (3) (1990) 355–359.
- [12] R. Kirolos, M. Javadpour, P. May, et al., Endoscopic treatment of suprasellar and third ventricle-related arachnoid cysts, *Childs Nerv. Syst.* 17 (12) (2001) 713–718.
- [13] G. Zada, M. Krieger, S. McNatt, et al., Pathogenesis and treatment of intracranial arachnoid cysts in pediatric patients younger than 2 years of age, *Neurosurg. Focus* 22 (2) (2007) 1–5.
- [14] A. Pierre-Kahn, P. Hanlo, P. Sonigo, et al., The contribution of prenatal diagnosis to the understanding of malformative intracranial cysts: state of the art, *Childs Nerv. Syst.* 16 (10–11) (2000) 618–626.
- [15] W. Blaicher, D. Prayer, S. Kuhle, et al., Combined prenatal ultrasound and magnetic resonance imaging in two fetuses with suspected arachnoid cysts, *Ultrasound Obstet. Gynecol.* 18 (2) (2001) 166–168.
- [16] C.P. Chen, Prenatal diagnosis of arachnoid cysts, *Taiwan. J. Obstet. Gynecol.* 46 (3) (2007) 187–198.
- [17] L.J. Salomon, C. Garel, Magnetic resonance imaging examination of the fetal brain, *Ultrasound Obstet. Gynecol.* 30 (7) (2007) 1019–1032.
- [18] T. Higuera, Fetal neuroimaging : US and MRI, *Pediatr. Radiol.* 39 (2009) 1020–1024.
- [19] S. Cooper, O. Bar-Yosef, M. Berkenstadt, et al., Prenatal evaluation, imaging features, and neurodevelopmental outcome of prenatally diagnosed periventricular pseudocysts, *AJNR Am. J. Neuroradiol.* 37 (12) (2016) 2382–2388.
- [20] S. Sparrow, V. Cicchetti, A. Balla, *Vineland Adaptive Behavior Scales*, 2nd ed., American Guidance Service, Circle Pines, MN, 2005.
- [21] O. Bar-Yosef, E. Barzilay, S. Dorembus, et al., Neurodevelopmental outcome of isolated ventriculomegaly: a prospective cohort study, *Prenat. Diagn.* 37 (8) (2017) 764–768.
- [22] S. Cooper, E. Katorza, M. Berkenstadt, et al., Prenatal abnormal width of the cavum septum pellucidum – MRI features and neurodevelopmental outcome, *J. Matern. Fetal. Neonatal. Med.* 7058 (2017) 1–8.
- [23] L. Yin, Z. Yfang, Q. Pan, et al., Sonographic diagnosis and prognosis of fetal arachnoid cysts, *J. Clin. Ultrasound* (2017), <https://doi.org/10.1002/jcu.22532>.
- [24] E.M. Pappalardo, M. Militello, G. Rapisarda, et al., Fetal intracranial cysts: prenatal diagnosis and outcome, *J. Prenat. Med.* 3 (6) (2009) 28–30.
- [25] B. De Keersmaecker, P. Ramaekers, F. Claus, et al., Outcome of 12 antenatally diagnosed fetal arachnoid cysts: case series and review of the literature, *Eur. J. Paediatr. Neurol.* 19 (2) (2015) 114–121.
- [26] W. Al-Holou, Y. Andrew, E. Zackary, et al., Prevalence and natural history of arachnoid cysts in children, *J. Neurosurg. Pediatr.* 5 (6) (2010) 578–585.