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Low flow intermittent bronchoscopic oxygen insufflation to identify occult tracheo-esophageal fistulas

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ABSTRACT

Background: Esophageal atresia and tracheo-esophageal fistula (TEF), a well described congenital anomaly of the aero-digestive tract, commonly presents with inability to swallow and feed immediately after birth. However, diagnosis of recurrent or isolated TEF can be challenging and requires a combination of endoscopic and contrast studies. We describe a hitherto unreported technique of low flow intermittent oxygen insufflation into the suspicious tract and examine its safety and diagnostic yield for identification of occult TEF.

Methods: A retrospective single center cohort study, analyzing case notes of patients with TEF who underwent bronchoscopic oxygen insufflation for suspected recurrent or isolated TEF between 2006 and 2019 at a tertiary pediatric hospital.

Results: One-hundred and seven patients with TEF underwent 142 bronchoscopies during the study period. Of these, 22 patients underwent 28 bronchoscopies with oxygen insufflation. Twelve (43%) open fistulas were identified; of these, 9 (75%) were found using oxygen insufflation, revealing the fistula in 4/9 (44%) cases that had not been apparent using simple bronchoscopic visualization alone. One fistula was missed with multiple investigations, including bronchography and found only using oxygen insufflation. No complications were encountered.

Conclusions: Recurrent or isolated TEF may be missed using ordinary flexible bronchoscopy and imaging studies. Low flow oxygen insufflation can be applied safely and may detect otherwise occult TEF.

1. Introduction

Esophageal atresia (EA) and tracheoesophageal fistula (TEF) is a well described congenital anomaly of the respiratory tract with incidence of approximately 1 in 3500 live births [1]. It is classified into five distinct subtypes according to the scheme developed by Vogt in 1929 and modified by Gross in 1953 [2–4]: Type A with EA and without a fistula (8% of cases), type B with EA and a proximal fistula (1%), type C, with proximal esophageal pouch and distal TEF (84%) and type D with EA and both distal and proximal TEF (3%) [5]. TEF can also occur in isolation, commonly referred to as "H-type fistula" or type E (4.2%) [6]. Patients with H-type TEF may present early when the defect is large, due to aspiration associated with feeding and reflux [7]. However, smaller defects of this type may not be obviously symptomatic in the newborn period. This can lead to delayed diagnosis up to the age of 4 years [8], on occasion even in adulthood, when the presentation is more subtle, typically with prolonged mild respiratory distress during feeding or recurrent pneumonia [9,10].

Recurrent tracheo-esophageal fistula (recTEF) is a frequent (3–10%) complication of congenital TEF (conTEF) and EA repair [11,12]. It usually occurs at the distal end of the tracheal diverticulum, a remnant of the conTEF commonly left behind following primary repair [13]. The identification of a recTEF or H-type TEF can be challenging when small and poorly accessible. Children often undergo a series of investigations until the diagnosis becomes clear. Traditionally, upper gastrointestinal (GI) imaging using thickened water-soluble contrast material is used for diagnosis, although its yield is sub-optimal [14]. The detection rate can be increased by supplementing it with a pull-back technique in which the distal esophagus is filled first and then the catheter is pulled in cephalad direction, injecting the contrast fluid under pressure whilst manipulating the child's position [15]. During examination of the airway with flexible or rigid bronchoscopy, less obvious TEF can be

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missed, especially when consisting of a small tract at the bottom of the collapsed tracheal diverticulum [13,16]. For this reason, recTEF constitute a diagnostic challenge [16]. The use of combined esophageal endoscopy and bronchoscopy, supplemented by injection of methylene blue or contrast liquid into suspicious areas on either side is valuable in revealing concealed TEFs [17]. However, these modalities are challenging in small and sick children, as they require high anesthetic and procedural skills, as well as a suitable set up including fluoroscopy.

In our practice, flexible bronchoscopy is supplemented by low flow oxygen insufflation (OI) via the suction port when occult TEF are suspected.

2. Objectives

We aimed to examine the safety and yield of intermittent bronchoscopic low pressure OI, a hitherto undescribed technique for detection of recTEF or H type conTEF.

3. Methods

This is a retrospective single center cohort study, based on the electronic medical records of patients with EA/TEF under follow up at a tertiary pediatric hospital, Schneider Children's Medical Center of Israel (SCMCI) between 2006 and 2019.

3.1. Study population

Demographic data and medical history including comorbidity, symptoms and hospitalizations were documented for children with a diagnosis of EA/TEF who underwent bronchoscopic OI for suspected recurrent or isolated TEF. Concurrent diagnostic modalities, employed at the behest of the treating physician, were listed. For each patient, the number of hospitalizations were retrieved for two time periods; between birth and the diagnostic bronchoscopy using oxygen insufflation, and between the procedure until present.

3.2. Description of the intermittent low-pressure oxygen insufflation technique

All bronchoscopies were undertaken under general anesthesia with a combination of sevoflurane, midazolam, propofol and atropine, as well as laryngeal instillation of topical lignocaine, using Olympus BF–3C 160, BF-XP 60, BF–P190 or BF-XP190 endoscopes, equipped with 1.2 mm or 2 mm working channels. During spontaneous breathing, the airway was accessed via the nose, laryngeal mask airway or endo-tracheal tube. The suspicious area in the trachea or fistular orifice was visualized. The plastic tubing connected to the suction valve (valve MAJ-209, Olympus, Tokyo, Japan) was disconnected from the wall suction and instead connected to an oxygen port, dialing a flow rate of 2L/min. As the tip of the bronchoscope approached the target site, the operator used the index finger to intermittently occlude the suction valve and thus carefully apply short and controlled bursts of oxygen via the working channel. The video clip in the online supplement shows the average speed at which these bursts were applied: During a 10 s period, about 20 insufflations were applied, using an insufflation to release ratio of 1:1, such that one occlusion would last 0.25 s. At a flow rate of 2L/min, every occlusion would thus generate a gas volume of 8.3 mls.

When the tip of the scope was located within the tracheal diverticulum, care was taken to avoid full wedging. Thus, the procedure was undertaken under the conditions of an "open system", avoiding the creation of a high pressure environment which might risk tearing open tissue, as well as minimizing the risk of producing interstitial emphysema, a pneumothorax or pneumomediastinum.

Following completion of the procedure, children were observed for several hours in the recovery bay of the ambulatory daycare unit. When clinically stable during the procedure and recovery period, chest radiographs were not routinely performed.

Table 1
Bronchoscopic oxygen insufflation and concurrent investigations.

Parameter	N	% of total bronchoscopies	% of total open TEF
Total Bronchoscopies with oxygen insufflation	28	100%	
Total of Open TEF after all modalities of testing	12	43%	
Findings of simple bronchoscopic inspection, prior to oxygen insufflation application			
Open TEF	4	14%	33%
Closed TEF	24	86%	
Missed Open TEF by this procedure	8	29%	67%
Findings of bronchoscopic oxygen insufflation application			
Open TEF	9	32%	75%
Closed TEF	19	68%	
Missed Open TEF by this procedure when done	3	11%	25%
Methylene blue injection	**4**	**14%**	
Open TEF identified with methylene blue injection and missed with oxygen insufflation	1	4%	8%
Closed TEF identified with methylene blue injection and confirmed with oxygen insufflation	3	11%	
Missed Open TEF by this procedure when done	0	0%	0%
UGI	**16**	**57%**	
Positive identification of open TEF	6	21%	50%
Closed vision of TEF	10	36	
Missed Open TEF by this procedure when done	3	11%	25%
Bronchography for identification of patent TEF	**2**	**71%**	
Positive identification of open TEF	1	8%	83%(50% of Bronchography)
Missed Open TEF by this procedure when done	1	8%	83%(50% of Bronchography)

TEF = Tracheo-esophageal fistula; UGI = Upper gastrointestinal imaging.

3.3. Statistics and ethics

Fisher exact test and chi-square tests were used for comparison between groups. The study was approved by the local Institutional Review Board (IRB).

4. Results

A total of 107 patients with any constellation of EA/TEF were followed at SCMCI between 2006 and 2019. For these patients, 142 bronchoscopies were performed during this period of time. Of these, 22 patients underwent 28 flexible bronchoscopies supplemented by OI. Twelve (55%) were males, median age (range) at the time of bronchoscopy was 1.44 years (3 weeks - 15.6 years). Six (27%) patients had other anomalies in keeping with the VACTERL association, one (5%) with Down syndrome and one with a pulmonary sequestration (5%). The indications for bronchoscopy were mainly recurrent cough (64%) and pneumonia (57%). Twenty (91%) patients were examined for suspected refistulisation (recTEF) and the remaining 2 (9%) for first assessment of suspected H-type conTEF.

Twenty-eight bronchoscopies using OI were performed in these 22 patients, see Table 1. Six patients required recurrent bronchoscopies due to recurrent respiratory symptoms, and high susceptibility for refistulization or misdiagnosis. Twelve (43%) open fistulas were found. Of these, 3 were missed by OI and were found using the following

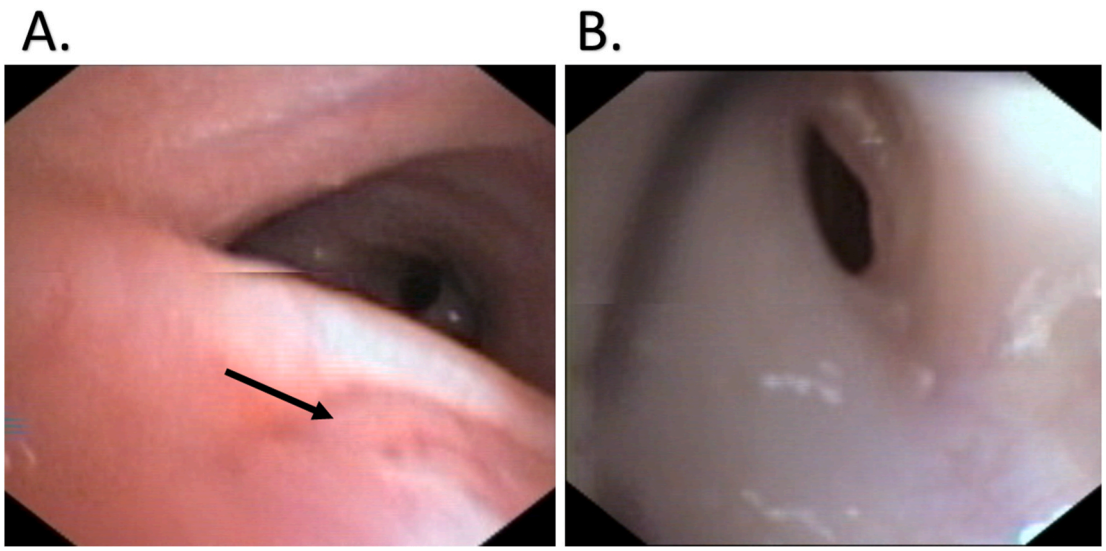

Fig. 1. Patent TEF: (A) On simple bronchoscopy seen as a mucous fold (B) Using oxygen bursts insufflation, showing a patent fistula.

modalities: One by methylene blue injection and upper GI imaging; one by upper GI alone, and one by bronchography. The remaining 9 were found using bronchoscopic OI, with only four of them identified during simple bronchoscopic observation. Six children had concomitantly positive upper GI imaging.

Illustrative case: One patient's fistula was missed with multiple investigations including bronchography. His upper GI imaging was negative. Conventional inspection via flexible bronchoscopy indicated a mucosal fold that appeared to be closed (Fig. 1a), but clearly opened up when short oxygen bursts were applied (Fig. 1b).

No complications were encountered during any of the procedures.

Following the diagnostic procedure, with ensuing surgical treatment when needed, a reduction in hospitalizations and emergency room attendances was noted. Prior to the diagnostic procedure, patients were frequently hospitalized for respiratory illness, with a mean (SD) of 2.8 (±2.52) admissions per patient. Following diagnosis and treatment, admissions decreased to 0.76 (±1.64) per patient ($p = 0.04$).

5. Discussion

Bronchoscopic insufflation has been described in the context of localizing occult bronchopleural fistulas [18] and the treatment of atelectasis [19], but its safety and yield in the context of EA/TEF in childhood are not clearly established, despite its anecdotal use in several centers. To our knowledge, this is the first formal report of bronchoscopic oxygen insufflation as a simple and valuable supplementary tool for the diagnosis of occult TEF.

Unfortunately, recurrent TEFs continue to be a common complication of primary repair with high morbidity and delays in diagnosis. In the most common type, "C", it almost universally occurs in the tracheal diverticulum, which is left behind as surgeons tend to place sutures 1–2 cm away from the tracheal wall to avoid the emergence of tracheal stenosis. Each diagnostic modality for the identification of occult TEFs, such as probing, UGI and methylene blue injection carries limitations, including radiation, anesthetic burden, procedural complexity and not least, a high rate of false negatives. In our cohort, OI proved clearly superior to simple inspection. It was also more sensitive than the traditionally employed UGI studies. In our series, accurate diagnosis led to fistula repair, reducing morbidity, which was apparent in the decline of hospital admissions. Timely diagnosis of recurrent TEF is essential to mitigate long term respiratory pathology [20–22].

Our study includes one case in which the fistula was missed using both upper GI study and bronchography, and diagnosed only via oxygen insufflation during bronchoscopy. Imaging studies performed during swallowing might miss TEFs due to the low pressure passage of contrast material, in particular if insufficient attention is paid to the positioning of the child, as some TEFs might only become obvious in prone position and using the pull back technique. This becomes increasingly difficult with older children, because of lack of cooperation [15].

A further drawback of GI imaging studies in this context is the difficulty differentiating between direct transition of contrast liquid into the airway via an open fistula on the one hand and aspiration of refluxate via the larynx on the other hand.[15,9] Furthermore, another study describes the difficulty with reaching a conclusive diagnosis with regards to isolated TEF. Eight out of 30 children required a second esophagogram, and 2/30 a third attempt, before the diagnosis was confirmed [9].

In theory, the insufflation of oxygen, or air for that matter, into an area that is suspected to have re-fistulized, might risk actively opening a membrane, rather than simply revealing an opening. Although, this unwanted effect cannot be ruled out, we regard the risk to be low, due to the following precautions taken: When approaching the suspicious area, e.g. tracheal diverticulum, we took care to use the smallest scope suitable and avoid completely wedging it. The duration of each insufflation was timed such, as to provide sufficient flow/pressure to distend otherwise flaccid tissue, exposing the pathway forward or the fistula itself, whilst minimizing the risk of causing interstitial emphysema, pneumomediastinum or pneumothorax.

The clinical situation indicating the examination was high risk for an open fistula to begin with. Moreover, it could be argued that tissues friable enough to give way in the face of such careful minimal insufflation do not constitute reliable separation between trachea and esophagus in the first place and in such a clinical situation, diagnosis and treatment are warranted. A further risk is the development of pneumothorax and it is reassuring that we did not encounter this in any of the 28 procedures.

The use of diagnostic bronchoscopy prior to EA/TEF surgery, without insufflation, is also recently gaining more popularity. Atzori et al. examined its importance prior to primary repair in 62 patients. Three of nine patients with suspected type A (no fistula) were re-categorized as type B, owing to the identification of a proximal fistula. In four patients, previously undetected malformations of the respiratory tree (two aberrant right upper lobe bronchi and two hypoplastic bronchi) were found. Carinal fistulas were seen in 14 type C patients, and subsequently occluded by Fogarty catheter to improve ventilation during repair [23].

Limitations of our study include its small size, making it impossible to draw clear conclusions about the yield of the various diagnostic modalities employed. Moreover, due its retrospective nature, not all patients underwent the same diagnostic work up. Only a few underwent bronchography and methylene blue injection, thus the comparitive significance is lacking. The assessment of recTEF is further complicated by the principle that fistulas might be intermittently patent, owing to an inflammatory process taking place under the influence irritating food stuff, gastro-esophageal reflux and cough related pressure changes. As such, concurrent examinations, even when carried out around the same time, cannot unambiguously be categorized as false negatives.

In summary, the present study demonstrates that bronchoscopic oxygen insufflation can be used in a safe manner and constitutes a further valuable modality for detecting occult tracheo-esophageal fistulas.

CRediT authorship contribution statement

Hagit Levine: Investigation, Writing – original draft, Methodology, Writing – review & editing, Visualization. **Tommy Schonfeld:** Conceptualization, Methodology, Reviewing. **Shahar Handelsman:** Investigation, date collection, Formal analysis. **Ophir Bar-On:** Writing – review & editingWriting- Reviewing and Editing, Visualization, Resources. **Guy Steuer:** Writing – review & editing, Resources. **Meir Mei-Zahav:** Writing – review & editingWriting - Reviewing and Editing, Formal analysis, Resources. **Dario Prais:** Writing – review & editing, Resources, Supervision. **Patrick Stafler:** Conceptualization, Methodology, Resources, Writing – review & editing, Formal analysis, Visualization.

Declaration of competing interest

We have no conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmed.2021.106544.

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Conflicts of interest

None declared.

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