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Evaluation of Fetuses with Intrauterine Hydrocephaly by Diffusion-Weighted Imaging

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Research Article

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ABSTRACT

Objective: Hydrocephaly is an important factor for neurological development. Microstructural changes of cerebral tissue are detected in diffusion-weighted imaging (DWI), and abnormal brain development can be detected early. In this study, it was aimed to evaluate fetuses with hydrocephaly by magnetic resonance imaging (MRI).

Method: In our study, nineteen fetuses with hydrocephaly and twenty-two fetuses without any pathology were analyzed retrospectively. Apparent diffusion coefficient (ADC) of fetal brain frontal, parietal, temporal white matter, cerebellar hemisphere and pons was measured. Case and control groups were compared statistically.

Results: When the individuals in the study and control groups were compared in terms of trimester, no significant difference was found ($p>0.05$). When the frontal, parietal and temporal white matter ADC values of the fetuses in both groups were compared, the difference between the groups was significant ($p<0.05$). Individuals in the study group also had lower ADC values. When the pons and cerebellum ADC values of the fetuses were compared, no significant difference was found between the groups ($p>0.05$).

Conclusions: Hydrocephaly is one of the most common congenital anomalies. Increased cerebrospinal fluid (CSF) pressure causes parenchymal compression, thus reducing perfusion and ischemia. As a result of ischemia, lactate concentration increases and fluid transfers into the cell. Then, diffusion restriction and a decrease in ADC values occur. Measurement of cerebral ADC values gives information about the neurological development of fetuses with hydrocephaly and can provide early recognition of problems that may occur in the postnatal period.

Keywords: Apparent diffusion coefficient, brain, fetus, hydrocephaly

İntrauterin hidrosefalisi bulunan fetüslerin difüzyon ağırlıklı görüntüleme ile değerlendirilmesi

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ÖZ

Amaç: Hidrosefali nörolojik gelişim için önemli bir faktördür. Difüzyon ağırlıklı görüntülemede (DAG) beyin dokusunun mikroyapısal değişiklikleri tespit edilir ve anormal beyin gelişimi erken dönemde saptanabilir. Bu çalışmada hidrosefalisi bulunan fetüslerin Manyetik Rezonans Görüntüleme (MRG) ile değerlendirilmesi amaçlandı.

Yöntem: Çalışmamızda hidrosefalisi bulunan 19 fetüs ve patolojisi olmayan 22 fetüs retrospektif olarak incelendi. Fetal beyin frontal, parietal, temporal beyaz cevher, serebellar hemisfer ve ponsun görünen difüzyon katsayısı (GDK) ölçüldü. Olgu ve kontrol grupları istatistiksel olarak karşılaştırıldı.

Bulgular: Çalışma ve kontrol grubundaki bireyler trimester açısından karşılaştırıldığında anlamlı fark bulunmadı ($p>0.05$). Her iki gruptaki fetüslerin frontal, parietal ve temporal beyaz cevher GDK değerleri karşılaştırıldığında gruplar arasındaki fark anlamlıydı ($p<0.05$). Çalışma grubundaki bireyler daha düşük GDK değerlerine sahipti. Fetüslerin pons ve serebellum GDK değerleri karşılaştırıldığında gruplar arasında anlamlı fark bulunmadı ($p>0.05$).

Sonuç: Hidrosefali en sık görülen doğumsal anomalilerden biridir. Beyin omurilik sıvısındaki (BOS) artan basınç parankimal kompresyona neden olarak perfüzyon ve iskemiyi azaltır. İskemi sonucunda laktat konsantrasyonu artar ve hücre içine sıvı transferi olur. Daha sonra difüzyon kısıtlaması ve GDK değerlerinde azalma meydana gelir. Serebral GDK değerlerinin ölçülmesi hidrosefalisi bulunan fetüslerin nörolojik gelişimi hakkında bilgi verir ve doğum sonrası dönemde oluşabilecek sorunların erken fark edilmesini sağlayabilir.

Anahtar sözcükler: Görünür difüzyon katsayısı, beyin, fetüs, hidrosefali

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Introduction

Brain development includes the stages of cell proliferation, histogenesis and myelination, which provide the formation of 100 billion neurons in the brain development process [1]. The most important stage of brain formation and maturation occurs during pregnancy. Therefore, imaging of the brain in the prenatal period can lead to very important and beneficial results [2]. Micro-structural changes of cerebral tissue are detected with diffusion-weighted imaging (DWI), and fetal brain maturation is investigated. Thus, it helps to recognize abnormal brain development cases earlier [2]. Hydrocephaly is one of the most common diseases in fetuses and it is diagnosed in approximately one out of 1000 live births at any gestational week [3], and 36,7% of them survive without any problems [4]. Hydrocephaly has been associated with numerous neurological conditions such as autism, epilepsy, and schizophrenia [5-7]. However, DWI studies in the fetal brain related to hydrocephaly are scarce.

In studies, it was observed that the neurological development of isolated mild hydrocephaly cases was normal [8]. Therefore, whether hydrocephaly is associated with other anomalies is an important prognostic factor. New diagnostic markers such as DWI need to be developed for a better understanding of hydrocephaly cases.

Fetal Magnetic Resonance Imaging (MRI) is mainly performed with 1,5 T MR to reduce the warming effects and potential risks of radiofrequency exposure [9]. Another limitation of fetal MRI is its artifact resulting from maternal and fetal movement. It causes inaccuracies in apparent diffusion coefficient (ADC) value due to partial volume artifact that occurs in small craniums, early gestational weeks and low solubility conditions.

The aim of this study is to investigate the effect of hydrocephaly on the brain in fetal MRI examination by looking at ADC values.

Material and Methods

Ethics committee approval was obtained from the relevant unit of the University for this retrospective study (decision no:2022-01/28). Fetal MRI examinations performed between January 2012 and March 2020 were scanned from the database. Eligibility criteria for the study were **(a)** fetuses with hydrocephaly (study group) and fetuses without hydrocephaly (control group), **(b)** singleton pregnancies, **(c)** 15-32 weeks gestational age. Nineteen fetuses with hydrocephaly constitute the study group, and twenty-two normal fetuses constitute the control group.

All MR images were made with a 1,5 Tesla MRI device (Siemens Magnetom Aera, Erlangen, Germany). The patients were placed in the supine position. Contrast material and anesthesia were not applied during the shooting. All images include T2 Haste (coronal, axial, sagittal) and diffusion weighted images.

Fetal MRI was performed to better evaluate brain pathologies in nineteen fetuses with hydrocephaly on ultrasound examination. Atrial diameter was measured on ultrasound and MRI according to the guidelines of the International Society of Obstetrics and Gynecology (ISUOG) [10]. Hydrocephaly was defined when the atrial diameter of one or both ventricles was ≥ 10 mm. Our study included nineteen fetuses with hydrocephaly and 22 normal fetuses with atrial diameter <10 mm. Traditional MRI examination consisting of T2-weighted images of the fetuses was performed. Various anomalies were detected in 12 of the fetuses with hydrocephaly. No anomaly was detected in seven fetuses with hydrocephaly and 22 fetuses in the control group.

DWI parameters; TR 8000 ms, TE 80 ms, 5 mm section thickness and two different b (0,800 s/mm^2) values. The axial section with the best view of the fetal brain was selected. Measurements were made from ADC maps. ROIs of equal size were manually placed in the frontal white matter, parietal white matter, temporal white matter, cerebellar hemisphere, and pons in the fetal brain. ADC measurements were made by two radiologists who were unaware of each other and their average was taken (Figure 1).

Statistical analyses were performed with SPSS version 22.0. All data were reported as means ±S.D. Unpaired t test was used for comparison of variables between the studied groups. A value of P <0,05 was considered significant.

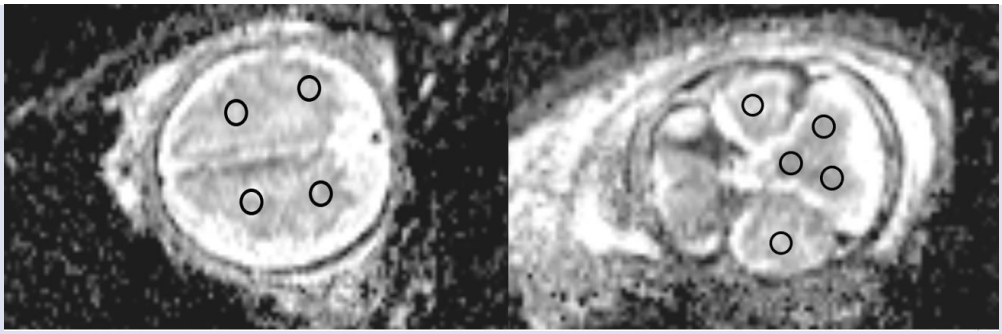

Figure 1. ADC measurement with ROI in Frontal white matter (WM), Parietal WM, Temporal WM, Cerebellar hemisphere and Pons

Results

Nineteen fetuses with hydrocephaly who met the criteria in fetal MRI constituted the study group. Twenty-two fetuses without any pathology formed the control group. Whilethere was no anomaly other than hydrocephaly in seven of the fetuses in the study group, central nervous system anomaly accompanying hydrocephaly was found in twelve fetuses. 84.3% of the pregnant women in the study group were at 14-26 weeks (2nd trimester), 15,7% were at 27- 40 weeks (3rd trimester). 63.7% of the pregnants in the control group were 14-26 weeks (2nd trimester), 36,3% were 27-40 weeks (3rd trimester). The difference between the groups in terms of trimester was found to be insignificant (p>0.05) (Table 1).

Table 1. Trimester distribution of individuals in case and control groups

			Trimester period		Total
			14-26 week	27-40 week	
Groups	Case	S	16	3	
		%	%84.3	%15.7	100.0%
	Control	S	14	8	
		%	%63.7	%36.3	100.0%
Total		S	30	11	
		%	73.1%	26.9%	100.0%

ADC measurements were made from the brain frontal, parietal, temporal white matter, pons and cerebellum of fetuses in the case and control groups. When the frontal, parietal and temporal white matter ADC values were compared, the difference between the groups was significant (p<0.05). Individuals in the case group also have lower ADC values. When the pons and cerebellum ADC values were compared, the difference between the groups was found to be insignificant (p>0.05) (Table 2)

Table 2. Frontal, parietal and pemporal white matter (WM), pons and perebellum ADC values of fetuses in case and control groups

	Groups	N	Mean	Std.Deviation	Result
Frontal WM ADC	Case	19	1485.4211	129.27203	t=6.92
	Control	22	1754.3636	119.27301	p=0.001*
Parietal WM ADC	Case	19	1543.6842	121.50265	t=5.15
	Control	22	1779.2273	163.79835	p=0.001*
Temporal WM ADC	Case	19	1357.2105	78.86386	t=12.15
	Control	22	1740.0455	114.68320	p=0.001*
Pons ADC	Case	19	1211.2632	211.85998	t=1.79
	Control	22	1225.4545	117.44167	p=0.081
Cerebellum ADC	Case	19	1386.0000	170.01961	t=1.36
	Control	22	1474.5455	146.18863	p=0.176

*p<0,05

It is isolated in seven of the fetuses with hydrocephaly, and various central nervous system anomalies are accompanied in twelve fetuses. Therefore, frontal, parietal and temporal white matter and pons and cerebellum ADC values of fetuses with hydrocephaly isolated or accompanied by anomaly were compared, and no statistically significant difference was found between the groups (p>0.05) (Table 3).

Table 3. Comparison of ADC values measured from frontal, parietal, and temporal white matter (WM), pons, and perebellum in fetuses with isolated or anomaly accompanied hydrocephaly

	Anomaly	N	Median	Min	Max	Result
Frontal WM ADC	No	7	1420	1226	1658	p=0.352
	Yes	12	1523	1342	1746	
Parietal WM ADC	No	7	1578	1278	1734	p=0.933
	Yes	12	1578	1419	1664	
Temporal WM ADC	No	7	1362	1253	1476	p=0.899
	Yes	12	1362	1228	1502	
Pons ADC	No	7	1130	852	1479	p=0.735
	Yes	12	1274	907	1504	
Cerebellum ADC	No	7	1266	1148	1533	p=0.118
	Yes	12	1409	1148	1750	

Discussion

Hydrocephaly is one of the most common congenital anomalies. It is a disease characterized by obstruction of cerebrospinal fluid (CSF) flow or decreased resorption. It should be differentiated from various pathologies caused by tissue loss (eg, Arnold-Chiari malformation, holoprosencephaly, corpus callosum agenesis) [11]. In addition, congenital pathologies should be differentiated from acquired pathologies such as infection and bleeding. Increased CSF pressure causes parenchymal compression. Thus, a decrease in perfusion and ischemia occur. As a result, low ADC values are measured on MRI. In the early phase of hydrocephaly, ADC values may increase due to CSF diapedesis, but ADC decreases as a result of long-term exposure to ischemia [11-13].

In our study, frontal, parietal and temporal white matter ADC values of fetuses in the case and control groups were compared and the difference was found to be significant (p<0.05). ADC values were lower in fetuses in the study group. When the pons and cerebellum ADC values of the fetuses in both groups were compared, the difference between the groups was found to be insignificant (p>0.05). In studies, lactate levels were found to increase in the brain and CSF of rats with hydrocephaly [14]. Increase in lactate is an indicator of decrease in cerebral blood flow and development of ischemia as a result of increased intraventricular pressure. As a result of decreased blood flow, anaerobic glycolysis develops and the amount of lactate increases. Increases tissue osmolarity with the increase of lactate, which leads to extracellular shrinkage with the passage of water into the intracellular compartment. As a result of all these factors, the ADC values decrease [12].

In the studies performed by Erdem et al. and Righini et al., ADC values measuredfrom the frontal and occipital white matter and basal ganglia were lower in the study group than in the control group, and were found to be statistically significant [11]. Data from these studies may be indicative of parenchymal damage in the brain with hydrocephaly. These findings support the view that ongoing hydrocephaly may become irreversible in the fetal period [15].

In our study, frontal, parietal and temporal white matter and pons and cerebellum ADC values of fetuses with hydrocephaly, isolated or accompanied by anomaly, were compared. There was no statistically significant difference between the groups (p>0.05). With this comparison, it was desired to look at the isolated effects of hydrocephaly on the brain. It was aimed to exclude other factors by demonstrating that there was no significant difference between the two groups.

Our study has some limitations. First limitation, the number of cases with hydrocephaly is small. The second limitation is that postnatal brain parenchymal ADC measurements of the fetuses in the case group were not compared with the control group. The third limitation is the lack of fetal brain MRS evaluation in addition to ADC value measurement.

Conclusion

Cerebral ADC values may be useful in demonstrating biophysical changes in the brain in fetuses with hydrocephaly. Thus, early recognition of problems that may arise in the postnatal period can be achieved. Therefore, we think that fetal DWI should be the routine sequence of fetal MRI.

Financial Disclosure: There are no financial supports.

Ethical approval: All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Human Research Ethics Committee of the Sivas Cumhuriyet University approval was received for this study [registry no: 2022-01/28]. Informed consent was not obtained from the participants included in this study because of the retrospective nature of the study.

Conflict of interest

There is no a conflict of interest

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