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Magnetic resonance imaging versus ultrasound in detection of congenital fetal malformations

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***Abstract*---**Background; Congenital anomalies are present in 2-4% of newborns and are an important cause of fetal and neonatal mortality and morbidity, Aim and objectives; to compare magnetic resonance imaging to ultrasound in detection of congenital fetal malformations, Subjects and methods; Our prospective randomized control study to compare magnetic resonance imaging to ultrasound in detection of congenital fetal malformations. The was carried out on 100 pregnant women at second and third trimesters who were divided into two equal groups: group A (cases) comprised fetus with congenital anomalies on ultrasound examination and group B (control Group): low risk pregnancies with no detected fetal anomalies on ultrasound examination, Result; Four of patients were diagnosed with congenital anomalies detected by prenatal MRI that differed from that of postnatal diagnosis which represented 8% of all cases and 46 of those cases were diagnosed as same as postnatal diagnosis which represented 92% of all cases. There was no significant difference between prenatal MRI and postnatal diagnosis in detection of prenatal congenital CNS anomalies with p value was 0.123, Conclusion; Fetal MRI has a superior diagnostic accuracy. It had a higher sensitivity for diagnosing CNS anomalies than did US, and provides additional findings in anomalies of CNS, GIT, and renal systems.

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***Keywords*---**Magnetic Resonance Imaging, ultrasound, congenital fetal malformations, review article.

Introduction

Congenital anomalies are present in 2-4% of newborns and are an important cause of fetal and neonatal mortality and morbidity. Ultrasound is the primary modality used to assess the fetus, this examination by a skilled operator, in most cases, provides adequate information regarding fetal morphology, its environment, and its well-being. The quality of Ultrasound however, is adversely affected by factors such as maternal obesity, unfavourable fetal position, multiple gestations, decreased amniotic fluid or the near-field reverberation artifact (1). MRI (Magnetic Resonance Imaging) is a valuable complement to US when additional information is needed to confirm diagnosis during pregnancy. Recently MRI with fast sequences has allowed images to be obtained during maternal breath holding, without fetal or maternal sedation, it gives superior soft tissue contrast resolution, because of which we are able to distinguish individual fetal structures such as lung, liver, kidney and bowel (2).

Moreover, it provides multiplanner imaging as well a large field of view, facilitating examination of foetuses with large or complex anomalies, and visualization of the lesions within the context of the entire fetal body (3). It allows better fetal imaging in situations such as maternal obesity and oligohydramnios, where it may be difficult to obtain images by US due to technical limitations (4). MRI is a non-invasive that doesn't involve ionizing radiation with no known associated side effects or reported delayed sequels (5). The aim of this study was to compare magnetic resonance imaging to ultrasound in detection of congenital fetal malformations

Patients and Methods

Our prospective randomized control study was done to compare magnetic resonance imaging to ultrasound in detection of congenital fetal malformations. The was carried out on 100 pregnant women at second and third trimesters that were divided into two equal groups: group A (cases) comprised fetus with congenital anomalies on ultrasound examination and group B (control Group): low risk pregnancies with no detected fetal anomalies on ultrasound examination.

Inclusion criteria: Pregnant women at second and third trimesters.

Exclusion criteria: Pregnant women with cardiac pacemaker, pregnant women with metallic devices in their bodies not compatible with MRI and pregnant women with severe claustrophobia.

Sample Size Calculation: The study was included a total of 100 pregnant women divided into two equal groups: **Group A** (Cases): have fetus with congenital anomalies on ultrasound examination and **group B** (Control Group): low risk pregnancies with no detected fetal anomalies on ultrasound examination.

Study tools: 2D, 3D and 4D ultrasound according the condition, MRI through abdominal coil and using the following sequences: Single shot fast spin-echo (SSFSE): two dimensional gradient echo (2D GRE) sequences as well as a faster version of the GRE sequence called ultrafast gradient echo sequences or turbo fast low-angle shot (FLASH): balanced steady-state free precession (SSFP) sequences as balanced fast field echo (b-FFE) and B-FEE was a preferred sequence for visualization of the fetal heart and vessels. Equipments: Voluson P8 ultrasound machine Philips MRI 1.5 tesla

Statistical analysis

The collected data will be, tabulated, and statistically analyzed using SPSS program (Statistical Package for Social Sciences) software version 26.0, Microsoft Excel 2016 and MedCalC program software version 19.1. Descriptive statistics were done for numerical parametric data as mean±SD (standard deviation) and minimum & maximum of the range and for numerical non parametric data as median and 1st& 3rd inter-quartile range, while they were done for categorical data as number and percentage. Inferential analyses were done for qualitative data using Chi square test for independent groups.

Results

This prospective randomized control study was carried out on 100 pregnant women at second and third trimesters at Qena university hospital, South Valley University. They divided into two equal groups: **Group A (Cases)** who had fetus with congenital anomalies on ultrasound examination. • **Group B (Control Group):** low risk pregnancies with no detected fetal anomalies on ultrasound examination

Table (1): Demographic characteristics among the studied groups

		Group A (Cases) (n.= 50)		*Group B (Control) (n.= 50)*		Test value	P-value
		N	*%*	*N*	*%*		
Maternal age (years)	Mean± SD	28.12± 4.91		28.84± 4.25		^{Z}MWU= 0.762	0.446
	Median	28.0		28.0			
	Range	19.0- 39.0		23.0- 38.0			
Fetal age (weeks)	Mean± SD	26.52± 6.15		32.04± 4.88		^{Z}MWU= 4.397	<0.001
	Median	26.0		35.0			
	Range	15.0 – 36.0		21.0 – 36.0			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, SD: standard deviation, analysis done by Independent-Samples Mann-Whitney U Test.

Table (1) shows demographic characteristics among the studied groups. Fetal age showed significant decrease in cases in comparison with control (p<0.001). on the other hand, there was no statistically significant difference between the two studied groups regarding maternal age (p value was 0.446).

Table (2): Comparison between studied groups according to consanguinity

		Group A (Cases) (n.= 50)		*Group B (Control) (n.= 50)*		Test value	P-value
		N	*%*	*N*	*%*		
Consanguinity	No	28	56.0%	38	76.0%	X^2= 4.46	0.035
	Yes	22	44.0%	12	24.0%		

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, SD: standard deviation, analysis done by Chi-Square Test

There was consanguinity in 44% cases in group A and 24% in group B. There was statistically significant difference between the two studied groups regarding consanguinity with p value was 0.035**.** Table (2)

Table (3): Comparative study between prenatal US, prenatal MRI imaging and postnatal imaging of fetal anomalies

No. of cases	Prenatal US	Prenatal MRI	Postnatal imaging	Comment
2	Sacral agenesis+ mermaid syndrome	The same	The same	The same
2	Dilated both lateral ventricles	Aqueductal stenosis	The same as MRI	Additional information by MRI
2	Duodenal atresia	CHPS	The same as MRI (CHPS)	Change of diagnosis by MRI
2	Dilated lateral ventricles, Lemon shape skull, lumbar spina bifida	Chiari II malformation	The same as MRI	Confirm diagnosis
2	Dilated lateral ventricles, proboscis	Corpus callosum agenesis	Corpus callosum agenesis, colpocephaly+ proboscis	Additional information by US
2	Dilated lateral ventricles	Dandy walker malformation	The same as MRI	Additional information by MRI
2	Occipital encephalocele	Occipital encephalocele + spinal deformity	The same as MRI	Additional information by MRI
2	Hygroma	Hygroma	The same	Same diagnosis
2	Gastrochisis	Gastrochisis	The same	Same diagnosis
2	Pelviabdominal cystic lesion, bilateral backpressure, oligohydramnios	Urethral stricture	The same	Additional information by MRI
2	exencephaly	exencephaly	Missed case due to termination of pregnancy	Missed case

No. of cases	Prenatal US	Prenatal MRI	Postnatal imaging	Comment
2	Thantophoric dysplasia	Missed	the same as ultrasound	Missed by prenatal MRI
2	Chiari II and LSS myelomeningocele	Chiari II and LSS myelomeningocele	The same	Same diagnosis
2	Anencephaly	Anencephaly	The same	Same diagnosis
2	Ventriculomegaly	Aqueductal stenosis	The same as MRI	Additional information by MRI
2	Multicystic dysplastic kidney disease	The same	The same	Same diagnosis
2	Pulmonary hypoplasia	Pulmonary hypoplasia	Missed case due to IUFD	Missed case
2	Posterior urethral valve	Posterior urethral valve+ right renal cyst	The same as MRI	Additional information by MRI
2	Double bubble sign	Duodenal atresia	Missed case due to termination of pregnancy	Missed case postnatal
2	Polycystic kidney	Polycystic kidney	The same	Same diagnosis
2	Renal agenesis	Renal agenesis	Missed case due to IUFD	Missed case postnatal
2	Intracranial cyst	Intracranial cyst	The same as MRI	Same diagnosis
2	Asymmetrical dilatation of both lateral ventricles	aqueductal stenosis	The same as MRI	Additional information by MRI
2	Right renal simple cyst	Mesenteric /enteric cyst	The same as MRI	Change of diagnosis by MRI
2	Hepatic simple cyst	The same diagnosis	The same	Same diagnosis

Different types of congenital anomalies. MRI and ultrasound showed concordant findings in 18 (36%) cases. MRI changed the diagnosis in 4 (8%) cases and provided additional information in 16 (32%) cases. Ultrasound was superior to magnetic resonance imaging in 4 cases. Table (3)

Table (4): Comparison between prenatal MRI and postnatal diagnosis in detection of prenatal congenital CNS anomalies

Prenatal MRI	Postnatal diagnosis					X2	P-value
	Negative		Positive		Total		
	No.	%	No.	%			
Negative	0	0%	4	8%	4	0.828	0.486
Positive	8	16%	38	76%	46		
Total	8	16%	42	84%	50 (100%)		

p≤0.05 is considered statistically significant, p≤0.01 is considered high statistically significant,
-comparison between groups done by Pearson Chi-Square test

There was no significant difference between prenatal MRI and postnatal diagnosis in detection of prenatal congenital CNS anomalies with p value was 0.123. Table (4)

Table (5): Inter-rater agreement of prenatal US and prenatal MRI in assessment of fetal GIT anomalies

		MRI		Total	Agreement	
		Negative	Positive		Kappa	p-value
US	Negative	40	4	44	0.706	**<0.001**
	Positive	0	6	6		
	Total	40	10	50		

Kappa statistics revealed good agreement between prenatal US and prenatal MRI of fetal GIT anomalies (kappa =0.706). Table (5)

Table (6): Inter-rater agreement of prenatal US and prenatal MRI in assessment of fetal renal anomalies

		MRI		Total	Agreement	
		Negative	Positive		Kappa	p-value
US	Negative	38	6	44	0.603	**<0.001**
	Positive	0	6	6		
	Total	38	12	50		

Kappa statistics revealed good agreement between prenatal US and prenatal MRI of fetal renal anomalies (kappa =0.603). Table (6)

Table (7): Comparative study between prenatal US, prenatal MRI imaging and postnatal imaging of other anomalies

No. of cases	Prenatal US	Prenatal MRI	Postnatal imaging	Comment
2	Sacral agenesis+ mermaid syndrome	The same	The same	Same diagnosis
2	Hygroma	Hygroma	The same	Same diagnosis
2	Thantophoric dysplasia	Missed	the same as ultrasound	Missed by prenatal MRI
2	Pulmonary hypoplasia	Pulmonary hypoplasia	Missed case due to IUFD	Missed case

Different types of other congenital anomalies. MRI and ultrasound showed concordant findings in 4 (8%) cases. It was found that ultrasound superior to magnetic resonance imaging in 2 (4%) cases with musculoskeletal anomalies. Table (7)

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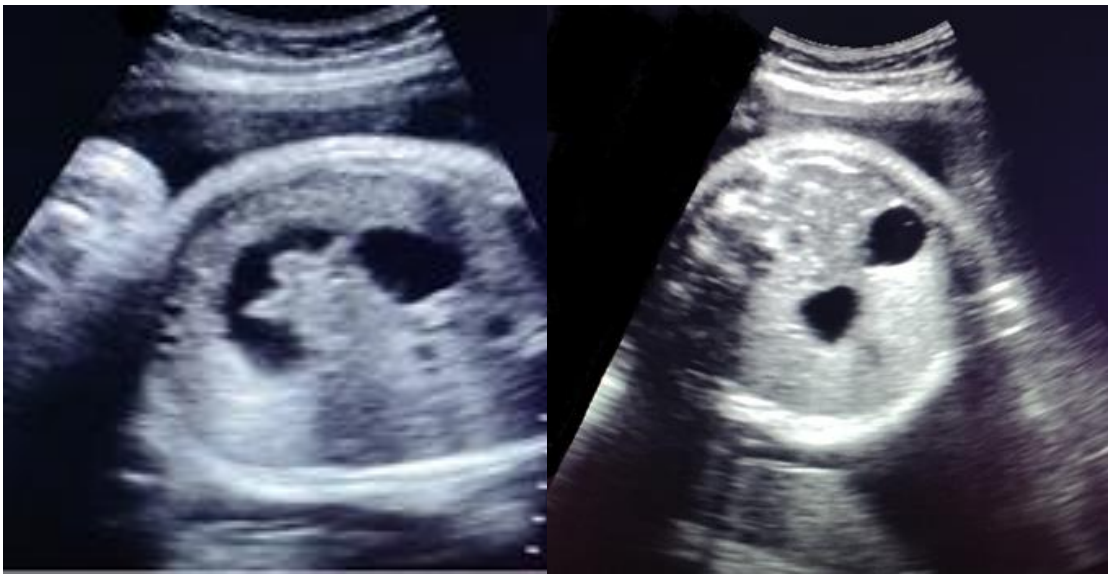
A 29-years-old woman, at 35 weeks of gestation complaining of polyhydraminos with history of? Duodenal atresia in previous baby who had IUFD.

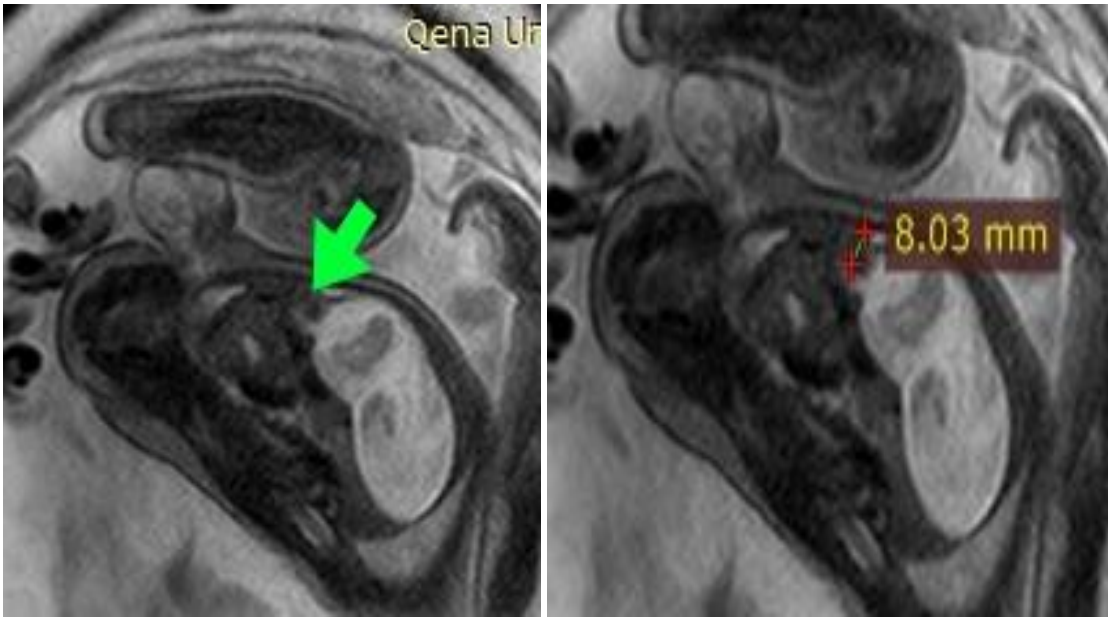
Ultrasonography: polyhydraminos, distended stomach with double bubble sign suggesting duodenal atresia.

Antenatal MRI: dilated stomach with thick elongated pyloric canal with single wall thickness (+/-8mm): polyhydramnios >>> intra uterine hypertrophic pyloric stenosis.

Postnatal ultrasound: thickened elongated pyloric canal, Length (19mm): W (15mm): single wall thickness (8mm)>>> congenital hypertrophic pyloric stenosis.



(A) **(B)**



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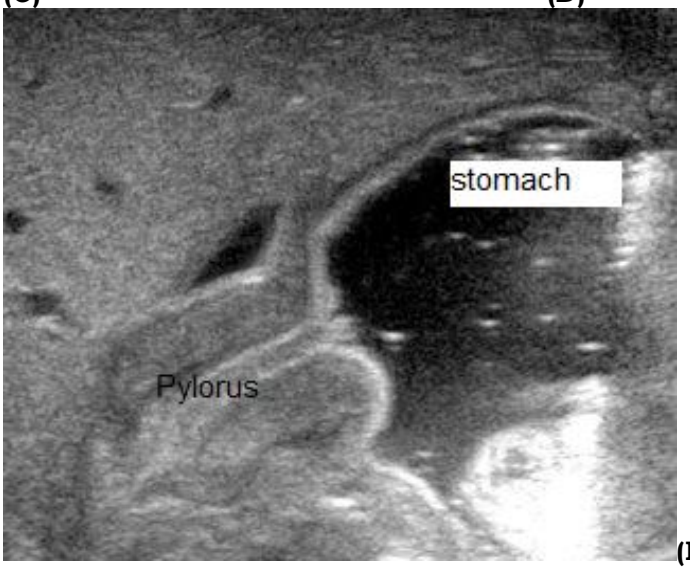


(E)

A , B- US of the fetal abdomen axial view showing dilated stomach with double bubble sign

C, D-MRI of the fetal abdomen sagittal view showing dilated stomach with thickened pyloric canal

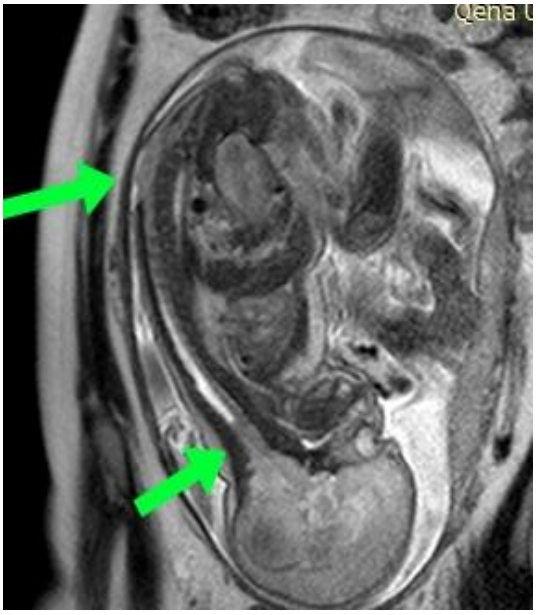
E-Postnatal abdominal ultrasound confirmed the diagnosis of hypertrophic pyloric stenosis.

A 22-years-old woman at 32weeks of gestation, positive consanguinity, no history of congenital anomalies

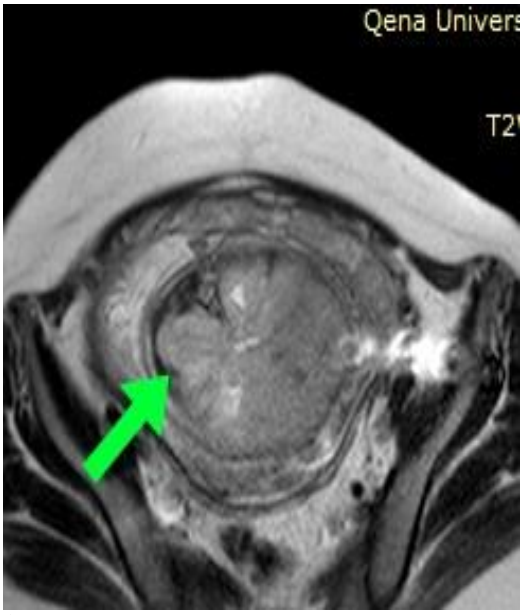
Obstetric Ultrasonography: Dilated lateral ventricles, Lemon shape skull, lumbar spina bifida (suggesting Chiari II malformation).

Antenatal MRI:
Mildly dilated lateral ventricles, small posterior fossa with downward herniation of cerebellar vermis and brain stem through foramen magnum to upper cervical spine with elongated low lying 4th ventricle , lumbosacral spina bifida with subcutaneous cystic lesion filled with CSF and neural content>>>> Chiari II malformation.

Postnatal MRI: Confirmed the diagnosis (Chiari II malformation)



(**A**)



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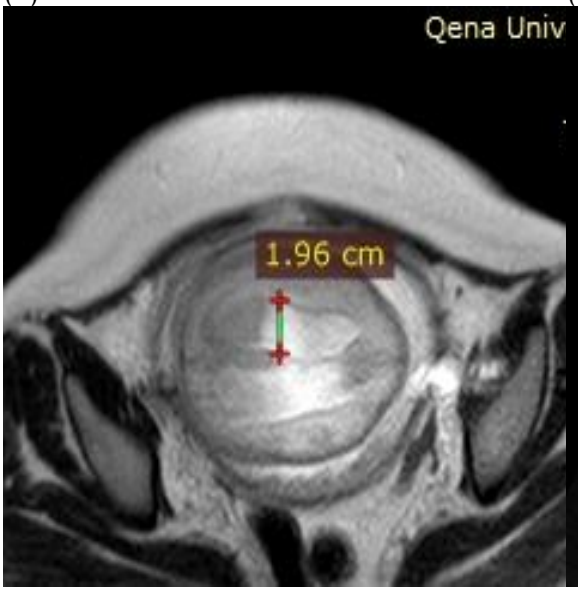
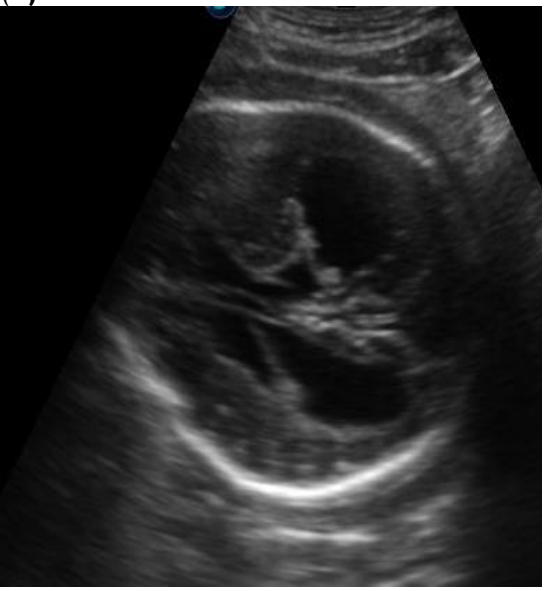
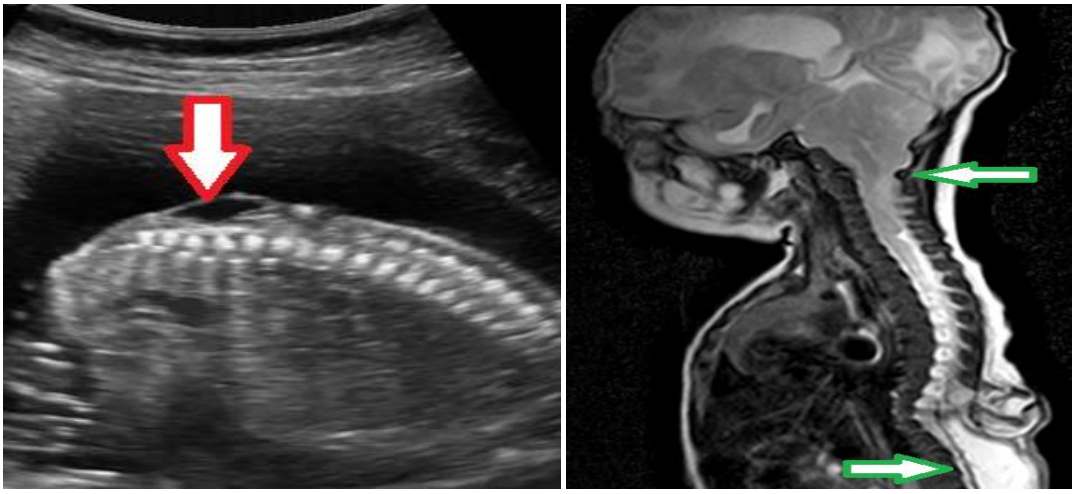


(C)



(**D**)



(E) **(F)**

(A): (B): Sagittal and axial fetal MRI show downward herniation of cerebellar vermis and brain stem through foramen magnum to upper cervical spine and lumbosacral myelomeningocele (green arrows).
(C): axial MRI of the fetal head show dilatation of both lateral ventricles.
(D): axial ultrasound of the fetal head show dilatation of both lateral ventricles with lemon shape skull
(E): sagittal view ultrasound of the fetal spine show lumbar myelomeningocele.
(F): postnatal MRI confirms the diagnosis of Chiari II malformation.

Discussion

Magnetic resonance imaging (MRI) is indispensable in clinical medicine for the morphological and tomographic evaluation of many parenchymal organs. With varied imaging methods, diverse biological information, such as the perfusion volume and measurements of metabolic products, can be obtained (6). Ultrasound imaging is considered by many to be a mature imaging technology, but the review by Wang et al, (7) in this issue of Investigational Radiology highlights the myriad advancements that prove it is anything but a plateaued technique. The inception of ultrasound as an imaging modality harkens back to the post World War II era when a diverse cadre of investigators involved in sonar and radar research began to explore the technology's diagnostic potential (8).

Congenital anomalies, also commonly referred to as birth defects, congenital disorders, congenital malformations, or congenital abnormalities, are conditions of prenatal origin that are present at birth, potentially impacting an infant's health, development and/or survival (9). In the present study, there was no statistically significant difference between the two studied groups regarding maternal age (p value was 0.446). Conceding with this results, Kurdi et al., (10) study showed that the burden of potentially modifiable risk factors included maternal age >40 years. In contrary to our results, Kwamboka et al., (11) study reported that there was no significant association between maternal age with the prevalence of congenital anomalies.
Based on postnatal diagnosis as a reference standard, prenatal MRI had overall sensitivity, specificity, and diagnostic accuracy of 90.5%, 100% and 92%

respectively in fetal anomalies in our cases. Positive predictive value was 100% while the negative predictive value was 66.7%. While prenatal US had overall sensitivity, specificity, and diagnostic accuracy of 76.19%, 100% and 80% respectively in fetal anomalies in our cases. Positive predictive value was 100% while the negative predictive value was 44.4%.

In agreement to our study, Recio Rodríguez et al., (12) study reported that the diagnostic accuracy of the fetal MRI was higher than that of fetal ultrasound in all cases and all indications. The differences in diagnostic accuracy between fetal ultrasound and fetal MRI were significant for all cases (90.4% vs 97%; $p<0.001$). In addition Our results agreed with those obtained by Recio Rodríguez et al., (12) study which showed that the diagnostic accuracy of the fetal MRI was higher than that of fetal ultrasound and the differences in diagnostic accuracy between fetal ultrasound and fetal MRI were significant for CNS pathology (89.7% vs 98.1%; $p<0.001$) while fetal ultrasound and fetal MRI were concordant in 90.2% of the cases.

Diagnostic performance of MRI was significantly higher than that of the US ($p < 0.05$) in the diagnosis of fetal craniospinal anomalies. In 28.7% cases, prenatal MRI contributed to US by either changing the wrong US diagnosis (8.9%): demonstration of additional findings (14%): or confirming the suspicious US diagnosis (5.8%) in Eyüboğlu & Dinç, (13) study. Tuan Linh et al, (14) study evaluated the ability to detect fetal central nervous system (CNS) anomalies using in utero magnetic resonance imaging (iuMRI) and ultrasound (US) techniques. According to this study, the comparison of iuMRI and US findings revealed similar diagnoses for 71 abnormalities (67%) and different diagnoses for 35 abnormalities (33%).

Conceding with our results regarding the superiority of MRI, Manganaro et al., (15) study reported that fetal MRI was able to confirm the sonographic findings in nine of 38 fetuses (23.7 %): to provide additional information in 23 of 38 fetuses (60.6 %): to exclude the US diagnosis in five cases (5.2 %) and to change it in two cases (5.2 %). Similar results reported in Chauhan & Nandolia, (16) study. According to postnatal imaging of fetal renal anomalies in our study, MRI and ultrasound showed concordant findings in 6 cases. It was found that was magnetic resonance superior to ultrasound imaging in 4 cases as MRI changed the diagnosis in 2 cases and provided additional information 2 cases. There was a moderate agreement between prenatal US and prenatal MRI of fetal renal anomalies. This result agreed with Recio Rodríguez et al., (12) study which reported that fetal MRI provided additional over fetal ultrasound in 16.7% of cases.

Our study showed that US was superior to MRI in the assessment of sacral agenesis with mermaid syndrome according to postnatal imaging. This result overlapped with the study which showed that a statistically significant relationship was observed between ultrasonographic and MRI findings in sacral agenesis.

Conclusion

Fetal MRI has a superior diagnostic accuracy. It had a higher sensitivity for diagnosing CNS anomalies than did US, and provides additional findings in anomalies of CNS, GIT, and renal systems.

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