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Debating the embolization of a large aberrant systemic artery for pulmonary sequestration using an Amplatzer duct occluder: a case report and literature review

Yulin Zhang, Yu Qiu and Yifei Li

Key Laboratory of Birth Defects and Related Diseases of Women and Children of MOE, Department of Pediatrics, West China Second University Hospital, Sichuan University, Chengdu, Sichuan 610041, China

Brief Report

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Author for correspondence:
Y. Li, Department of Pediatrics, West China Second University Hospital, Sichuan University, No. 20, 3rd section, South Renmin Road, Chengdu 610041, China.
E-mail: liyfwcsh@scu.edu.cn

Zhang Y and Qiu Y contributed equally to this work.

Abstract

Here, we report two rare cases of pulmonary sequestration that were fed by large systemic arteries and embolized with a large Amplatzer duct occluder and their 3-year follow-up, and we discuss the efficacy and safety of the embolization of a large aberrant systemic artery to pulmonary sequestration using an Amplatzer duct occluder. A 9-year-old boy complained of chest pain for 1 month, and a 6-year-old boy initially complained of recurrent cough for 3 months. A series of examinations was launched to evaluate any possible malformation or abnormalities in the patients. Chest CT and CTA identified a right lower pulmonary sequestration with infection. After admission, transcatheter device occlusion was planned after essential antibiotic treatment, and postoperative infection prevention and anti-inflammatory treatment were given. In the following 2 years of follow-up, neither of the children had recurrent chest pain, cough or other related symptoms. However, the CT follow-up demonstrated that a residual mass was visible in both patients. The same chest scan section revealed slight reductions in lung lesions from 38.344 cm^2 to 37.119 cm^2 (3% reduction) and 14.243 cm^2 to 13.178 cm^2 (7.5% reduction) for each patient. No follow-up data demonstrated the long-term clinical outcomes of the residual lesion. We do not recommend that embolization be performed for large pulmonary sequestration lesions with an aberrant artery larger than 6 mm that is planned to receive a device larger than 10 mm, as their outcomes showed a higher possibility of rebuilding the vascularization network feeding the pulmonary sequestration, indicating a higher risk for long-term complications.

Pulmonary sequestration is a rare condition.[1,2] The lesion is mostly located on the left side. Pulmonary sequestration is defined as a segment of lung parenchyma separated from the tracheobronchial tree and receiving its blood supply from a systemic artery rather than a pulmonary arterial branch. The aberrant supplying artery usually originates from the thoracic descending aorta or the abdominal aorta. It mainly presents symptoms in young adults, including continuous cough, hemoptysis, recurrent bronchopulmonary infections, and chest pain, while growth retardation can be found in pediatric cases. However, with the development of fetal ultrasound and magnetic resonance imaging (MRI) scanning, some cases of pulmonary sequestration can be identified during the prenatal phase.[2,3] A study report from Khen-Dunlop in 2018 demonstrated a cohort of pulmonary sequestration therapeutic alterations among 99 children, and 86 (87%) of all cases achieved prenatal diagnosis.[2] Therefore, an increasing number of young patients have recently been scheduled to receive treatment after birth. Enhanced CT with three-dimensional reconstruction and MRI are commonly used in clinical diagnosis. However, selective arteriography is the gold standard for diagnosing pulmonary sequestration, as it helps to obtain the shapes, margins and numbers of feeding vessels, providing the essential criteria for choosing transcatheter embolization or surgical resection. Normally, if there is a solitary arterial branch, embolization is considered to be performed. Surgical removal should be performed if there are multiple arterial vessel.

Transcatheter embolization has been used to treat pulmonary sequestration for the past 20 years.[4] Initially, coils were the most common types to be used for embolization. Amplatzer vascular plugs and duct occluders have also been introduced to pulmonary sequestration patients with solitary feeding arteries. Two issues were controversial. One issue was whether management should be provided for asymptomatic cases, and observation is usually proposed for such patients. However, risks for pulmonary infections still exist. The second issue was the indication for transcatheter embolization. Systemic vessel embolization has been proposed as an alternative to surgery because systemic vessel thrombosis leads to the regression of the bronchopulmonary malformation. However, current reports presented limited cases with pulmonary sequestration fed by a single small- or medium-sized artery (diameter < 5 mm) in

which coils and small Amplatzer plugs were used. No study has paid enough attention to the changes in residual lesion masses, such as how their volume changes and their long-term risks. Herein, we report two rare cases of pulmonary sequestration that were fed by large systemic arteries, were embolized with a large Amplatzer duct occluder and were followed up for 3 years. In addition, we also summarize current published studies on children's pulmonary sequestration treatment to define optimal indications for transcatheter embolization for pulmonary sequestration. This research study was approved by the ethics committee of our hospital (2014-034).

Case presentation

Case 1

A 9-year-old boy was first admitted to a local hospital with a main complaint of recurrent chest pain for 1 month, mainly at the root of the xiphoid process, with dull pain and no radiating pain in the shoulder and back. Chest CT scan revealed "a potential vascular malformation in the posterior segment of right lower lobe". The patient was transferred to our hospital to receive an enhanced CT scan, which identified a right lower pulmonary sequestration with infection. The patient did not present any palpitation, shortness of breath, dyspnea, continuous cough, expectoration or other discomfort. Physical examinations demonstrated that the xiphoid process was concave in shape and oriented inward and that the thoracic cavity was funnel-shaped. Bilateral respiratory movements were symmetrical. The respiratory sounds of both lungs were thick, and no rales were heard. The diagnosis was right lower pulmonary sequestration (intralobar type, with multiple cystic shadows), accompanied by left heart enlargement, based on chest CTA. In addition, pulmonary function tests showed that the child suffered mild restrictive ventilation dysfunction.

After admission, antibiotic treatment was administered for 1 week, and transcatheter embolization was planned for the occlusion of the sequestration. Hemodynamic evaluation revealed a left pulmonary pressure of 38/21 (29) mmHg, a main pulmonary artery pressure of 38/22 (31) mmHg, and a right ventricular pressure of 40/11 (25) mmHg. Aorta angiography showed a solitary artery arising from the descending aorta at the level of the diaphragm, and the narrowest size of the feeding artery was 8.54 mm (Fig 1a). A 16/14 mm size Amplatzer duct occluder was placed in the main feeding artery before its branches via a 9 Fr delivery sheath. The vessel was completely occluded, as post angiography showed no significant aorta-pulmonary flow to the lesioned lung segment (Fig 1a). The total procedure time was 65 minutes.

Thereafter, the patient received treatment with ceftriaxone to prevent infection and oral prednisone to prevent inflammation. However, the patient suffered transitory chest pain and a fever for 36 hours up to 38.7 °C. In the following 2 years of follow-up, the child did not have recurrent chest pain, cough or other related symptoms. The respiratory function test showed a slight dysfunction at 3 years post occlusion. However, the CT follow-up demonstrated that a residual mass was visible. The same chest scan revealed a slight reduction in the lung lesion from 38.344 cm^2 (height, 142 cm; weight, 32 kg; body surface, 1.122 m^2) to 37.119 cm^2 (height, 160 cm; weight, 40 kg; body surface, 1.335 m^2), and the lesion of pulmonary reduction is 3.19% and 18.64% normalized to body surface, which indicated a mild absorption of lesion (Fig 1c and d).

Case 2

A 6-year-old boy was first admitted to our hospital with the main complaint of continuous cough and expectoration for 3 months, as well as a long-term fever with the highest temperature above 39 °C. During that period, the child's symptoms progressed, accompanied by dizziness and sweating at night. The patient was initially diagnosed with a pulmonary abscess and was provided antibiotics for 9 days. Then, he was transferred to our hospital, and chest CT revealed a right lower lobe pulmonary sequestration with infection. Physical examinations were remarkable only because the respiratory sounds of the right lower lung were decreased, though no rales were heard. ECG and cardiac ultrasound were generally negative and presented abnormally shaped cardiac chambers. CTA revealed multiple cystic shadows with consolidation and cord shadows in the right lower lobe and a feeding vessel arising from the thoracic aorta to supply the pulmonary sequestration segment.

After admission, transcatheter device occlusion was planned after essential antibiotic treatment. Hemodynamic evaluation revealed that the systemic and pulmonary pressures were normal. Aorta angiography showed a solitary artery arising from the descending aorta at the level of the diaphragm, and the narrowest size of the feeding artery was 7.32 mm (Fig 1b). A 12/10 mm size Amplatzer duct occluder was placed in the main feeding artery before its branches via a 7 Fr delivery sheath. The vessel was completely occluded, as post angiography showed no significant aorta-pulmonary flow to the lesioned lung segment (Fig 1b). The total procedure time was 110 minutes.

After embolization, the child suffered transitory chest pain for 3 days and a fever for 48 hours up to 39.0 °C. In the following 2 years of follow-up, the child did not have recurrent chest pain, cough or other related symptoms. The respiratory function test showed a slight dysfunction at 3 years post occlusion. However, the CT follow-up demonstrated that a residual mass was visible. The same chest scan revealed a slight reduction in the lung lesion from 14.243 cm^2 (height, 114 cm; weight, 20 kg; body surface, 0.7985 m^2) to 13.178 cm^2 (height, 127 cm; weight, 27 kg; body surface, 0.9674 m^2), the lesion of pulmonary reduction is 7.47% and 23.55% normalized to body surface, which indicated that the absorption of the lung lesion was not a promising result (Fig 1e and f).

Discussion

Pulmonary sequestration is a rare type of congenital malformation of the lung and its vessels, accounting for approximately 0.15–6.40% of malformations.[5] The cause is believed to be that a part of the lung bud tissue is separated from the bronchial tree, resulting in abnormal lung tissue, which is either connected or not connected with the normal trachea and bronchus during the development of the embryonic lung. As its blood supply comes from the systemic circulation, the oxygen content of the blood from the systemic circulation is completely different from that of the blood from the pulmonary artery. The clinical manifestations of pulmonary sequestration depend on the types of lesions and the volume of the abnormal lung lesion mass.[6] Such patients have been divided into three main populations based on their clinical manifestations. The first population is asymptomatic patients, who usually have only a small proportion of lung malformations. The pulmonary sequestration in these patients is always discovered accidentally by imaging diagnostic methods. The second population is the group presenting respiratory symptoms,

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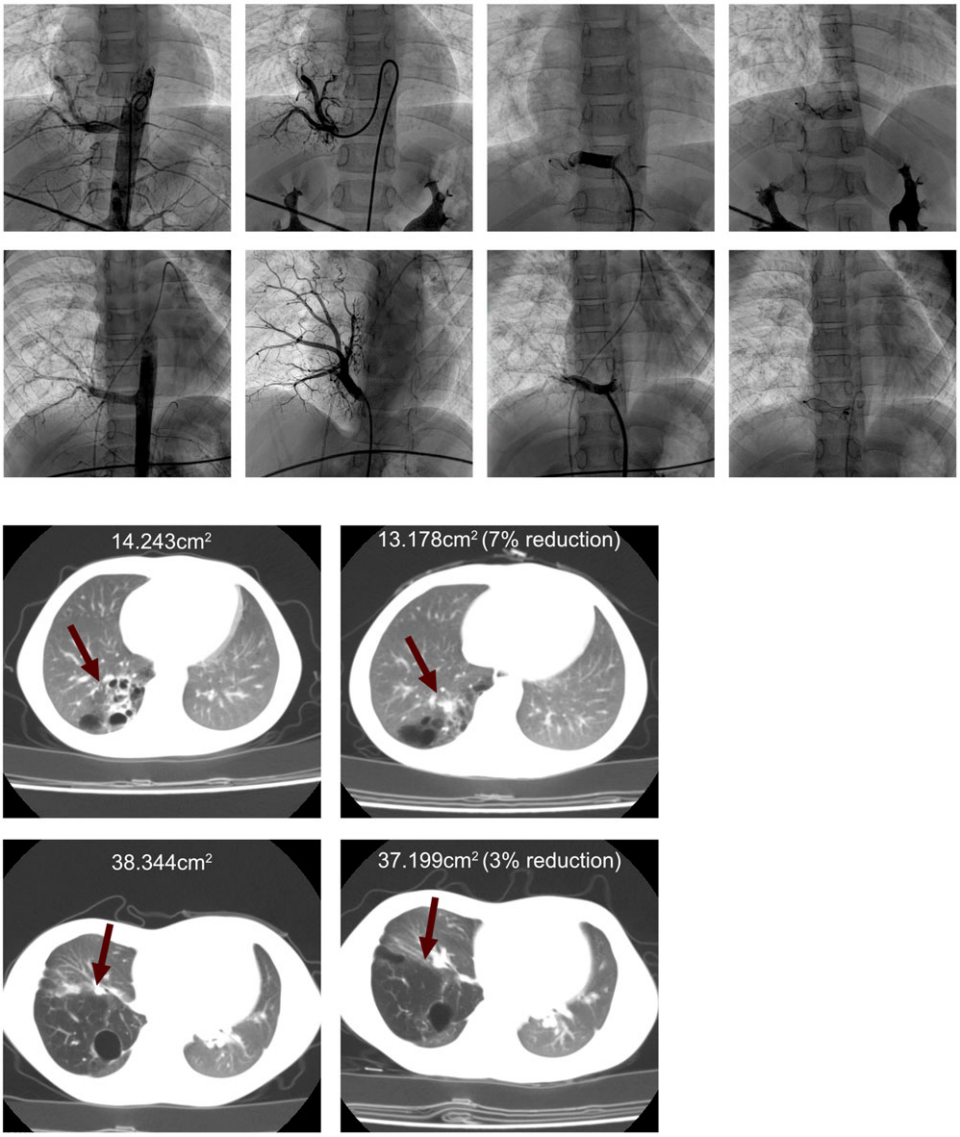

Figure 1. The angiography and implantation of Amplazter occluder for two patients of pulmonary sequestration with large aberrant systemic artery (*a* for patient 1, and *b* for patient 2). CT scanning demonstrated the lesions of lungs before and after occlusion (*c* for patient 1 before occlusion, *d* for patient 1 after 2-year-follow-up post occlusion; *e* for patient 1 before occlusion, *f* for patient 1 after 2-year-follow-up post occlusion). The follow-up results demonstrated the large residual lesions after Amplatzer occluder implantation for a large aberrant artery supplying pulmonary sequestration.

such as recurrent cough, pulmonary infection, and even hemoptysis, which is the most important and earliest clinical symptom of pulmonary sequestration. The last population of patients demonstrates cardiovascular onset symptoms, which are extremely rare and caused by abnormal blood shunts.

Intralobar pulmonary sequestration is often seen in young adults. Because it has normal or pathological channels with the bronchus, local infection of the lesion easily occurs repeatedly. Such cases are often misdiagnosed as pulmonary infections, pulmonary cysts complicated by infection or bronchiectasis. Extralobar pulmonary sequestration is usually asymptomatic without bronchial communication. Therefore, the treatment timing and approaches are mainly based on the manifestation and volume of lung malformation lesions. Adults are the patients who most often receive treatment, including surgical resection and transcatheter embolization. However, with the rapid development of imaging diagnostic methods, pulmonary sequestration can be found prenatally or at a young age.[2,7–9] Decades ago, pulmonary sequestration was mainly treated by the resection of the dysfunctional lung tissues via traditional thoracotomy. With continuous advances in video-assisted thoracoscopic surgery, video-assisted thoracoscopic surgery has become the main surgical technique in treating pulmonary sequestration.[2] Moreover, a series of studies reported that endovascular embolization of systemic arterial abnormal vessels is a valid alternative therapeutic choice due to its advantages of minimal trauma, limited hospitalization and rapid activity. In these two cases, we used the Amplatzer duct occluder to achieve efficient embolization using a strategy which is based on the experiences and protocol for patent ductus arteriosus closure. Generally, the size of occluder is 1.5–2 times of the diameter of the artery. Under the consideration of absence of significant difference of blood pressure between the lateral sides of occluder, the selection criteria of occluder preferred to touch the lower border of the range as 1.5 times of artery dimeter.

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Table 1. Summary of transcatheter embolization of PS in children patients

Author	Year	Journal	Symptoms	Age at procedure	Types of occluder	Size of occluder	Size of aberrant atery	Follow-up term	Outcomes
Khen-Dunlop	2018	Eur J Cardiothorac Surg	Asymptomatic	Median age of 21.6 months (range 5.2–63.5 months)	N.A	N.A	N.A	13.3 (±2.7) months	All cases a residual mass was still visible without contrast enhancement
Berthod	2017	Quant Imaging Med Surg	Chest pain	14 years	Duct occluder	8 mm	N.A	3 months	No recurrence and the patient was asymptomatic
Borgia	2017	Int J Cardiol	Eight repeated respiratory infections, one respiratory distress and four no symptoms	Mean 1.96 years	Duct occluder	5.38 mm	Mean 2.88 mm	1 year	It revealed regression of PS with disappeared enhancement in 12 out of 13 paitents
Herbert	2016	Cardiol Young	Mild mitral valve insufficiency	5 years	Duct occluder	7/8 mm	N.A	2 months	Mild mitral regurgitation, and normalisation of her left ventricular end-diastolic Z score from +2.8 to +0.77
Álvarez	2014	Rev Chil Pediatr	Repeated respiratory infections and heart failure	13 years	Cook coil and duct occluder	5 mm and 6 mm	4 mm and 2 mm	2 years	Reduction of lesion without exact size measurement
Örün	2011	J Cardiol Cases	Cough, tachypnea, and feeding difficulty	9 months	Duct occluder	8 mm	5.6 mm	1 week	Normal right heart size with significant clinical improvement
Turkay	2010	J Cardiovasc Dis Res	Asymptomatic	1 month	Cook coil	N.A	N.A	3 months	Not provided, closure along with Balloon angioplasty of aortic coarctation
Zhang	2010	Pediatr Cardiol	Shortness of breath and repeated respiratory infections	7 months	Duct occluder	6 mm	N.A	N.A	No follow-Up
Hwang	2008	Pediatr Pulmonol	Chest pain, cough	7 years	Duct occluder	10 mm	6.6 mm	1 year	Chest CT-scan at 1 year showed a 22% volume reduction of the lesion
Crushell	2002	J Interv Cardiol	Asymptomatic	Infant	Duct occluder	6/4 mm	N.A	1 year	Not provided, closure along with PBPV
Tokel	2000	AJR Am J Roentgenol	Respiratory distress, recurrent respiratory infections and difficulty feeding	6 months and 11 months	Cook coil	5 mm	N.A	3 months	Improve growth and development

However, embolization is not efficient for all patients because its mechanism is to embolize the blood supply vessels to reduce the blood flow perfusion of the separated lung tissue. The isolated lung tissue first exhibits ischemic degeneration, then fibrosis and atrophy, and finally absorption. Therefore, if an isolated lung lesion is supplied by several vessels, the placement of several devices to achieve full embolization is not a good choice. Moreover, the clinical manifestations are usually based on the volume of pulmonary sequestration segments. Larger lesions are always supplied by larger aberrant arteries with a few surrounding vessels. We retrieved all the published reports of transcatheter embolization of pulmonary sequestration in children,[2,10–19] and the devices in the two cases presented here are the largest that have been placed. We noticed that the absorption of the lesion was very slow (3% and 7.5% for each patient, for 3 years), which may be due to the essential surrounding vessels supplying the embolized lung segment. In summary, transcatheter embolization of pulmonary sequestration has been performed in children ranging from infants to teenagers aged 14 years. Cook coils and Amplatzer occluders are the most common devices for embolization.[13,16,19] A 10-mm Amplatzer occluder has been reported to close a 6.6-mm aberrant artery of the pulmonary sequestration. CT scans at the 1-year follow-up recorded only a 22% volume reduction in the pulmonary sequestration lesions.[17] In addition, Khen-Dunlop[2] and Álvarez[13] also reported reductions in residual mass but failed to provide an exact measurement. Moreover, in the cohort reported by Cho et al,[20] among the embolization group, complete regression was observed in only 3 patients, 4 showed no regression, and 35 (83.3%) had residual lesions, with four patients developing sepsis or other blood vessel complications. In all the reported cases, the occluder sizes ranged from 4 to 10 mm, and the follow-up times ranged from 1 week to 2 years. All of the cases demonstrated an improvement in clinical manifestations, and the patients suffered no severe complications. All the previously reported data are summarized in Table 1.

In our cases, both children had a good prognosis for clinical improvement. However, there was a slower reduction (around 20% reduction in 3 years) in their lesion masses than that observed in previous reports (which should reach at 20% reduction in 1 year). Compared to previous cases, our cases had the largest aberrant artery sizes of 8.54 and 7.32 mm, receiving 16- and 12-mm Amplatzer duct occluders. Although the main clinical concerns were relieved after closure, the imaging changes still remain controversial, with some debate regarding the indications for transcatheter embolization application. However, we still observed the growth developments on both children were delay, especially in height. No oblivious catch-up growth had been identified after occlusion. Due the poor absorption of such lesion, recurrent pulmonary infection is expected in long term results. Besides, the long-term residual mass complications, such as the revascularization of pulmonary sequestration lesions, inducing severe infection and requiring surgical resection, are still unknown. In addition, we do not know the relationship of the residual mass with the risk of lung tumors. For large pulmonary sequestration lesions, embolization does not lead to absorption in the short or mid term; therefore, an unknown risk remains for such patients in the long term.

Accordingly, we consider that transcatheter embolization should be avoided with an aberrant artery size greater than 6 mm that is planned to receive an occluder larger than 10 mm, even if a solitary feeding artery has been identified. Second, for small pulmonary sequestration lesions supplied by a small artery, Cook coils and an Amplatzer occluder are safe and practical approaches that are alternatives to surgical resection.

Conclusion

Our cases presented the clinical and imaging follow-up of the embolization of large aberrant systemic artery to pulmonary sequestration using Amplazter Duct Occluder. The two cases who received 16 mm and 12 mm are the largest ones reported among children patients. Although the clinical improvement has been achieved, but the reduction of lesion mass brought us to re-consider the indication for pulmonary sequestration using transcatheter embolization. As no follow-up data to demonstrated the long term clinical outcomes of the residual lesion. We would not recommend embolization to perform for large pulmonary sequestration lesion with an aberrant artery larger than 6 mm, which is planned to receive a device more than 10 mm as they showed a higher possibility to re-build a vascularization network to feeding pulmonary sequestration indicating a higher risk for long term complications.

Data availability statement. Further supporting data is available from the authors on request.

Author contributions. Zhang Y and Qiu Y contributed equally to this work. Li Y was the patient's physicians. Zhang Y and Qiu Y reviewed the literature and contributed to manuscript drafting; Li Y conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content. Zhang Y, Qiu Y and Li Y were responsible for the revision of the manuscript for important intellectual content; all authors issued final approval for the version to be submitted.

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Conflicts of interest. None.

Ethical standards. The guardians of both patients signed an informed consent statement to allow this case report to be published.

International review board approval. This research study was approved by the ethics committee of our hospital (2014-034).

Clinical trial registration. As this is not a clinical trail, such registration is not required.

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