Original Article

Antenatally Detected Thoracic Lesions: Prognosis, Management and Outcome

Md. Mokarram Ali, Nilesh Tank[1], Monika Bawa[2]

Department of Pediatric Surgery, PGIMS, Rohtak, Haryana, [1]Department of Pediatric Surgery, Geetanjali Medical College and Hospital, Udaipur, Rajasthan, [2]Department of Pediatric Surgery, PGIMER, Chandigarh, India

Abstract

Background: Foetal thoracic lesions are uncommon, with the incidence of 1 in 15,000 live births. Antenatal monitoring of these lesions is required to prognosticate the parents about the postnatal outcome of the lesions and about the well-being of the baby. Foetal ultrasound and magnetic resonance imaging (MRI) are the modalities to detect these lesions and follow-up during pregnancy and postnatally. Congenital pulmonary adenomatoid malformations (CPAM), congenital diaphragmatic hernia (CDH) and bronchopulmonary sequestrations (BPS) are the commonly detected foetal thoracic lesions. Parameters such as congenital cystic adenomatoid malformation (CCAM) volume ratio (CVR) and lung-to-head ratio (LHR) determine the prognosis of these lesions. With this background, we planned to study the prognosis and outcome of antenatally detected thoracic lesions. **Materials and Methods:** This was a prospective study carried out for 2 years (January 2017 to December 2018). Pregnant females with foetuses diagnosed to have thoracic lesions on the second- and third-trimester ultrasound and foetal MRI were enrolled for the study. CVR and LHR were noted. Outcomes were analysed in terms of the need of termination of pregnancy, foetal or neonatal demise and need of surgery or conservative management. **Results:** Of a total of 521 pregnancies, thoracic lesions were detected in 22 (4.22%) cases. Individually, the incidence of each lesion was: CPAM-10 (45.45%), BPS-5 (22.73%), CDH-5 (22.73%) and congenital higher airway obstruction-2 (9.1%). Chromosomal screening was normal in 100% of cases. Follow-up was done for 2 years. Termination of pregnancy was required in 3 (13.64%) cases, postnatal death occurred in 4 (18.2%) cases, surgery was required in three cases of CDH soon after birth and two cases of extralobar BPS at 2 years of age. 10 (45.45%) cases were managed conservatively, who are doing well at 2-year follow-up. **Conclusion:** CPAMs, BPSs and CDH are the commonly detected antenatal thoracic lesions. Ultrasonography and MRI help detect and prognosticate the parents about the outcomes of these lesions. CVR and LHR with associated congenital malformations are important prognostic markers for these lesions. There is a need of long-term prospective studies to delineate the natural history of these lesions.

Keywords: Antenatal monitoring, foetal thoracic lesions, outcome, prognostic markers

Introduction

Thoracic lesions are one of the most frequently detected congenital malformations on antenatal screening ultrasounds. These are heterogeneous group of rare disorders involving the upper and lower respiratory tract or lung parenchyma in a variable extent.[1] Lesions such as congenital pulmonary airway malformations (CPAMs), bronchopulmonary sequestrations (BPS) and congenital diaphragmatic hernia (CDH) are common. Other rarely detected thoracic lesions are congenital higher airway obstruction (CHAOS) and cystic hygromas. These can be detected earliest by the early second-trimester antenatal ultrasonography (USG) and can be confirmed by ultrafast foetal magnetic resonance imaging (MRI).[2] The prognosis of these antenatally detected thoracic lesions is determined by various factors such as their size, CCAM volume-to-head circumference ratio (CVR),[3] lung-to-head ratio (LHR) and the contents in the case of CDH. These lesions have variable natural course, especially CCAMs and BPSs (intralobar), which are expected to resolve spontaneously. Postnatally, these lesions may present in the form of respiratory distress, tachypnoea and cyanosis, or may remain asymptomatic. Approach to their management also varies from case to case,

Address for correspondence: Dr. Md. Mokarram Ali, Department of Pediatric Surgery, PGIMS, Rohtak, Haryana, India. E-mail: mohdmokarramali1990@gmail.com

Received: 18-08-2022 **Revised:** 05-12-2022 **Accepted:** 09-01-2023 **Available Online:** 10-04-2023

Access this article online

Quick Response Code:

Website: https://journals.lww.com/AJPS

DOI: 10.4103/ajps.ajps_116_22

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Ali MM, Tank N, Bawa M. Antenatally detected thoracic lesions: Prognosis, management and outcome. Afr J Paediatr Surg 2024;21:117-22.

with some requiring immediate postnatal surgery, while some need surgical intervention later on. A few of the patients can be kept on conservative management as well. In this prospective study, we have analysed the antenatally detected thoracic malformations and studied their prognosis, and outcomes in terms of survival, death or requirement of medical termination of pregnancy (MTP). Postnatal requirement of surgery or expectant management has also been noted in these patients. Studies regarding the natural history and outcome of antenatally detected thoracic lesions are limited, especially from the Indian subcontinent. Hence, this study will help us in developing a general idea about prognosticating future parents and planning the management of these lesions.

Materials and Methods

This was a prospective study carried out for 2 years, from January 2017 to December 2018. A total of 521 pregnant women who were referred to the department of paediatric surgery for antenatal counselling after the detection of some congenital anomaly on antenatal USG were enrolled in this study. The follow-up started right from the time of initial diagnosis by antenatal ultrasound. They were evaluated with the second- and third-trimester level II USG, quadruple screening, chromosomal study, foetal echo and foetal MRI when indicated. The age of the mother, gestational age at diagnosis, gravida status and other comorbidities were noted. The USGs and MRIs were studied to determine the size of lesion, LHR in the case of CDH, CVR in the case of CPAM and whether intralobar or extralobar in the case of BPS. LHR was determined using the standard definition of cross-sectional area of the contralateral lung at the level of the cardiac atria divided by head circumference at that gestational age. CVR is calculated by the formula – 0.52 × height × anteroposterior diameter × transverse diameter (0.52 is a constant).[2] The parents were prognosticated depending on the factors analysed. Outcomes were assessed in terms of need of MTP, survival after birth or death, requirement of surgery or expectant management.

Results

Thoracic lesions were detected in 22 (4.22%) of 521 patients, who were enrolled in the study, during the study. The number of individual lesions was: CPAM-10 (45.45%), BPS-5 (22.73%), CDH-5 (22.73%) and CHAOS-2 (9.1%). There was no finding of combination of these lesions in a single foetus. Chromosomal screening was normal in all cases. Termination of pregnancy was done in 3 (13.64%) cases. All of these cases had CPAMs with the mean CVR of 1.93.

Of those who got delivered, 12 babies with thoracic lesions (seven CPAMs and five BPSs) were initially managed conservatively. All of these babies were healthy after 2-year follow-up. Two cases with persistent extralobar BPSs were operated at 2 years of age and are doing well after surgery.

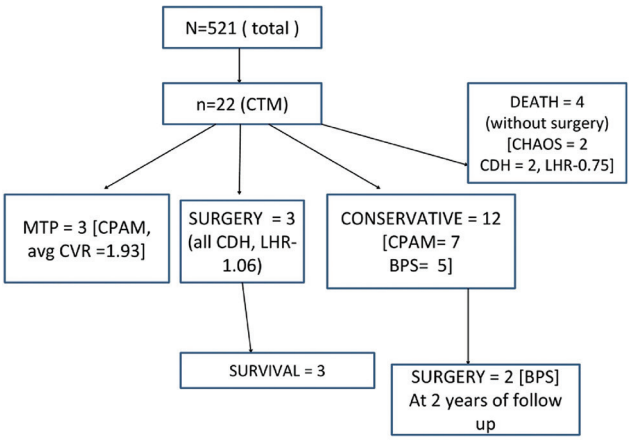


Figure 1: Flowchart showing the distribution of cases and their outcome. CTM: Congenital thoracic malformations, CPAM: Congenital pulmonary airway malformations, CVR: CPAM volume ratio, MTP: Medical termination of pregnancy, CDH: Congenital diaphragmatic hernia, LHR: Lung-to-head ratio, BPS: Bronchopulmonary sequestrations, CHAOS: Congenital higher airway obstruction syndrome

Of five babies with CDH, two died immediately after birth. Three are surviving in good health after surgery. The two babies with antenatal diagnosis of CHAOS died immediately after birth due to difficult airway, in which intubation could not be done [Figure 1].

CPAM

There were 10 (45.45%) cases of CPAMs. The average age of gestation at diagnosis was 23 weeks. Three pregnant women underwent MTP with the mean CVR of 1.93 at the mean gestational age of 18.3 weeks. Of these three, one case with CVR of 2.1 and gestational age of 19 weeks had features of hydrops such as skin oedema, ascites and pericardial effusion. The quadruple screening was normal in all cases.

The remaining seven cases were followed with serial USGs. Their average CVR was 0.72. Foetal echo was grossly normal in all cases.

All of them were delivered in good health. Postnatally, they were followed by serial USGs and CT thorax at 6 months, which showed regression in the size of lesion. At 2-year follow-up, all of these seven cases were doing well on conservative management [Table 1 and Figure 2].

Bronchopulmonary sequestrations

There were 5 (22.73%) cases of BPS with an average size of the lesion of 17.8 mm × 20.6 mm × 17.8 mm and average age of gestation at diagnosis of 22.6 weeks. Of these, three were extralobar and two were intralobar. These lesions were followed antenatally by serial USGs and foetal MRI. The two intralobar BPSs were seen to be resolved during the last trimester of gestation. One extralobar BPS resolved at 34 weeks of gestation as demonstrated by USG. Rest of the two extralobar BPS was seen to be persistent with having feeding vessels. All of them were delivered normally and are

Table 1: Clinical profile of antenatally detected congenital pulmonary adenomatoid malformations, management and outcome

Mother age/G	Gestational age at diagnosis	CVR	Nature of lesion	Echo	Associated other CMF	QS	Perinatal	Postnatal
31/G2	22	Bilateral Right-1.2 Left-0.8	Right-52 mm×46 mm×40 mm Left-33 mm×20 mm×21 mm	Normal	No	Normal	FT/LSCS Respiratory distress at birth-NICU stay for 18 days	CX
27/G2	18	1.8	Left upper lobe enlarged, 27 mm×25 mm×19 mm, pushing the heart toward the right side	Normal	No	Normal	MTP	
30/G3	30	1.0	2.4 cm×2.5 cm cystic lesion in the left upper lobe, air fluid in few cysts	Normal	No	Normal	FTNVD asymptomatic	CX
25/G2	18	1.9	Left lower lobe 4 mm×7 mm	Normal, mediastinal shift	No	Normal	MTP	
28/G2	29	0.6	Right upper lobe 14 mm×7 mm cystic lesion	Normal	No	Normal	FTNVD	CX
24/G1	25	0.7	Polyhydramnios, right lung cystic lesion	Normal	No	Normal	FTNVD	CX
25/G1	19	0.6	Right middle lobe cystic lesion	Normal	No	Normal	FTNVD	CX
34/G3	19	2.1	Left lung cystic lesion occupying entire left hemithorax	Normal	Skin oedema, pericardial effusion, ascites	Normal	MTP	
26/G2	28	0.3	Right lung cystic lesion volume 9 cm^3	Normal	No	Normal	FTNVD	CX
29/G2	22	0.9	Right lung cystic lesion Size 19 mm×15 mm×10 mm	Normal	No	Normal	FTNVD	CX

G: Gravida, CVR: CPAM volume ratio, CMF: Congenital malformation, QS: Quadruple screening, MTP: Medical termination of pregnancy, FT: Full term, FTNVD: FT normal vaginal delivery, FTLSCS: FT lower segment caesarean section, CX: Conservative management, CPAM: Congenital pulmonary airway malformation, NICU: Neonatal intensive care unit

Table 2: Clinical profile of bronchopulmonary sequestrations, management and outcome

Mother age/G	Gestational age at diagnosis	Size and location	Fate	Echo	Associated other CMF	QS	Perinatal	Postnatal
24/G2	21	24 mm×32 mm×19 mm Intralobar Right lung	Resolved 6 months after birth	Normal	No	Normal	FTNVD	CX
23/G1	20	15 mm×22 mm×10 mm Extralobar Left lung	Resolved At 34 weeks of gestation	Normal	No	Normal	FTNVD	CX
29/G3	19	16 mm×15 mm×25 mm Extralobar Left lung	Unresolved	Normal	No	Normal	FTNVD	Operated at 2 years of age
28/G2	28	14 mm×18 mm×10 mm Extralobar Left lung	Unresolved	Normal	No	Normal	FTNVD	Operated at 2 years of age
29/G1	25	20 mm×16 mm×25 mm Intralobar Right lung	Resolved 6 months	Normal	No	Normal	FTNVD	CX

G: Gravida, CMF: Congenital malformation, QS: Quadruple screening, FTNVD: Full-term normal vaginal delivery, CX: Conservative management

being monitored clinically and by serial postnatal USGs and computed tomography (CT) at 6 months. All of them were doing well at 1-year follow-up. The two cases with persistent extralobar BPSs have undergone surgical excision of the lesion at 2 years of age and are doing well in the follow-up [Table 2].

Congenital diaphragmatic hernia

CDH is one of the common differential diagnoses of antenatal thoracic cystic lesions. Of the 22 cases with antenatally detected thoracic lesions, we had 5 (22.73%) cases of CDH. The average age at diagnosis was 22.4 weeks. Of these, two cases with an average

Table 3: Clinical profile of congenital diaphragmatic hernia, management and outcome

Mother age/G	Gestational age at diagnosis	LHR	Echo	Associated CMF	QS	Perinatal	Postnatal
22/G1	22	0.6 Polyhydramnios Stomach in the left hemithorax, heart shifted to the right	Normal	No	Normal	FTNVD Delivered outside, died soon after birth	Death
25/G2	21	1.1 Liver and stomach bubble in the left hemithorax Mediastinal shift to right	Moderate PAH	No	Normal	FTNVD Ventilator support and surgery	Doing well
24/G2	18	1.2 small bowel loops in the left hemithorax No mediastinal shift	Mild PAH	No	Normal	FTNVD repair	Doing well
28/G2	28	0.9 Polyhydramnios Stomach, liver and spleen in the left hemithorax, heart shifted to the right	Severe PAH	No	Normal	FT-LSCS respiratory distress, died 3 h after birth in NICU before surgery	Death
29/G1	25	0.9 Stomach in the left hemithorax Mediastinal shift to the right	Normal	No	Normal	FTNVD repair	Doing well

G: Gravida, LHR: Lung-to-head ratio, CMF: Congenital malformation, QS: Quadruple screening, PAH: Pulmonary arterial hypertension, FTNVD: Full-term normal vaginal delivery, FTLSCS: Full-term lower segment caesarean section

Table 4: Clinical profile of congenital higher airway obstruction and its final outcome

Mother age/G	Gestational age at diagnosis	Level 2/MRI	Echo	QS	Perinatal	Postnatal
22/G1	17	DCDA Twin A-normal Twin B-bilateral lungs enlarged and echogenic, flattened diaphragm, trachea and both main bronchi dilated Ascites, hydrops	Dextrocardia	Normal	FTLSCS	A-died soon after birth Twin B-doing well
29/G3	31	Bilateral hyperechoic lungs, ascites and gross polyhydramnios	Right heart failure	Normal	FTNVD, difficult airway security	Died after birth

G: Gravida, DCDA: Dichorionic diamniotic, QS: Quadruple screening, FTNVD: Full-term normal vaginal delivery, FTLSCS: Full-term lower segment caesarean section, MRI: Magnetic resonance imaging

Table 5: Comparison of the current study with other previous studies on congenital thoracic malformations

Study	Duration (years)	Number of thoracic lesions	CPAM (%)	BPS (%)	CHAOS (%)	CDH (%)	MTP	Conservative	Death
Adzick *et al*.[8]	12	175	134 (76)	41 (23.4)	-	-	16 (9.14%) 14 CPAM+2 BPS	104 (59.43%) 76 CPAM+28 BPS	32 (18.23%) 31 CPAMs+1 BPSs
MacGillivray *et al*.[11]	3	9	3	6	-	-	-	9	-
Hedrick *et al*.[15]	-	4	-	-	4	-	2	-	2
Our study	2	22	10 (45.45)	5 (22.7)	2 (9.1)	5 (22.73)	3 (13.6%) All CPAM	10 (45.45%) 7 CPAM+3 BPS	4 (18.12%) 2 CHAOS+2 CDH

CPAM: Congenital pulmonary airway malformation, BPS: Bronchopulmonary sequestrations, CHAOS: Congenital higher airway obstruction, CDH: Congenital diaphragmatic hernia, MTP: Medical termination of pregnancy

LHR of 0.75 died soon after birth before undergoing surgery. The remaining 3 (60%) cases with an average LHR of 1.06 underwent surgery and are doing well at 2-year follow-up [Table 3].

Congenital higher airway obstruction

We had two cases of CHAOS. Both of them were diagnosed with characteristic USG findings of foetal ascites, bilateral hyperechoic lungs and flattening of the diaphragm. One case was twin pregnancy, so MTP was not advised even after being diagnosed at 17 weeks of gestation. The other case was diagnosed at 31 weeks of gestation. Pregnancies were continued to term in both cases. Postnatally, both babies with CHAOS died soon due to failure to secure airway carrying 100% mortality [Table 4].

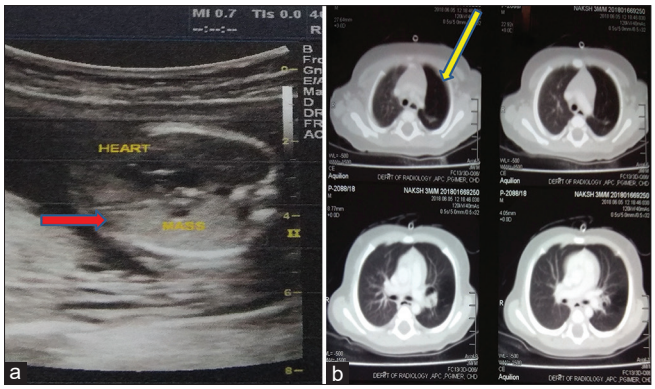


Figure 2: Representative pictures of CPAM: (a) in antenatal ultrasonography (red arrow), (b) in follow-up CT chest (yellow arrow) at 6 months of age. CT: Computed tomography, CPAM: Congenital pulmonary airway malformations

Discussion

Surgery is the accepted standard of care for all symptomatic congenital thoracic lesions. However, management for cases who are asymptomatic at birth and in the neonatal period is still controversial. The proponents of conservative management of asymptomatic CTMs believe in the possibility of postnatal regression of these malformations and also weigh the risks of thoracotomy and lung resection in the newborn period higher.[4] Because of the variable natural course of CTMs, it is difficult to prognosticate the parents about the disease in their baby. Therefore, we need certain parameters to be evaluated serially that can guide us accurately predict the prognosis and outcome in these foetuses. In the current study, we have studied CVR in CPAMs, LHR and contents of sac in CDH, size of the lesion in case of sequestrations as well as gestational age at the time of diagnosis and compared with previous studies.

CPAMs

Congenital pulmonary adenomatoid malformations are the anomalies of lung bud development and require regular antenatal monitoring and strict postnatal evaluation.[5] CPAM volume and CVR are important predictor parameters. It has been observed that CVR ≥1.6 was associated with an increased risk of hydrops (80%), whereas those with CVR <1.6 have only a 2% risk of hydrops.[3]

Various antenatal and intrapartum interventions for CPAMs have been studied.[6] However, appropriate management of the child with suspected CPAM, but no symptoms postnatally, is controversial. Prophylactic surgery for asymptomatic cases has been advocated by some,[7] whereas some surgeons, on the contrary, prefer a "wait-and-watch" approach for asymptomatic cases and go for surgical excision in only those who become symptomatic. In the study by Adzick *et al*., 175 lung lesions were reported for 12 years, of which 134 were CPAMs. There were 14 terminations of pregnancies, 101 cases with expectant management, open foetal surgery in 13 cases and thoracoamniotic shunt placement in six foetuses. 100% survival was seen in 76 foetuses that did not develop hydrops.[8] In our series, three foetuses were terminated at the mean gestation age of 18.3 weeks with an average CVR of 1.93. Remaining seven cases had a mean CVR of 0.72. They were followed regularly in the antenatal period and are being managed conservatively in the postnatal period. None of them has shown any symptom till 2 years of follow-up.

Bronchopulmonary sequestrations

The typical appearance of BPSs on antenatal USG is a well-defined, echodense and homogeneous masses. Colour Doppler US demonstrates the systemic blood supply, which usually confirms the diagnosis.[9] Ultrafast foetal MRI is advanced imaging technique that helps in delineating the nature of the lesion, the feeding vessels and exclusion of other potential associated anomalies.[10]

The natural history of BPS depends on whether lesions are intralobar or extralobar, where they are located (chest or abdomen) and the presence or absence of hydrops and other associated anomalies. MacGillivray *et al*.[11] reported six cases of BPS with the contralateral mediastinal shift that showed a dramatic decrease in size over the course of the pregnancy and resolved spontaneously. Postnatally, these lesions could only be detected by CT scan or MRI. Adzick *et al*.[8] reported spontaneous resolution in 75% of cases of antenatally diagnosed BPSs. In our study, one of 5 (20%) cases of BPS showed spontaneous resolution in antenatal period itself. It was an extralobar sequestration. The rest four cases were managed conservatively with regular follow-up without developing any symptom. Two cases with extralobar BPS (40%) underwent surgical excision prophylactically due to persistence of lesion and also due to parental anxiety. Thus, spontaneous resolution was seen in 60% of cases.

Congenital diaphragmatic hernia

CDH is one thoracic lesion which carries a poor prognosis when detected antenatally. There are various antenatal parameters that can predict the outcome. Of these, the important one is LHR.[12] LHR <1 carries a poor survival, with a value <0.6 carrying 100% mortality.[13] In our series, of five foetuses with antenatal diagnosis of CDH, two cases with LHR of 0.6 and 0.9 died immediately after birth. Rest of the 3 (60%) with an average LHR >1 underwent surgery and are surviving in good health at 2-year follow-up. This is comparable to various studies which have demonstrated higher mortality if CDH is diagnosed antenatally.

Congenital higher airway obstruction

Congenital high airway obstruction syndrome is a result of inadequate recanalisation of the upper airways around the 10th week of gestation.[14] Antenatal foetal ultrasound suggestive of bilateral large and hyperechoic lungs, a small, compressed and centrally placed heart, flattened or inverted diaphragm and ascites is characteristic of CHAOS.

In our study, the two cases of CHAOS were diagnosed with these typical features on level II ultrasound. Both of these

cases succumbed immediately after birth due to difficult airways. CHAOS carries almost 100% mortality without any intervention[15] [Figure 2]. In the recent 16 reported cases of CHAOS diagnosed prenatally, only one foetus survived the immediate postnatal period, which was supposed to be due to partial subglottic stenosis.[16]

Through our study, we find that with a proper antenatal follow-up with serial ultrasound and a detailed study of suitable markers, we can satisfactorily prognosticate future parents about the course of disease in their foetus. This surely helps them decrease the level of anxiety and mental stress. Hence, we recommend a detailed and structured antenatal monitoring of every pregnant female carrying a foetus with congenital thoracic malformations. As most of these lesions can be managed satisfactorily in the postnatal period and a few of them even resolve spontaneously, parents should be counselled to undergo serial imaging to monitor the progress in the womb. Our study is unique as we have covered almost all commonly encountered antenatal thoracic lesions [Table 5]. No such study has been published in the past, especially from the Indian subcontinent. The small sample size is a limitation of our study, and more such studies with a more number of cases should be encouraged to further strengthen our knowledge regarding the prognosis and outcome of antenatal thoracic lesions.

Conclusion

Congenital thoracic malformations are rare developmental abnormalities. Due to the availability of advanced antenatal USG and foetal MRI, these lesions are being detected with increased frequency nowadays. Increased detection rate has led to increased anxiety among parents due to which they require accurate prenatal counselling, prognostication and advice about appropriate perinatal management. Parameters such as CVR, LHR and gestational age at diagnosis as well as the size of lesion are the markers of predicting the prognosis and outcome of these lesions. The best postnatal management of completely asymptomatic malformation is still unclear. Therefore, these lesions need to be approached with detailed and systematic study about their natural history both antenatally and postnatally as well as their clinical and pathological behaviour.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Kotecha S, Barbato A, Bush A, Claus F, Davenport M, Delacourt C, *et al.* Antenatal and postnatal management of congenital cystic adenomatoid malformation. Paediatr Respir Rev 2012;13:162-70.
2. Pacharn P, Kline-Fath B, Calvo-Garcia M, Linam LE, Rubio EI, Salisbury S, *et al.* Congenital lung lesions: Prenatal MRI and postnatal findings. Pediatr Radiol 2013;43:1136-43.
3. Crombleholme TM, Coleman B, Hedrick H, Liechty K, Howell L, Flake AW, *et al.* Cystic adenomatoid malformation volume ratio predicts outcome in prenatally diagnosed cystic adenomatoid malformation of the lung. J Pediatr Surg 2002;37:331-8.
4. Laberge JM, Bratu I, Flageole H. The management of asymptomatic congenital lung malformations. Paediatr Respir Rev 2004;5 Suppl A:S305-12.
5. Calvert JK, Boyd PA, Chamberlain PC, Syed S, Lakhoo K. Outcome of antenatally suspected congenital cystic adenomatoid malformation of the lung: 10 years' experience 1991-2001. Arch Dis Child Fetal Neonatal Ed 2006;91:F26-8.
6. Wilson RD, Baxter JK, Johnson MP, King M, Kasperski S, Crombleholme TM, *et al.* Thoracoamniotic shunts: Fetal treatment of pleural effusions and congenital cystic adenomatoid malformations. Fetal Diagn Ther 2004;19:413-20.
7. Butterworth SA, Blair GK. Postnatal spontaneous resolution of congenital cystic adenomatoid malformations. J Pediatr Surg 2005;40:832-4.
8. Adzick NS, Harrison MR, Crombleholme TM, Flake AW, Howell LJ. Fetal lung lesions: Management and outcome. Am J Obstet Gynecol 1998;179:884-9.
9. Hernanz-Schulman M, Stein SM, Neblett WW, Atkinson JB, Kirchner SG, Heller RM, *et al.* Pulmonary sequestration: Diagnosis with color Doppler sonography and a new theory of associated hydrothorax. Radiology 1991;180:817-21.
10. Quinn TM, Hubbard AM, Adzick NS. Prenatal magnetic resonance imaging enhances fetal diagnosis. J Pediatr Surg 1998;33:553-8.
11. MacGillivray TE, Harrison MR, Goldstein RB, Adzick NS. Disappearing fetal lung lesions. J Pediatr Surg 1993;28:1321-4.
12. Heling KS, Wauer RR, Hammer H, Bollmann R, Chaoui R. Reliability of the lung-to-head ratio in predicting outcome and neonatal ventilation parameters in fetuses with congenital diaphragmatic hernia. Ultrasound Obstet Gynecol 2005;25:112-8.
13. Tanacan A, Orgul G, Aydin E, Kayki G, Celik HT, Yalcin S, *et al.* Antenatal management and outcomes of pregnancies with congenital diaphragmatic hernia. J Neonatal Perinatal Med 2020;13:323-30.
14. Roybal JL, Liechty KW, Hedrick HL, Bebbington MW, Johnson MP, Coleman BG, *et al.* Predicting the severity of congenital high airway obstruction syndrome. J Pediatr Surg 2010;45:1633-9.
15. Hedrick MH, Ferro MM, Filly RA, Flake AW, Harrison MR, Adzick NS. Congenital high airway obstruction syndrome (CHAOS): A potential for perinatal intervention. J Pediatr Surg 1994;29:271-4.
16. Richards DS, Yancey MK, Duff P, Stieg FH. The perinatal management of severe laryngeal stenosis. Obstet Gynecol 1992;80:537-40.