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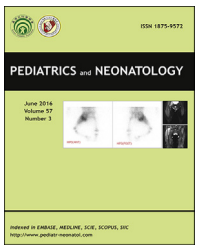

REVIEW ARTICLE

Longitudinal Follow-up of Chronic Pulmonary Manifestations in Esophageal Atresia: A Clinical Algorithm and Review of the Literature

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In the past decades improved surgical techniques and better neonatal supportive care have resulted in reduced mortality of patients with esophageal atresia (EA), with or without tracheoesophageal fistula, and in increased prevalence of long-term complications, especially respiratory manifestations. This integrative review describes the techniques currently used in the pediatric clinical practice for assessing EA-related respiratory disease. We also present a novel algorithm for the evaluation and surveillance of lung disease in EA. A total of 2813 articles were identified, of which 1451 duplicates were removed, and 1330 were excluded based on review of titles and abstracts. A total of 32 articles were assessed for eligibility. Six reviews were excluded, and 26 original studies were assessed. Lower respiratory tract infection seems frequent, especially in the first years of life. Chronic asthma, productive cough, and recurrent bronchitis are the most common respiratory complaints. Restrictive lung disease is generally reported to prevail over the obstructive or mixed patterns, and, overall, bronchial hyperresponsiveness can affect up to 78% of patients. At lung imaging, few studies detected bronchiectasis and irregular cross-sectional shape of the trachea, whereas diffuse bronchial thickening, consolidations, and pleural abnormalities were the main chest X-ray findings. Airway endoscopy is seldom included in the available studies, with tracheomalacia and tracheobronchial inflammation being described in a variable proportion of cases. A complete diagnostic approach to long-term respiratory complications after EA is mandatory. In the presence of moderate-to-severe airway disease, patients should undergo regular tertiary care follow-up with functional assessment and advanced chest imaging.

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1. Introduction

Esophageal atresia (EA) with or without tracheoesophageal fistula (TEF) occurs in one per 3000 live births.[1–3] In recent decades, improved surgical techniques and better neonatal supportive care have resulted in reduced mortality and increased prevalence of long-term disease-related complications, the most frequent of which include respiratory manifestations.[4]

Recurrent-to-chronic respiratory symptoms may upset daily life of EA survivors,[5] and this is the reason why the assessment of pulmonary disease is recommended in these patients. This integrative review describes the various techniques currently used in pediatric clinical practice for assessing EA-related respiratory disease. Moreover, we present a novel algorithm for the evaluation and surveillance of lung disease in EA survivors. We carried out an electronic keyword literature search for English articles published on this topic up to September 22, 2015, in the Scopus, Web of Science, PubMed, and MEDLINE databases. We excluded the studies conducted exclusively on adults, but included those with a study population comprising children (or adolescents) and adults. The terms "esophageal atresia" AND (lung OR respiratory OR pulmonary OR airway or spirometry or complications or diagnostic tools) were used as keywords in combination, and the studies found were evaluated for selecting relevant literature. In addition, a manual search was conducted to evaluate review articles' references. Literature reviews on diagnostic procedures for EA-related pulmonary disease prompted us to develop a novel algorithm for the evaluation and surveillance of lung disease in EA survivors.

2. Etiology

The etiology of pulmonary manifestations following EA repair is multifaceted. Because newborns with EA have an increased risk of premature birth that may initiate the clinical scenario,[6] the association with anomalies such as tracheomalacia and lung hypoplasia may significantly contribute to respiratory morbidity since birth.[2] Gastrointestinal symptoms (i.e., regurgitation and/or feeding difficulties with repetitive cough during swallowing, and/or dysphagia and heartburn likely due to peptic esophagitis and Barrett's esophagus) represent the major complaints at any age, and an association of gastrointestinal and respiratory symptoms has been hypothesized to imply a correlation between esophageal and lung dysfunction.[1,5,7] Indeed, esophageal dysmotility and gastroesophageal reflux (GER) may cause and/or worsen wheezing, bronchial asthma, and pneumonia.[8] Although the underlying mechanisms are still being debated, literature suggests that chronic asthma is likely elicited by a reflex mechanism and that recurrent pneumonia may be explained by repetitive acid aspiration.[9,10] Chronic airway inflammation with bouts of infection can eventually result in segmental or even lobar damage leading to the development of severe, life-threatening lung disease in a proportion of patients.[11–14] Finally, recurrent TEF may further complicate the clinical course.[15] Following EA-TEF repair, structural anomalies persist in both the trachea and the esophagus, and chest wall deformities, exacerbated by thoracotomy, may further contribute to alter pulmonary function.[2]

3. Respiratory complications

Patients with EA with or without TEF experience respiratory complaints more often and more persistently than other individuals, and recurrent bronchitis, chronic cough, repeated pneumonia, and asthma-like wheezing represent the major clinical manifestations.[11,16]

Lower respiratory tract infection is abnormally common especially in the first years of life, with more than five annual respiratory tract infections and a rate of more than three attacks of bronchitis per year of up to 78%.[17,18] In a study from Finland, aspiration pneumonia likely related to impaired esophageal peristalsis and esophageal stricture was reported in approximately 50% of affected children, although they did not experience more current respiratory or esophageal symptoms than those without.[12]

Coughs with sputum production and recurrent bronchitis are significantly more common among patients with repaired EA than among healthy individuals,[19] and although respiratory morbidity tends to improve with age, chronic cough, associated with bronchial constriction and hyperresponsiveness, can persist or even become more frequent in adulthood.[20] As a consequence of repeated bouts of lower airways infection, bronchiectasis may also develop.[21]

Although some respiratory complications may be accounted for by documented tracheomalacia, esophageal dysmotility, GER disease (GERD), or surgical complications, a high proportion of EA survivors have abnormal pulmonary function that is apparently unrelated to these conditions.[2] A restrictive pattern generally prevailing over obstructive or restrictive-obstructive airway disease has been described in up to 96% of children, adolescents, and adults previously treated for EA with or without TEF.[1,12,22–24] Interestingly, approximately one-third of a Finnish pediatric population had restrictive or obstructive defects that were apparently unrelated to current respiratory or esophageal symptoms.[12] In the same study, bronchial hyperresponsiveness was found to be severe/moderate or mild in 26% or 52% of the cases, respectively. Airflow obstruction may be explained by several mechanisms including small airway disease or proximal obstruction due to airway malacia or epithelial damage caused by GERD and recurrent episodes of bronchitis or aspiration pneumonia worsened by poor tracheal clearance, or decreased lung growth during infancy.[25] Multiple potential predisposing factors to restrictive lung disease are also congenital or acquired vertebral or chest wall abnormalities (i.e., scoliosis or postoperative rib fusions), surgical trauma, aspiration, and/or recurrent chest infections.[1]

Chronic asthma is considered to be common in EA survivors, with significant bronchial inflammation also occurring in patients with nonallergic asthma.[13,26] Whatever the initial trigger is, asthma significantly contributes to respiratory morbidity in EA, and it might even worsen pre-existing GERD.[13]

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Table 1 Main findings from the 26 original articles that exclusively investigated respiratory disease in esophageal atresia survivors.

Study	Age (y)	Lung imaging	Pulmonary function tests	Bronchoscopy	Other	Main findings
Dudley & Phelan[18]	1 to >9	—	—	—	Clinical outcome	Recurrent bronchitis during the first 3 y (78%)
Milligan & Levison[22]	7–18	—	Spirometry MCT	—	—	Obstructive (54%) & restrictive (21%) lung diseases Bronchial hyperreactivity (65%)
Couriel et al[31]	8–17	—	Spirometry MCT	—	Clinical outcome	Bronchitis for > 8 y (25%) Mild restrictive lung disease Bronchial hyperreactivity (22%)
LeSouëf et al[25]	12–21	—	Spirometry Body plethysmography	—	—	Significant reduction of lung volumes in the pneumonia group vs. the nonpneumonia group
Chetcuti et al[32]	0–25	—	Body plethysmography	—	—	Daily cough (15%), wheezing (40%), bronchitis (34%) RV increase (77%), significant reduction in VC & FEV_1 in patients who wheezed in the past 12 mo
Griscom & Martin[40]	2–21	CT	Spirometry	—	—	Bronchiectasis (40%) Mild restrictive (20%) & obstructive lung disease (40%)
Chetcuti et al[33]	6–37	—	Spirometry Body plethysmography	—	—	Reduced FEV_1 (25%) & RV/TLC ratio (41%) Restrictive lung disease (18%)
Chetcuti & Phelan[11]	1–37	—	—	—	Clinical outcome	In the 0–5-y age group, pneumonia (50%), recurrent pneumonia (25%) Persistent cough (32% aged 0–5 y, 13% 5–10 y, 15% 10–15 y, & 9% > 15 y) Typical harsh cough (71% aged 0–5 y, 60% 5–10 y, 57% 10–15 y, & 40% > 15 y)
Beardsmore et al[38]	2–13 wk	—	Body plethysmography	—	—	Thoracic gas volume increase (33%), abnormalities in airway resistance pattern (78%), airway resistance increase (33%), limitation of inspiratory & expiratory airflow (11%)
Montgomery et al[34]	8–21	—	Spirometry Body	—	Clinical outcome	Asthma or bronchitis (39%)

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Table 1 (*continued*)

Study	Age (y)	Lung imaging	Pulmonary function tests	Bronchoscopy	Other	Main findings
			plethysmography Bicycle ergometer			Obstructive (44%) & restrictive (55%) lung disease Decreased maximal working capacity (53%)
Robertson et al[35]	7–28	X-ray	Spirometry Body plethysmography MCT	—	Clinical outcome	Respiratory symptoms (72%), bronchiectasis (4%), obstructive (12%), restrictive (36%), & mixed (4%) lung disease Positive MCT (24%)
Somppi et al[36]	3.5–30	—	Spirometry	Yes	Clinical outcome	Reduced FEV_1 (67%) Tracheal inflammation (37%). Respiratory infections (29%), recurrent dyspnea (28%), & cough during the night (37%)
Agrawal et al[26]	7–12	—	Spirometry Body plethysmography	—	—	Restrictive lung disease (67%)
Choudhury et al[14]	0 d to >30 d	—	—	—	Clinical outcome	Aspiration & pneumonia (13%) as early death causes Aspiration, tracheomalacia, & reactive airway disease as late death causes (59%)
Soto et al[30]	1–15	—	Spirometry	—	—	Restrictive lung disease (50%)
Little et al[28]	18.7	—	—	—	Clinical outcome	Respiratory infections (29%)
Sarnelli et al[13]	0.8–14.6	X-ray HRCT Perfusion scintigraphy	—	Yes	—	Family history of atopy (40%) & allergic asthma (10%), lobar consolidations (80%), bronchiectasis (20%)
Banjar[21]	1.25 ± 2.4	CT	Spirometry Body plethysmography	—	—	Tracheomalacia (29%), bronchiectasis (17%), obstructive (7%), restrictive (20%), & mixed lung disease (7%)
Lilja & Wester[29]	1–20	—	—	—	Clinical outcome	At 16–20 y, frequent cough between (36%), impaired exercise capacity (20%), respiratory infections (40%), & shortness of breath (53%)
Malmström et al[12]	9.7–19.4	—	Spirometry Histamine challenge test	Yes	FeNO, clinical outcome	Obstructive (30%) & restrictive (35%) lung diseases Bronchial hyperreactivity (78%) Current respiratory symptoms (44%),

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Table 1 (*continued*)

Study	Age (y)	Lung imaging	Pulmonary function tests	Bronchoscopy	Other	Main findings
						wheezing (52%), pneumonia (52%) Mild (72%) & moderate bronchitis in biopsies (7%) Abnormal FeNO (23%)
Gischler et al[17]	5–6.5	—	Spirometry Treadmill test	—	FeNO, clinical outcome	Reduced FEV_1 (25%) Abnormally low maximal exercise tolerance (6.3%) Normal FeNO High proportion of patients with >5 respiratory tract infections in 5 y (74%)
Harrison et al[37]	7.6 ± 2.2	—	Spirometry Forced oscillation technique Body plethysmography	—	—	Reduced Rrs6 (27%) & Rrs8 (24%) FEV_1 significantly lower in EA with TEF vs. healthy controls
Peetsold et al[8]	13.2 ± 2.9	—	Spirometry Body plethysmography Cardiopulmonary exercise testing	Yes	—	Obstructive lung disease (13%) FVC & TLC significantly lower in EA with TEF vs. patients with gastroesophageal reflux disease
Spoel et al[39]	24–66 wk	—	Body plethysmography	—	—	Obstructive lung disease (19%)
Legrand et al[23]	13.3	—	Spirometry	—	Clinical outcome	Chronic cough (19%) & dyspnea (37%) Obstructive (50%) or restrictive (11%) lung disease
Beucher et al[24]	8.5	X-ray	Spirometry MCT Bicycle ergometer	—	—	Bilateral opacities, right lower lobe infiltrate, or pleural abnormalities (10%) Obstructive (19%) & restrictive (23%) lung disease Bronchial hyperreactivity (39%) Reduced ventilation reserve (45%)

CT = computed tomography; EA = esophageal atresia; FeNO = fractional concentration of exhaled nitric oxide; FEV_1 = forced expiratory volume in one second; FVC = forced vital capacity; HRCT = high-resolution computed tomography; MCT = methacholine challenge test; Rrs6 = resistance at 6 Hz; Rrs8 = resistance at 8 Hz; RV = residual volume; TEF = tracheoesophageal fistula; TLC = total lung capacity; VC = vital capacity.

4. Management

With improved patient survival due to better neonatal care and surgery, the importance of recognition and management of pulmonary disease has increased. Table 1 summarizes the main findings from 26 original articles that exclusively investigated respiratory disease in EA survivors.

Several studies focused only on clinical outcomes,[27–29] whereas others also included functional assessment by spirometry,[30–38] airway challenge tests,[12,24] and/or lung volumes measurement.[8,39] The restrictive pattern was generally reported to prevail over the obstructive or mixed ones, and, overall, bronchial hyperresponsiveness was found in up to 78% of patients.[12] Of note, there were a few

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studies on chest imaging findings, which were reported in only five articles.[13,21,24,35,40] In particular, three chest computed tomography (CT) studies detected bronchiectasis[13,40] and irregular cross-sectional shape of the trachea[21] in a subgroup of patients, respectively. Chest CT findings may also include consolidations and/or bronchiectasis (Figure 1). By contrast, diffuse bronchial thickening, consolidations, and pleural abnormalities were the main chest X-ray findings described in a minority of patients.[13,24,35] Airway endoscopy was seldom included in the available studies, with tracheomalacia representing a common finding[8,12,41] and tracheobronchial inflammation being described in a variable proportion of cases.[12,36] In addition to tracheomalacia and bronchomalacia, less common anatomic abnormalities may include ectopic or absence of bronchus and congenital bronchial stenosis.[1] Undoubtedly, evaluation of the airways structure via flexible bronchoscopy can help identify these problems in infants and children before EA/TEF repair, or also in those with persistent respiratory symptoms after EA/TEF surgery.[12,13]

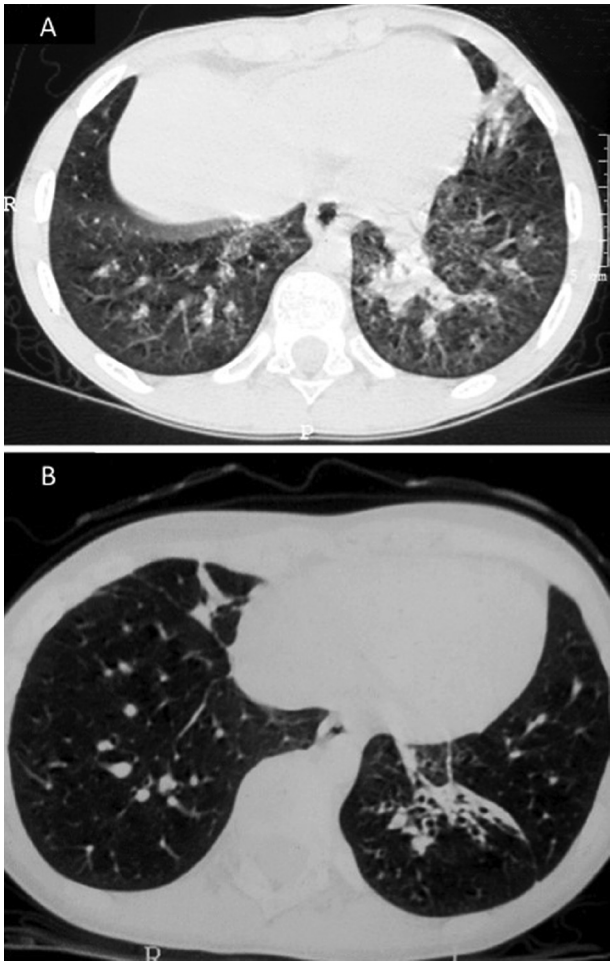

Figure 1 Chest high-resolution computed tomography from two children with esophageal atresia and tracheoesophageal fistula repaired at birth and followed at our department: (A) left lower lobe consolidations and (B) left lower lobe consolidation with bronchiectasis.

Although several articles on the main long-term respiratory complications in EA repair survivors have been published, a shared executive protocol has never been developed, nor have the available diagnostic tools been ordered in a management algorithm. Indeed, the few studies regarding the practical management of pulmonary complications in EA survivors and their heterogeneity make the development of an evidence-based operative algorithm virtually impossible. Nevertheless, due to the severe chronic complaints that some patients may experience and the impact on the healthcare costs, we propose a novel synthetic management algorithm (Figure 2), which may be helpful for clinicians dealing with lung disease secondary to EA. Basically, procedures are selected on the basis of the current clinical features. Present literature does not specify the timing of both follow-up visits and functional/chest imaging work-up. We suggest that basic procedures including transcutaneous pulse oximetry (SpO_2), chest radiographs, and lung function tests (the latter only on cooperating patients) are at least obtained in all patients at baseline. We also propose that EA survivors, with or without TEF, should be differentiated between those with mild airway disease and those with moderate-to-severe airway disease. In particular, patients with respiratory symptoms (persistent cough, recurrent-to-persistent wheezing, recurrent respiratory infections) who show slight abnormalities or normal results of SpO_2 at rest (ranging from 90% to 93%),[42,43] and/or chest radiography, and/or spirometry (i.e., forced expiratory volume in 1 second and forced vital capacity $\geq$ 70% predicted)[44] are defined as having mild airway disease. Conversely, patients with respiratory symptoms and more relevant abnormalities of SpO_2 at rest, and/or chest radiography, and/or spirometry are defined as having moderate-to-severe airway disease. We suggest that only the latter cases undergo regular tertiary care follow-up, including more extensive lung function assessment and advanced chest imaging (i.e., high-resolution CT and/or magnetic resonance imaging). A complete diagnostic approach to long-term respiratory complications after EA should also include tracheobronchial endoscopy with instillation of methylene blue for excluding recurrent TEF.[5] Recurrent TEF should be corrected using laparoscopic antireflux procedures to prevent lung damage.[45,46] These considerations lead to the conclusion that the evaluation of these patients is most efficiently accomplished in a tertiary care center where pediatric pulmonologists, gastroenterologists, radiologists, and surgeons are all available.

5. Conclusion

In patients following EA repair, recurrent-to-persistent respiratory disease represents a major feature, especially in early to middle childhood.[47] The persistence or recurrence of troublesome clinical manifestations imposes a scheduled follow-up of a large proportion of EA survivors, ideally through a multidisciplinary care approach for addressing their special needs. Pulmonary care of these patients involves managing comorbidities and preventing or minimizing damage to the lungs. Early detection and management of aspiration and other causes of recurrent-to-persistent lower airways infections in this population may

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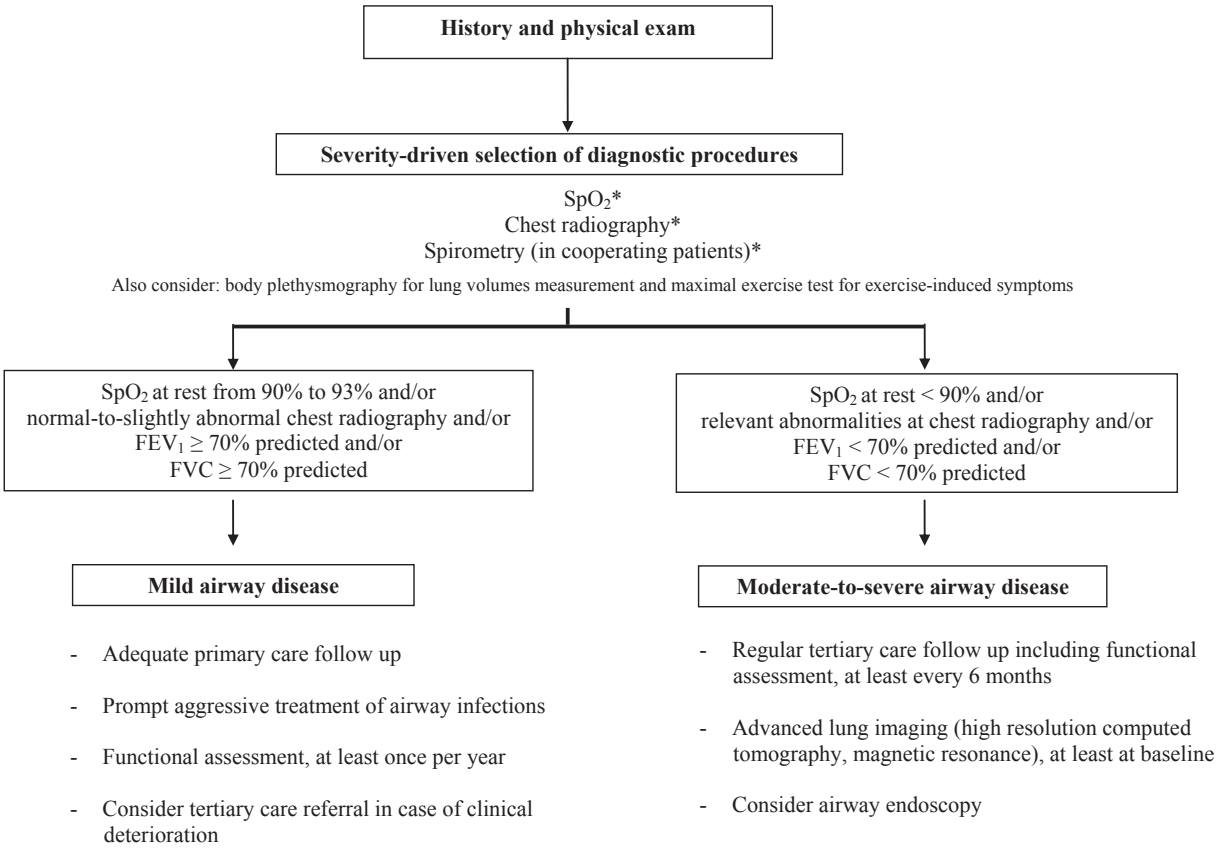

Figure 2 Algorithm for the evaluation and surveillance of chronic pulmonary manifestations in esophageal atresia survivors with or without tracheoesophageal fistula. * To be obtained in all patients. FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; SpO_2 = arterial oxygen saturation measured by pulse oximetry.

be important to prevent decrements in pulmonary function and serious long-term complications.[3] A management algorithm for the evaluation and surveillance of EA-related respiratory disease based on the evidence from literature review is proposed. Like all algorithms, it is not meant to replace clinical judgment, but it should rather drive physicians to adopt a systematic approach to chronic pulmonary manifestations in EA survivors.

Ethical statement

This article does not contain any studies with human or animal subjects performed by any author(s).

Conflicts of interest

There are no financial or other relations that could lead to a conflicts of interest.

References

1. Kovesi T, Rubin S. Long-term complications of congenital esophageal atresia and/or tracheoesophageal fistula. *Chest* 2004;**126**:915–25.
2. Fragoso AC, Tovar JA. The multifactorial origin of respiratory morbidity in patients surviving neonatal repair of esophageal atresia. *Front Pediatr* 2014;**2**:39.
3. Kovesi T. Long-term respiratory complications of congenital esophageal atresia with or without tracheoesophageal fistula: An update. *Dis Esophagus* 2013;**26**:413–6.
4. Castilloux J, Noble AJ, Faure C. Risk factors for short- and long-term morbidity in children with esophageal atresia. *J Pediatr* 2010;**156**:755–60.
5. Delacourt C, de Blic J. Pulmonary outcome of esophageal atresia. *J Pediatr Gastroenterol Nutr* 2011;**52**:S31–2.
6. Gibson AM, Doyle LW. Respiratory outcomes for the tiniest or most immature infants. *Semin Fetal Neonatal Med* 2014;**19**:105–11.
7. Faure C. Endoscopic features in esophageal atresia: From birth to adulthood. *J Pediatr Gastroenterol Nutr* 2011;**52**:S20–2.
8. Peetsold MG, Heij HA, Nagelkerke AF, Deurloo JA, Gemke RJ. Pulmonary function impairment after trachea-esophageal fistula: A minor role for gastro-esophageal reflux disease. *Pediatr Pulmonol* 2011;**46**:348–55.
9. Cucchiara S, Santamaria F, Minella R, Alfieri E, Scoppa A, Calabrese F, et al. Simultaneous prolonged recordings of proximal and distal intraesophageal pH in children with gastroesophageal reflux disease and respiratory symptoms. *Am J Gastroenterol* 1995;**90**:1791–6.
10. Berquist WE, Rachelefsky GS, Kadden M, Siegel SC, Katz RM, Fonkalsrud EW, et al. Gastroesophageal reflux-associated recurrent pneumonia and chronic asthma in children. *Pediatrics* 1981;**68**:29–35.
11. Chetcuti P, Phelan PD. Respiratory morbidity after repair of oesophageal atresia and tracheo-oesophageal fistula. *Arch Dis Child* 1993;**68**:167–70.
12. Malmström K, Lohi J, Lindahl H, Pelkonen A, Kajosaari M, Sarna S, et al. Longitudinal follow-up of bronchial

Please cite this article in press as: Mirra V, et al., Longitudinal Follow-up of Chronic Pulmonary Manifestations in Esophageal Atresia: A Clinical Algorithm and Review of the Literature, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.03.005

inflammation, respiratory symptoms, and pulmonary function in adolescents after repair of esophageal atresia with tracheoesophageal fistula. *J Pediatr* 2008;**153**:396–401.
13. Sarnelli P, Cucchiara S, Celentano L, Settimi A, Tramontano A, Barbarano F, et al. Pulmonary manifestations following esophageal atresia repair: A case series. *Ital J Pediatr* 2004;**30**:174–7.
14. Choudhury SR, Ashcraft KW, Sharp RJ, Murphy JP, Snyder CL, Sigalet DL. Survival of patients with esophageal atresia: Influence of birth weight, cardiac anomaly, and late respiratory complications. *J Pediatr Surg* 1999;**34**:70–3.
15. Rintala RJ, Sistonen S, Pakarinen MP. Outcome of esophageal atresia beyond childhood. *Semin Pediatr Surg* 2009;**18**:50–6.
16. Sulkowski JP, Cooper JN, Lopez JJ, Jadcherla Y, Cuenot A, Mattei P, et al. Morbidity and mortality in patients with esophageal atresia. *Surgery* 2014;**156**:483–91.
17. Gischler SJ, van der Cammen-van Zijp MH, Mazer P, Madern GC, Bax NM, de Jongste JC, et al. A prospective comparative evaluation of persistent respiratory morbidity in esophageal atresia and congenital diaphragmatic hernia survivors. *J Pediatr Surg* 2009;**44**:1683–90.
18. Dudley NE, Phelan PD. Respiratory complications in long-term survivors of oesophageal atresia. *Arch Dis Child* 1976;**51**:279–82.
19. Gatzinsky V, Jönsson L, Ekerljung L, Friberg LG, Wennergren G. Long-term respiratory symptoms following oesophageal atresia. *Acta Paediatr* 2011;**100**:1222–5.
20. Gatzinsky V, Wennergren G, Jönsson L, Ekerljung L, Houltz B, Redfors S, et al. Impaired peripheral airway function in adults following repair of esophageal atresia. *J Pediatr Surg* 2014;**49**:1347–52.
21. Banjar H. Bronchiectasis following repair of esophageal atresia and tracheo-esophageal fistula. *Saudi Med J* 2005;**26**:1661–2.
22. Milligan DW, Levison H. Lung function in children following repair of tracheoesophageal fistula. *J Pediatr* 1979;**95**:24–7.
23. Legrand C, Michaud L, Salleron J, Neut D, Sfeir R, Thumerelle C, et al. Long-term outcome of children with oesophageal atresia type III. *Arch Dis Child* 2012;**97**:808–11.
24. Beucher J, Wagnon J, Daniel V, Habonimana E, Fremond B, Lapostolle C, et al. Long-term evaluation of respiratory status after esophageal atresia repair. *Pediatr Pulmonol* 2013;**48**:188–94.
25. LeSouëf PN, Myers NA, Landau LI. Etiologic factors in long-term respiratory function abnormalities following esophageal atresia repair. *J Pediatr Surg* 1987;**22**:918–22.
26. Agrawal L, Beardsmore CS, MacFadyen UM. Respiratory function in childhood following repair of oesophageal atresia and tracheoesophageal fistula. *Arch Dis Child* 1999;**81**:404–8.
27. Delius RE, Wheatley MJ, Coran AG. Etiology and management of respiratory complications after repair of esophageal atresia with tracheoesophageal fistula. *Surgery* 1992;**112**:527–32.
28. Little DC, Rescorla FJ, Grosfeld JL, West KW, Scherer LR, Engum SA. Long-term analysis of children with esophageal atresia and tracheoesophageal fistula. *J Pediatr Surg* 2003;**38**:852–6.
29. Lilja HE, Wester T. Outcome in neonates with esophageal atresia treated over the last 20 years. *Pediatr Surg Int* 2008;**24**:531–6.
30. Soto MC, Rivilla F, Dorado MJ, Rueda S, Balboa F, Casillas JG. Pneumopathy in patients surgically treated for type III esophageal atresia. *Cir Pediatr* 2000;**13**:136–40 [Article in Spanish].
31. Couriel JM, Hibbert M, Olinsky A, Phelan PD. Long term pulmonary consequences of oesophageal atresia with tracheo-oesophageal fistula. *Acta Paediatr Scand* 1982;**71**:973–8.
32. Chetcuti P, Myers NA, Phelan PD, Beasley SW. Adults who survived repair of congenital oesophageal atresia and tracheo-oesophageal fistula. *BMJ* 1988;**297**:344–6.
33. Chetcuti P, Phelan PD, Greenwood R. Lung function abnormalities in repaired oesophageal atresia and tracheo-oesophageal fistula. *Thorax* 1992;**47**:1030–4.
34. Montgomery M, Frenckner B, Freyschuss U, Mortensson W. Esophageal atresia: Long-term-follow-up of respiratory function, maximal working capacity, and esophageal function. *Pediatr Surg Int* 1995;**10**:519–22.
35. Robertson DF, Mobaireek K, Davis GM, Coates AL. Late pulmonary function following repair of tracheoesophageal fistula or esophageal atresia. *Pediatr Pulmonol* 1995;**20**:21–6.
36. Somppi E, Tammela O, Ruuska T, Rahnasto J, Laitinen J, Turjanmaa V, et al. Outcome of patients operated on for esophageal atresia: 30 years' experience. *J Pediatr Surg* 1998;**33**:1341–6.
37. Harrison J, Martin J, Crameri J, Robertson CF, Ranganathan SC. Lung function in children with repaired tracheo-oesophageal fistula using the forced oscillation technique. *Pediatr Pulmonol* 2010;**45**:1057–63.
38. Beardsmore CS, MacFadyen UM, Johnstone MS, Williams A, Simpson H. Clinical findings and respiratory function in infants following repair of oesophageal atresia and tracheo-oesophageal fistula. *Eur Respir J* 1994;**7**:1039–47.
39. Spoel M, Meeussen CJ, Gischler SJ, Hop WC, Bax NM, Wijnen RM, et al. Respiratory morbidity and growth after open thoracotomy or thoracoscopic repair of esophageal atresia. *J Pediatr Surg* 2012;**47**:1975–83.
40. Griscom NT, Martin TR. The trachea and esophagus after repair of esophageal atresia and distal fistula: Computed tomographic observations. *Pediatr Radiol* 1990;**20**:447–50.
41. Nasr A, Ein SH, Gerstle JT. Infants with repaired esophageal atresia and distal tracheoesophageal fistula with severe respiratory distress: Is it tracheomalacia, reflux, or both? *J Pediatr Surg* 2005;**40**:901–3.
42. Balfour-Lynn IM, Field DJ, Gringras P, Hicks B, Jardine E, Jones RC, et al. BTS guidelines for home oxygen in children. *Thorax* 2009;**64**:ii1–26.
43. Aubertin G, Marguet C, Delacourt C, Houdouin V, Leclainche L, Lubrano M, et al. Recommendations for pediatric oxygen therapy in acute and chronic settings: Needs assessment, implementation criteria, prescription practices and follow-up. *Rev Mal Respir* 2013;**30**:903–11 [Article in French].
44. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. *Eur Respir J* 2005;**26**:319–38.
45. Esposito C, Langer JC, Schaarschmidt K, Mattioli G, Sauer C, Centonze A, et al. Laparoscopic antireflux procedures in the management of gastroesophageal reflux following esophageal atresia repair. *J Pediatr Gastroenterol Nutr* 2005;**40**:349–51.
46. Wheatley MJ, Coran AG, Wesley JR. Efficacy of the Nissen fundoplication in the management of gastroesophageal reflux following esophageal atresia repair. *J Pediatr Surg* 1993;**28**:53–5.
47. Connor MJ, Springford LR, Kapetanakis VV, Giuliani S. Esophageal atresia and transitional care—Step 1: A systematic review and meta-analysis of the literature to define the prevalence of chronic long-term problems. *Am J Surg* 2015;**209**:747–59.

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