Fetal cardiac MRI for congenital heart disease

Shanghai Children’s Medical Center

Introduction

CHD is the most common type of birth defects in China

2000-2017年全国围产期主要出生缺陷发生率（1/万）顺位

顺位	2000年	2005年	2010年	2015年	2016年	2017年
1	总唇裂 (14.07)	先天性心脏病 (23.96)	先天性心脏病 (32.74)	先天性心脏病 (66.51)	先天性心脏病 (62.10)	先天性心脏病 (71.53)
2	多指/趾 (12.45)	多指/趾 (14.66)	多指/趾 (16.39)	多指/趾 (18.07)	多指/趾 (18.53)	多指/趾 (18.74)
3	神经管缺陷 (11.96)	总唇裂 (13.73)	总唇裂 (12.78)	总唇裂 (7.41)	总唇裂 (6.97)	马蹄内翻 (6.64)
4	先天性心脏病 (11.40)	神经管缺陷 (8.84)	脑积水 (6.02)	马蹄内翻 (6.20)	并指（趾） (6.07)	并指（趾） (6.21)
5	脑积水 (7.10)	脑积水 (7.52)	神经管缺陷 (5.74)	脑积水 (5.30)	马蹄内翻 (6.00)	总唇裂 (6.01)
6	肢体短缩 (5.79)	肢体短缩 (5.76)	马蹄内翻 (5.08)	并指（趾） (5.17)	尿道下裂 (4.99)	尿道下裂 (5.42)
7	马蹄内翻 (4.97)	尿道下裂 (5.24)	尿道下裂 (4.87)	尿道下裂 (5.10)	脑积水 (4.50)	脑积水 (4.17)
8	尿道下裂 (4.07)	马蹄内翻 (5.06)	并指（趾） (4.81)	小耳 (3.03)	小耳 (3.06)	直肠肛门闭锁或狭窄（2.87）
9	并指（趾） (3.95)	并指（趾） (4.94)	肢体短缩 (4.74)	直肠肛门闭锁或狭窄（2.89）	肢体短缩 (2.93)	腭裂 (2.72)
10	直肠肛门闭锁或狭窄（3.43）	小耳 (3.60)	小耳 (3.09)	肢体短缩 (2.86)	直肠肛门闭锁或狭窄（2.59）	肢体短缩 (2.66)

Introduction

- Prenatal detection of CHD such as transposition of great arteries, pulmonary atresia with intact ventricle septum, hypoplastic left heart syndrome, obstructive total anomalous pulmonary venous connection may reduce associated mortality
- MRI has been confirmed as an important tool for the fetal central nervous and other system. MRI has also been confirmed as a powerful imaging tool for CHD in infants

Introduction

- Fetal cardiac MRI should be an useful imaging tool for CHD. But it still is one of the most difficult imaging examination and the clinical experience remains limited

- The fetal heart is routinely studied using echocardiography. Unlike echo, MRI is relatively unaffected by maternal conditions such as obesity, twins, uterine myoma and oligohydramnios which impair US visualization

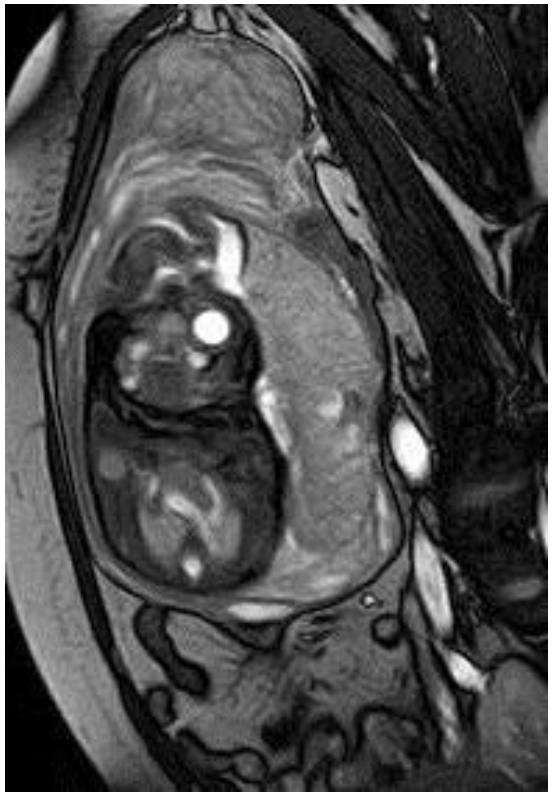
Introduction

- There also has been general agreement that MRI can provide some additional information for fetal cardiac tumor, pericardium cyst, pericardium effusion and cardiomegaly
- The question is whether MRI can provide different information for CHD when fetal echo is not affected by mother obesity, uterine myoma, twins and oligohydramnios

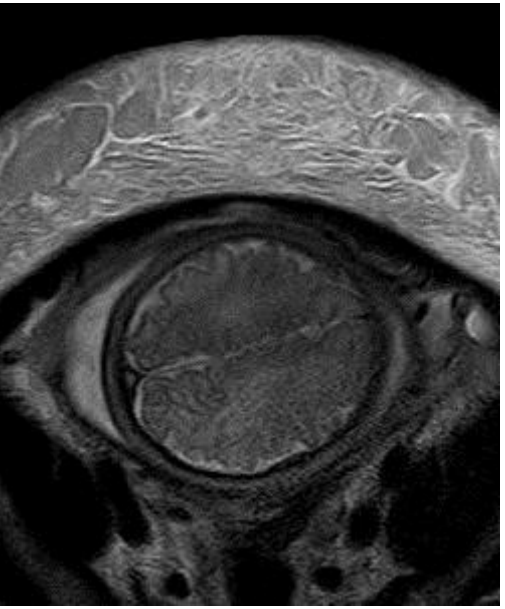
Conjoined Twins and Twins with TGA

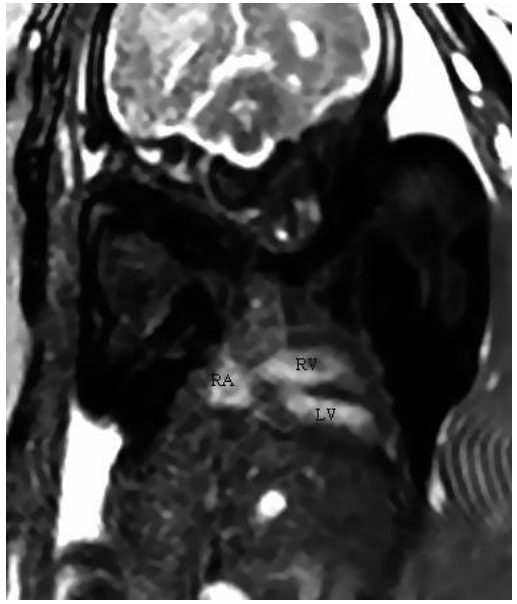
TOF— oligohydramnios

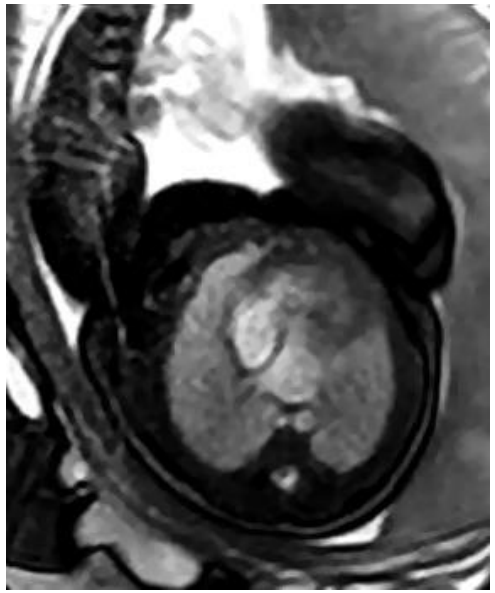


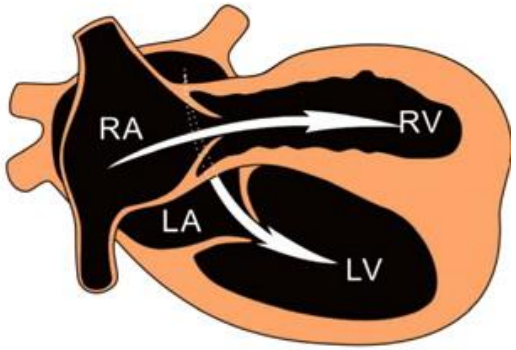


Criss-Cross Heart– mother obesity



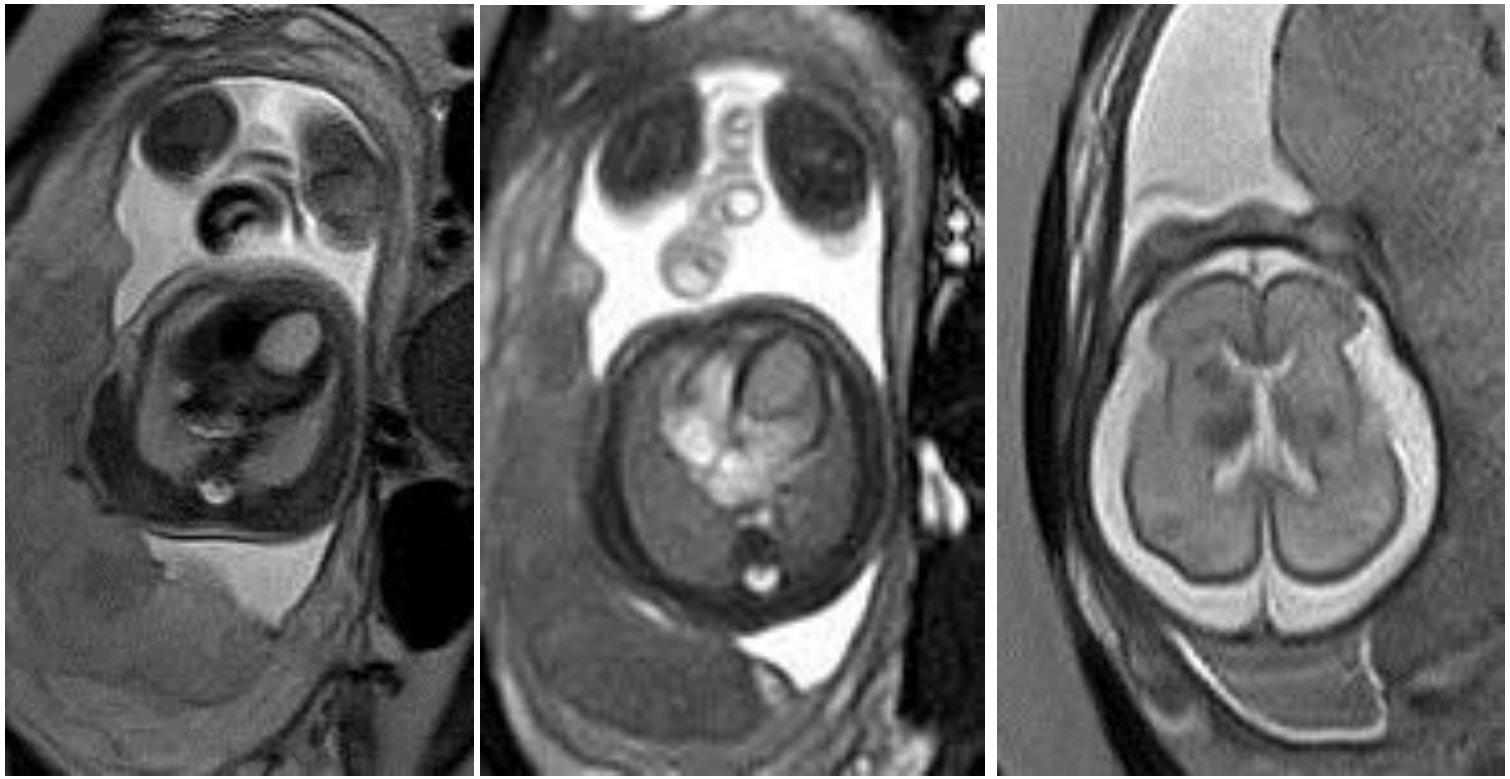


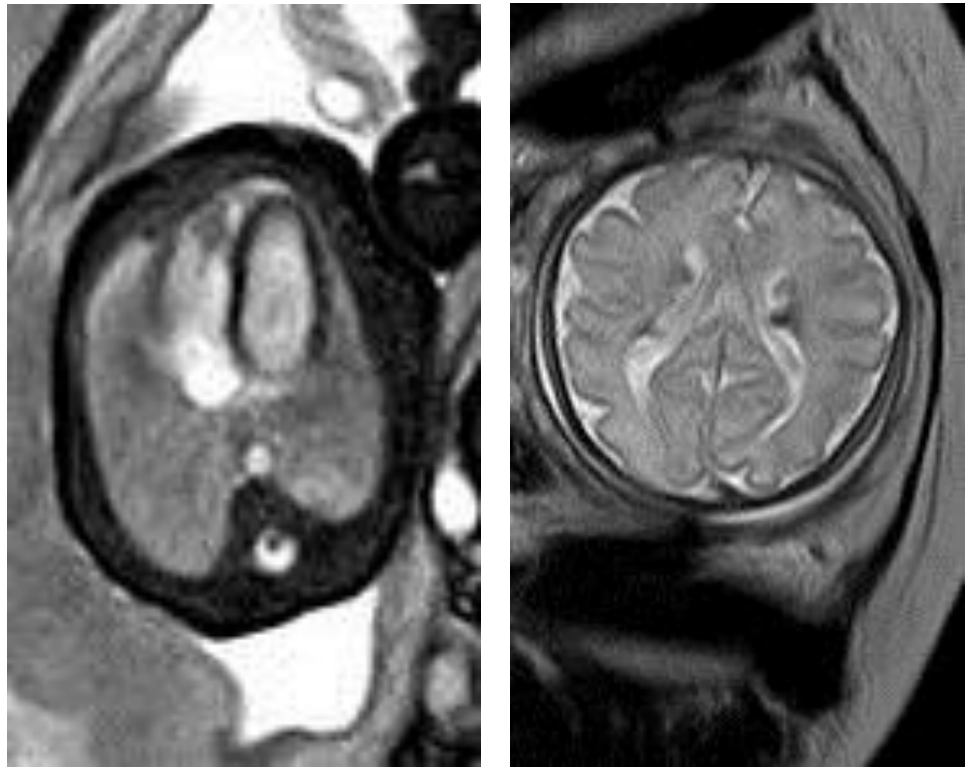




Thoracic ectopia cordis

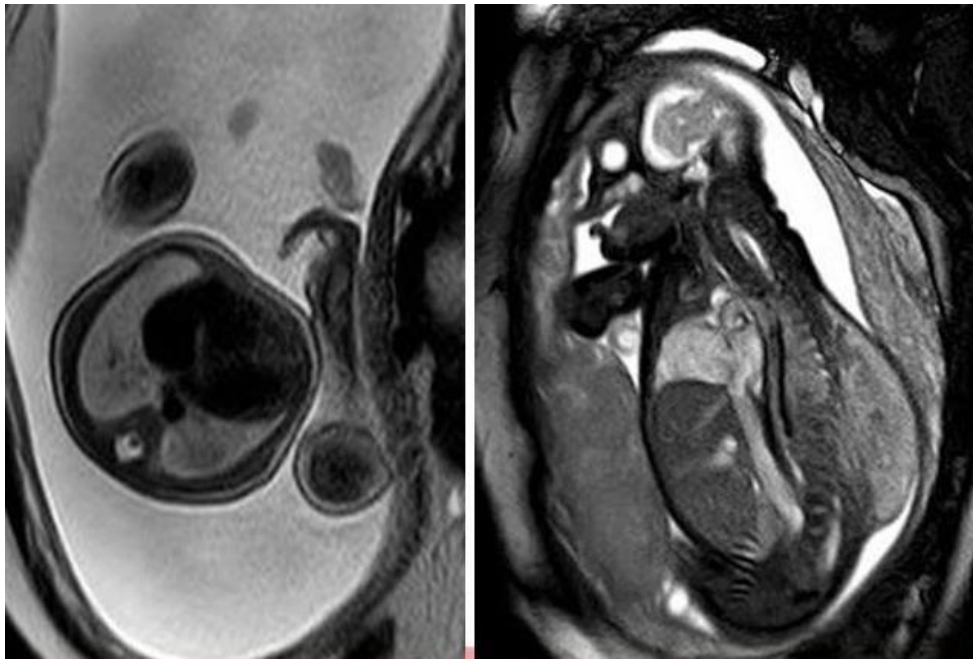
Rhabdomyoma with tuberous sclerosis



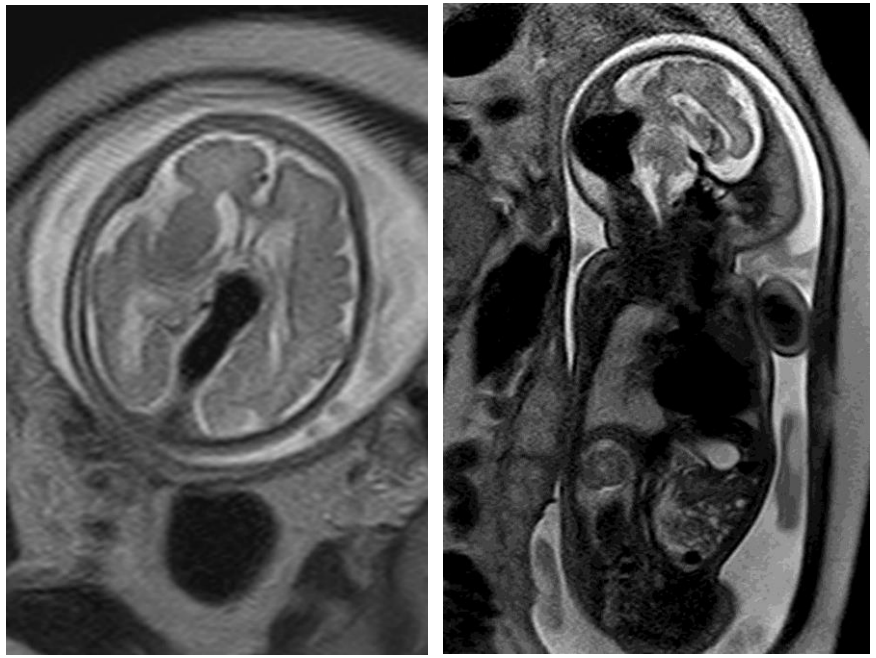


Cardiomegaly

Hemangioendothelioma



Vein of Galen malformation



Fetal cardiac MRI articles in Lancet 2019

Lancet. 2019 Mar 22. pii: S0140-6736(18)32490-5. doi: 10.1016/S0140-6736(18)32490-5. [Epub ahead of print]

Three-dimensional visualisation of the fetal heart using prenatal MRI with motion-corrected slice-volume registration: a prospective, single-centre cohort study.

Lloyd DFA[1], Pushparajah K[1], Simpson JM[2], van Amerom JFP[3], van Poppel MPM[3], Schulz A[3], Kainz B[4], Deprez M[3], Lohezic M[3], Allsop J[3], Mathur S[2], Bellsham-Revell H[2], Vigneswaran T[2], Charakida M[2], Miller O[2], Zidere V[2], Sharland G[2], Rutherford M[3], Hajnal JV[3], Razavi R[5].

Author information

Abstract

BACKGROUND: Two-dimensional (2D) ultrasound echocardiography is the primary technique used to diagnose congenital heart disease before birth. There is, however, a longstanding need for a reliable form of secondary imaging, particularly in cases when more detailed three-dimensional (3D) vascular imaging is required, or when ultrasound windows are of poor diagnostic quality. Fetal MRI, which is well established for other organ systems, is highly susceptible to fetal movement, particularly for 3D imaging. The objective of this study was to investigate the combination of prenatal MRI with novel, motion-corrected 3D image registration software, as an adjunct to fetal echocardiography in the diagnosis of congenital heart disease.

METHODS: Pregnant women carrying a fetus with known or suspected congenital heart disease were recruited via a tertiary fetal cardiology unit. After initial validation experiments to assess the general reliability of the approach, MRI data were acquired in 85 consecutive fetuses, as overlapping stacks of 2D images. These images were then processed with a bespoke open-source reconstruction algorithm to produce a super-resolution 3D volume of the fetal thorax. These datasets were assessed with measurement comparison with paired 2D ultrasound, structured anatomical assessment of the 2D and 3D data, and contemporaneous, archived clinical fetal MRI reports, which were compared with postnatal findings after delivery.

Fetal MRI and prenatal diagnosis of congenital heart defects

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See Online/Articles
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Congenital anomalies are among the leading causes of infant mortality in developed countries.[1] Mortality associated with congenital heart defects is decreasing; however, it remains unacceptably high.[2] The conventional approach for prenatal diagnosis of congenital heart defects is two-dimensional (2D) fetal echocardiography. Using this approach, one group[3] reported a significant increase in the detection of congenital heart defects (from 35·8% to 59·7%) after the introduction of a national screening programme. Over the past decade, the use of three-dimensional (3D) and four-dimensional (4D) fetal echocardiography has been introduced into clinical practice as a strategy to facilitate

2D ultrasonography and those obtained from reconstructed 3D datasets obtained from 2D MRI data (0·78, 0·68–0·84). The authors show that high-resolution 3D imaging of the fetal cardiovascular system can be obtained with the proposed algorithm, which could be complementary to fetal echocardiography. To support this hypothesis, the authors reported that in ten cases, MRI-reconstructed datasets allowed for the identification of anatomical features that had not been previously described using ultrasonography.

In 4D fetal echocardiography, volume datasets obtained with spatiotemporal image correction can be compared with blocks of pathological specimens

Methods

- Fetal cardiac MRI is a clinical examination in Shanghai Children’s Medical Center from July 2005 to April 2019
- We usually finish a fetal cardiac MRI examination in 20-40 minutes
- We have scanned more than 3000 fetal heart cases
- The fetal cardiac MRI examinations were performed at 16 to 39 weeks' gestation

Technique

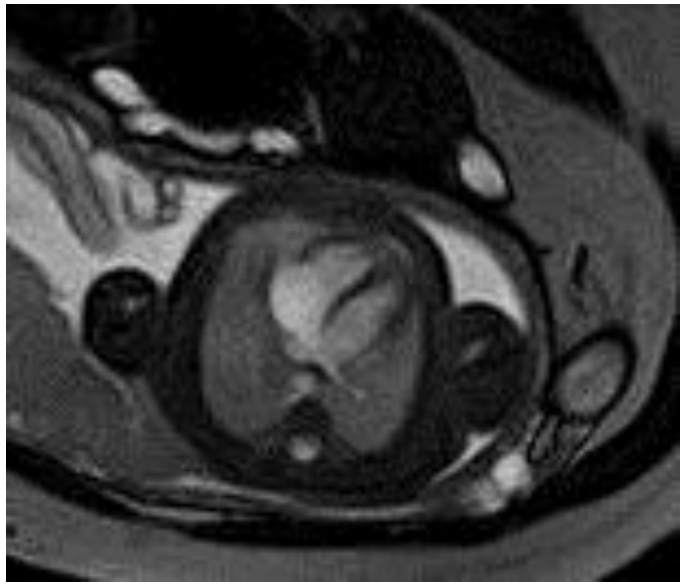
- Fetal cardiac MRI was performed with two 1.5T MR unit (Signa Echospeed; GE and Achieva Nova dual; Philips) and one 3.0 T unit（Discovery 750; GE ）
- No sedatives, intravenous gadolinium-based contrast media, or fetal cardiac gating were used in any of the cases in the study

Imaging sequences

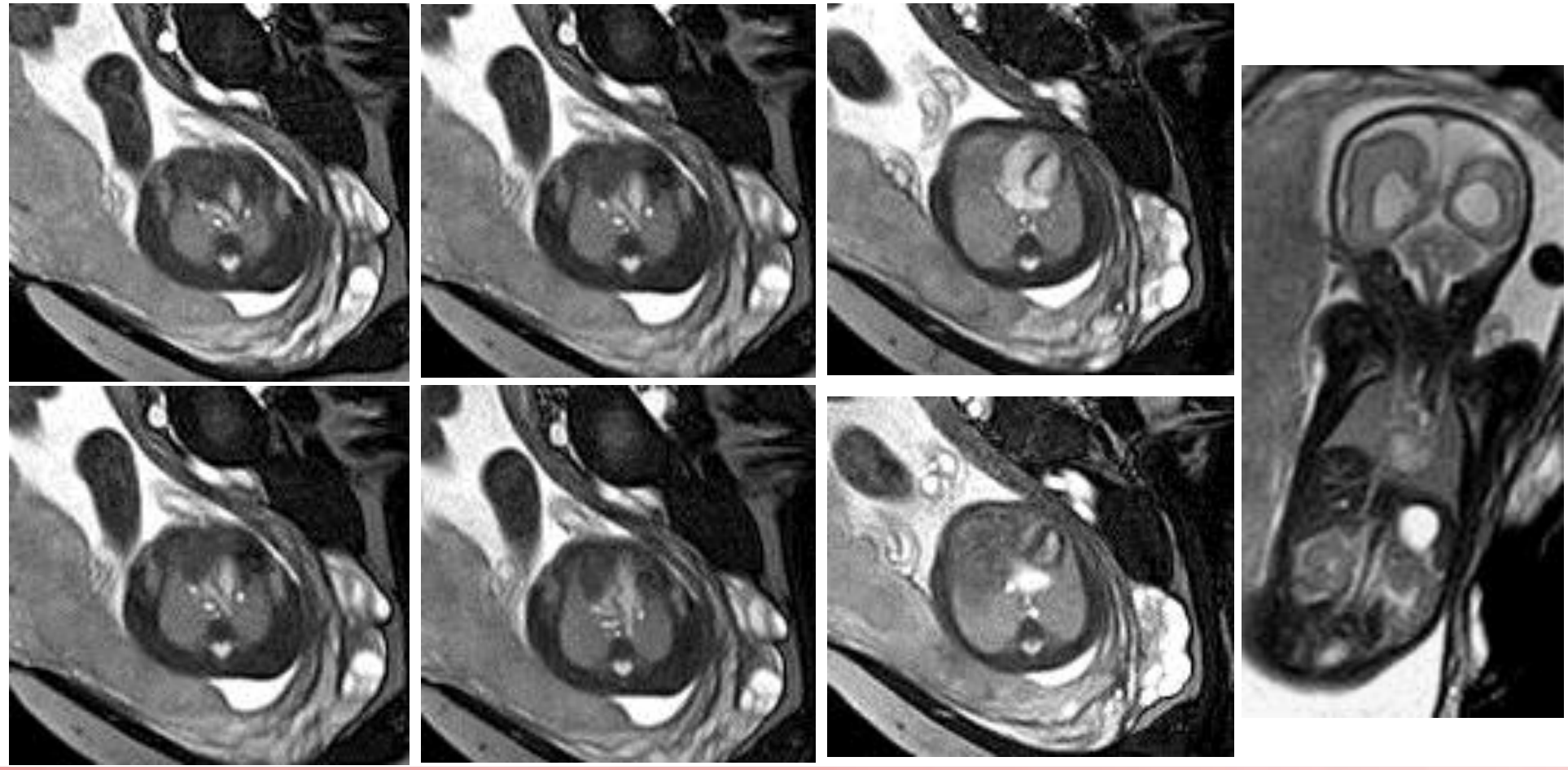
- 2D SSFP (Steady-State Free-Precession). B- TFE sequence with overlapping slice is a key point of scan technique
- Real time non gated SSFP Cine
- SS-TSE or SS FSE
- Non gated PC Cine

SSFP，Normal

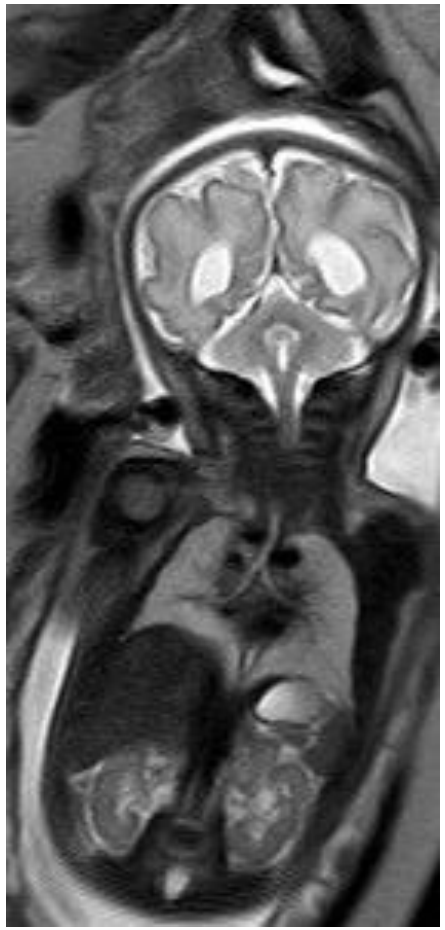





LSVC- Overlapping slice (slice thickness 5mm; spacing -4 mm)



SS TSE

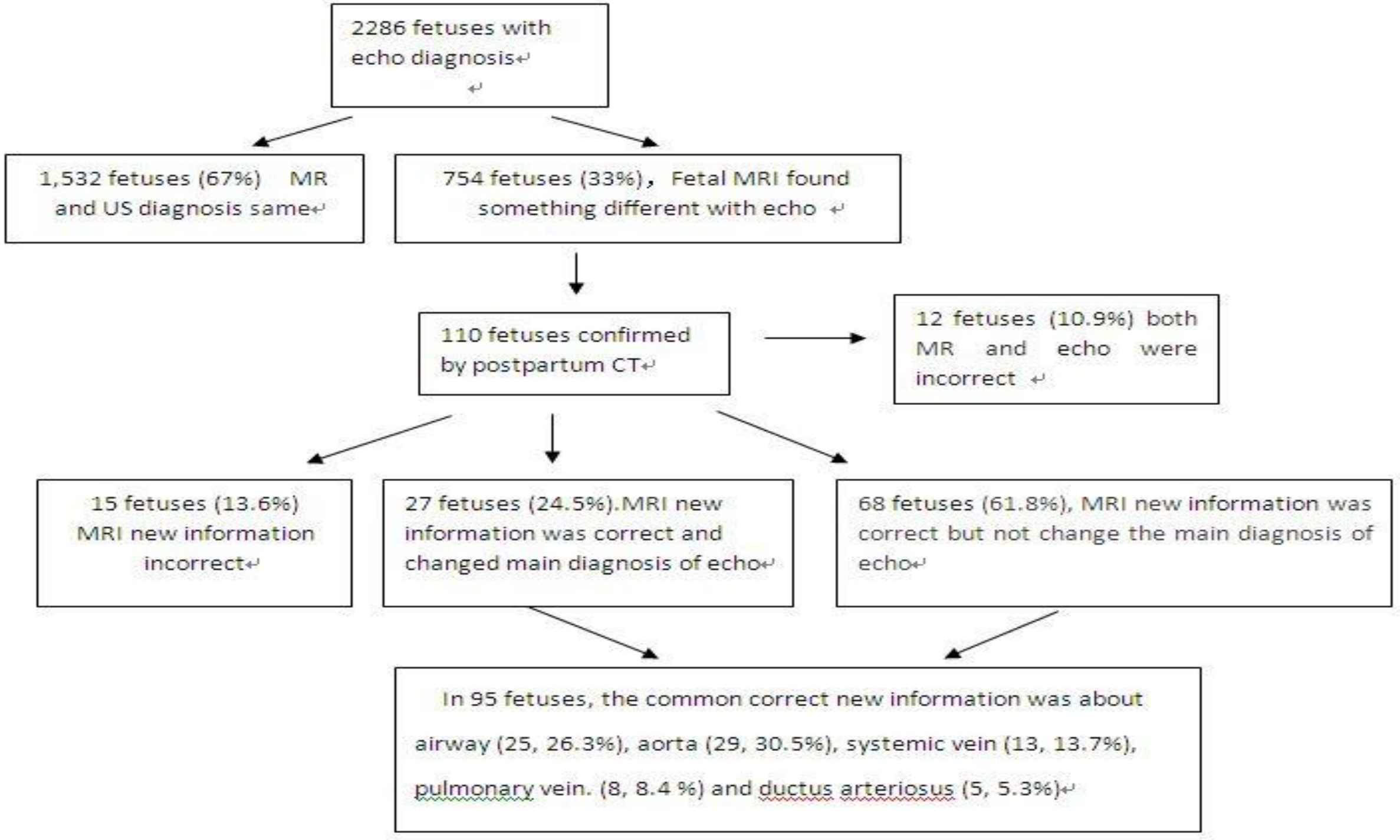


Results

- Fetal MRI confirmed the echo diagnosis without additional information in 67% cases
- Fetal MRI provided additional information to the prenatal echo diagnosis in 33% cases
- In the 33% cases, the new information was incorrect in 13.6% cases and was correct in 86.4% cases

Results

- In the 86.4% cases, the new information changed the main diagnosis of echo in 24.5% cases. The new information was correct but did not change the main diagnosis of echocardiography alone in 61.8% cases
- The most common correct new information was about airway, aortic arch and systemic vein


2286 fetuses with echo diagnosis
1,532 fetuses (67%) MR and US diagnosis same
754 fetuses (33%), Fetal MRI found something different with echo
110 fetuses confirmed by postpartum CT
12 fetuses (10.9%) both MR and echo were incorrect
15 fetuses (13.6%) MRI new information incorrect
27 fetuses (24.5%).MRI new information was correct and changed main diagnosis of echo
68 fetuses (61.8%), MRI new information was correct but not change the main diagnosis of echo
In 95 fetuses, the common correct new information was about airway (25, 26.3%), aorta (29, 30.5%), systemic vein (13, 13.7%), pulmonary vein. (8, 8.4 %) and ductus arteriosus (5, 5.3%)

Articles with similar results

Arch Gynecol Obstet. 2019 May 1. doi: 10.1007/s00404-019-05169-x. [Epub ahead of print]

Another merit of fetal MRI in prenatal diagnosis of right aortic arch.

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3 Obstetrics and Gynecology, Jichi Medical University, 3311-1 Yakushiji, Shimotsuke, 329-0498, Tochigi, Japan.

Arch Gynecol Obstet. 2019 May 1. doi: 10.1007/s00404-019-05166-0. [Epub ahead of print]

Response: "Another merit of fetal MRI in prenatal diagnosis of right aortic arch".

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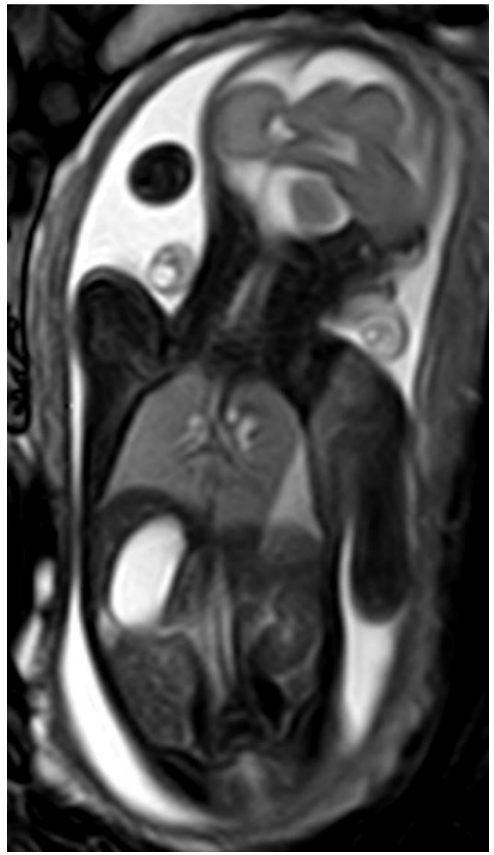
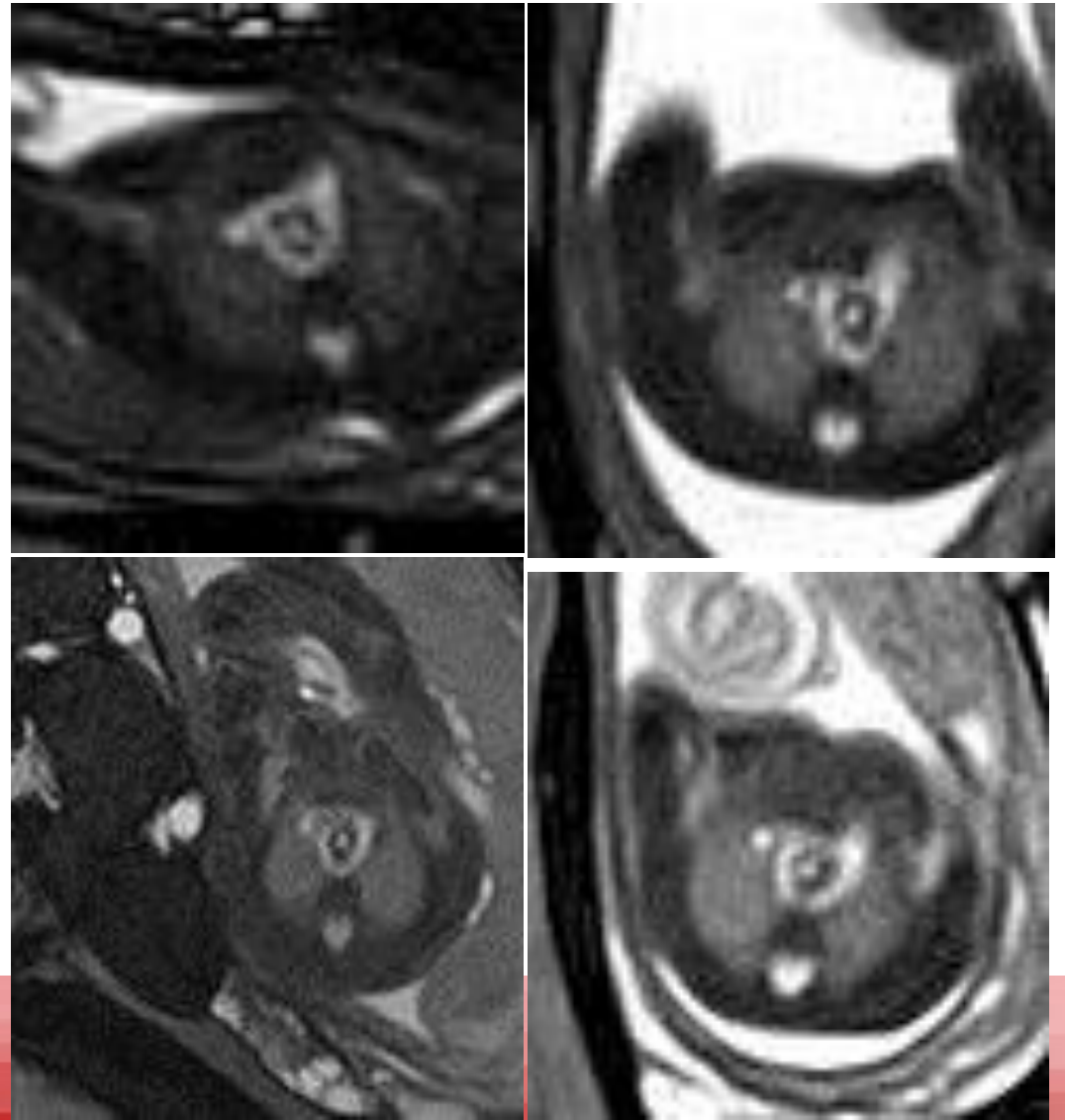
Fetal air way



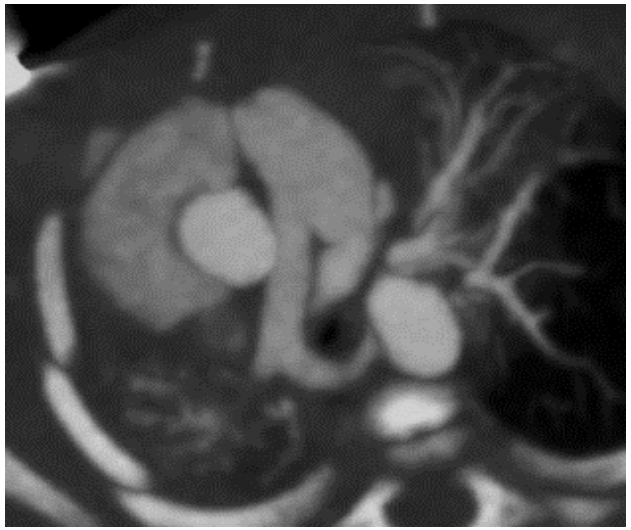



Double aortic arch and air way

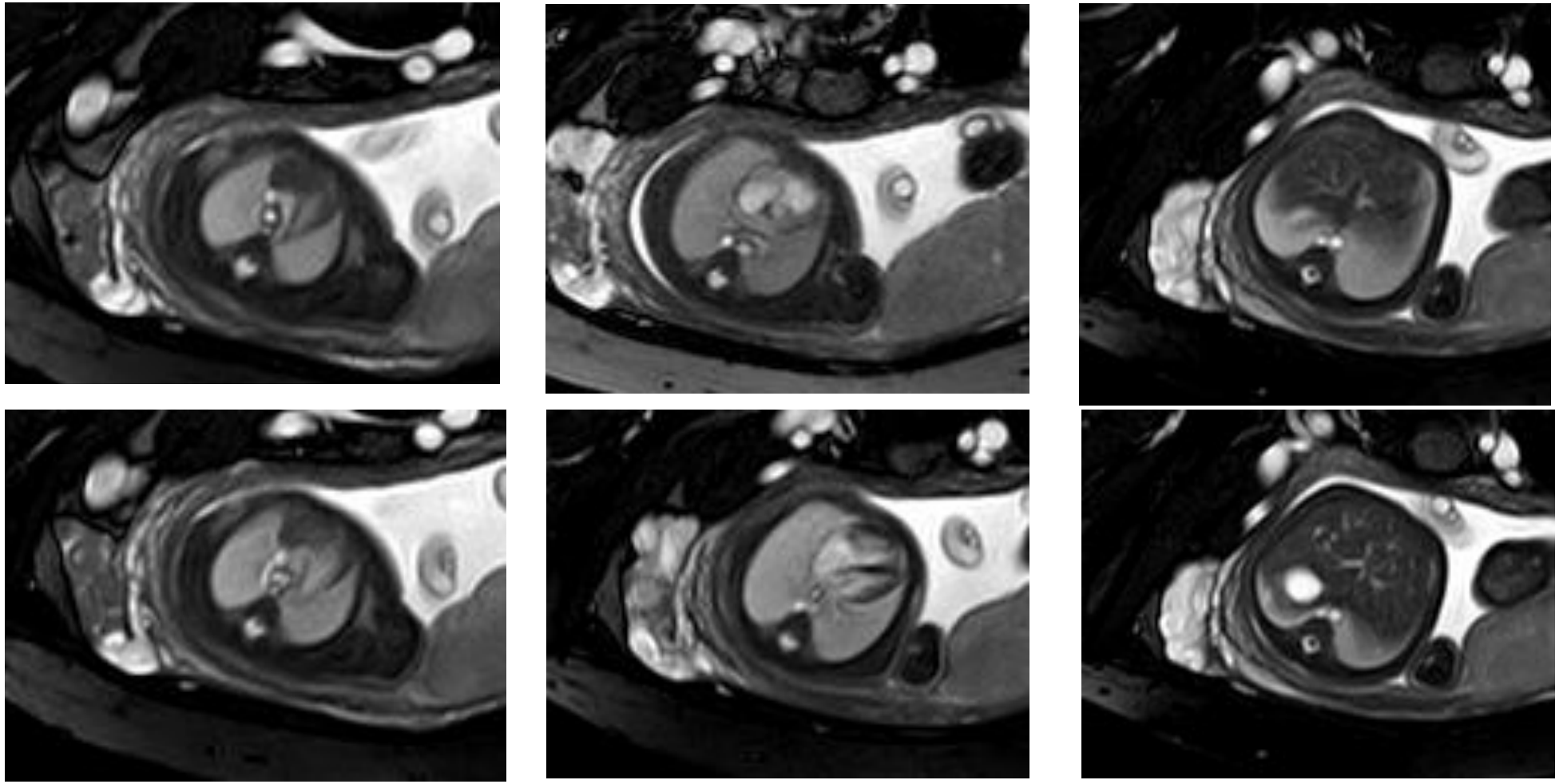


Fetal air way- pulmonary sling

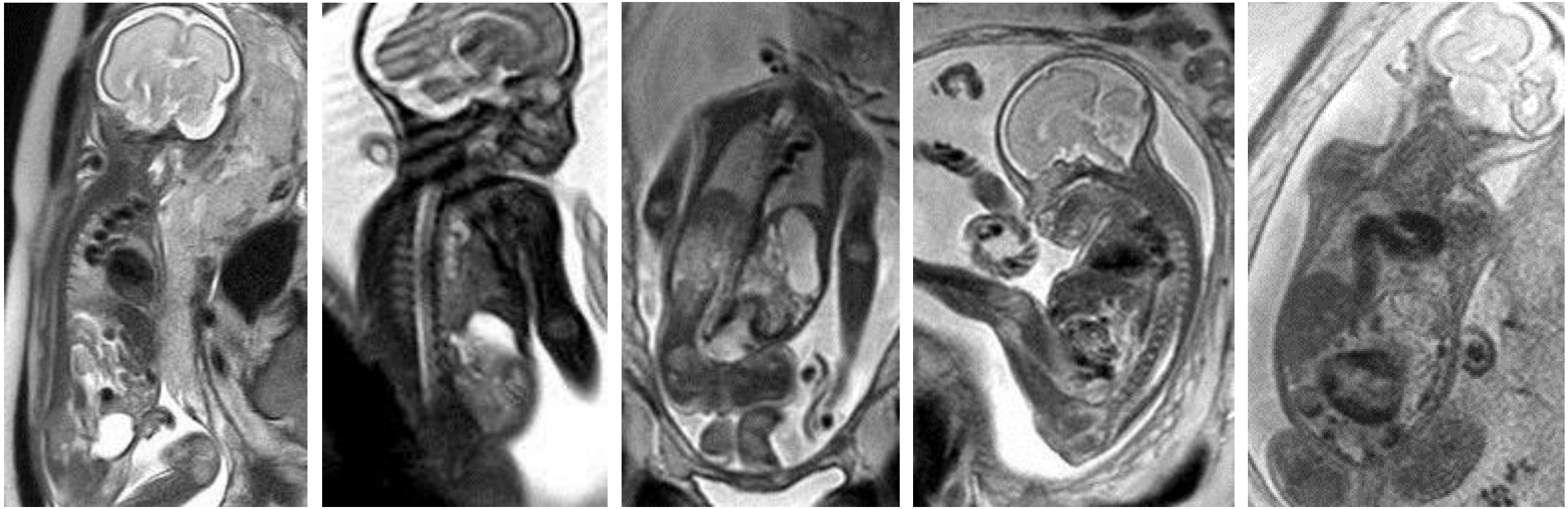




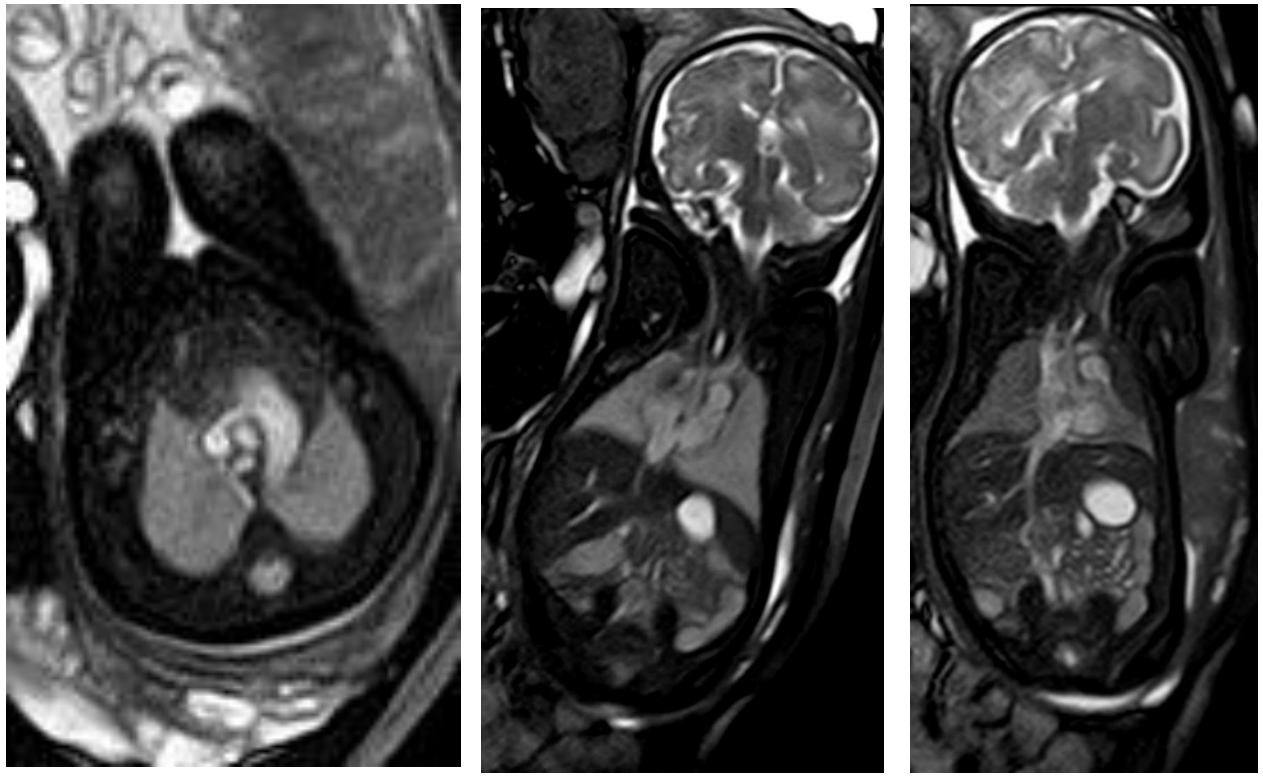

Polysplenia syndrome

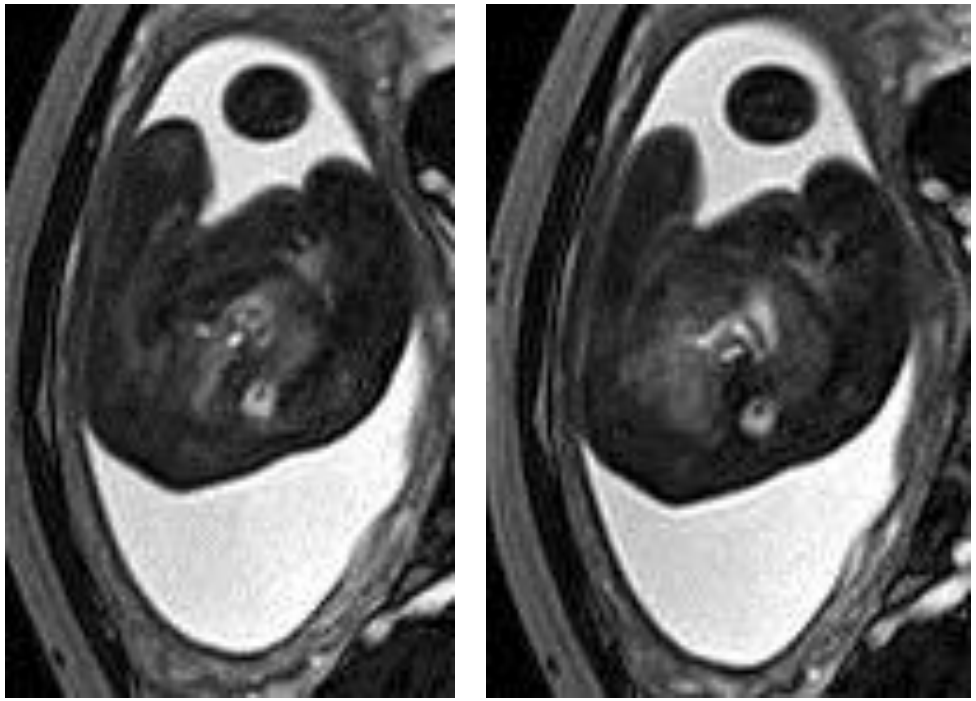


Arterial Tortuosity Syndrome, ATS



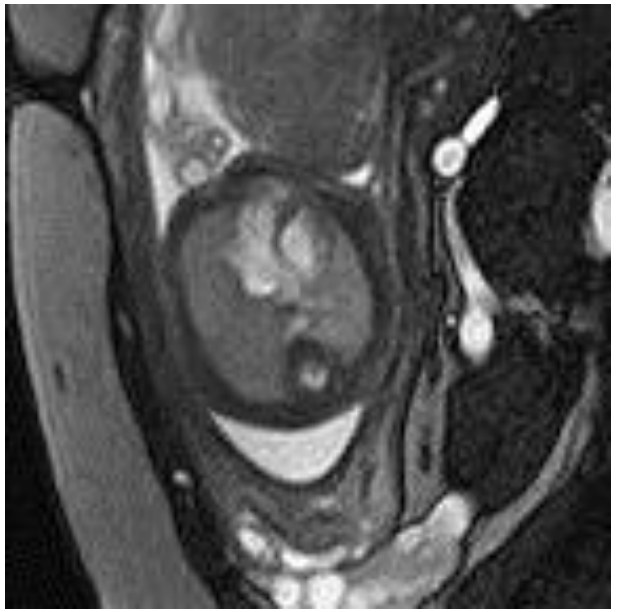
IAA, CoA



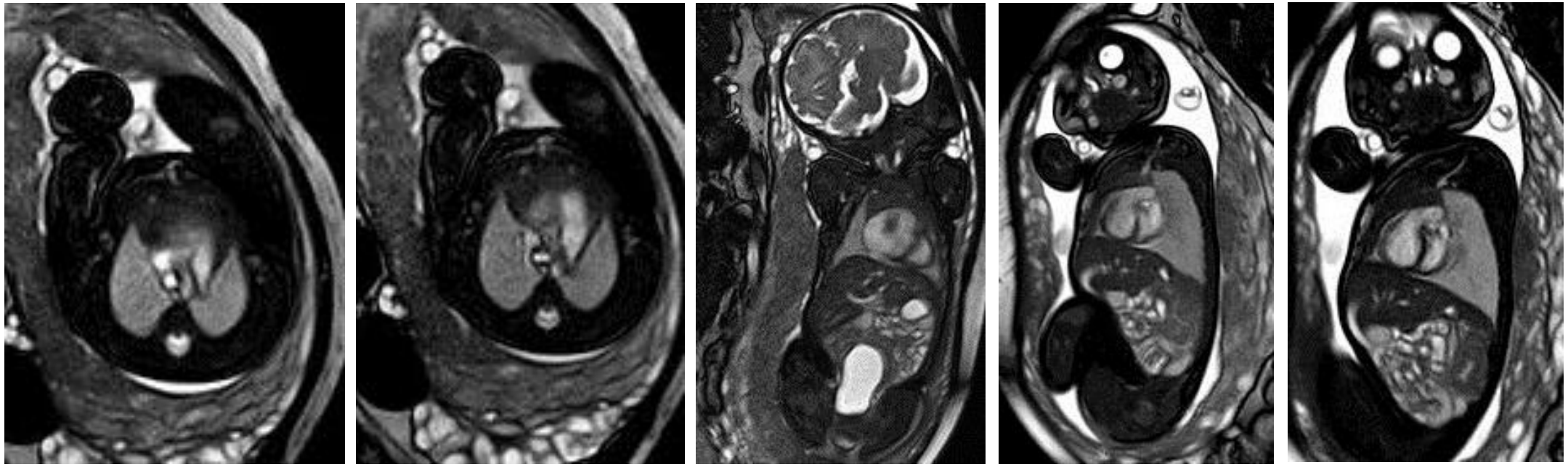


TAPVC






Fetal premature restriction/closure of ductus arteriosus



Conclusion

- Fetal echo still was the first choice method in fetal CHD
- Our study shows fetal MRI is a valuable addition to fetal echo in the detection of fetal airway and great vessels anomalies even when without limitation of acoustic windows. But MRI is not necessary for intra cardiac malformations
- SSFP over continuous slice scan and the radiologist who read MRI understanding CHD enough are the key points

Thanks