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INTRODUCTION
Transient paradoxical closure of the larynx, occurring in the absence of any underlying structural or neurological defect, is a recognized cause of paroxysmal breathlessness and wheeze. This phenomenon, most commonly termed vocal cord dysfunction and more recently termed inducible laryngeal obstruction (ILO),1 is often misdiagnosed and mistreated as asthma.2,3 This may be explained by the lack of a robust, accepted diagnostic methodology.4,5

Central to the diagnosis of ILO is endoscopic visualization of the larynx in order to capture paradoxical narrowing of the laryngeal inlet occurring concurrently with compatible clinical features.6 This process is also dependent on successful exposure to a specific or relevant inducer; that is, to provoke closure. Exercise-induced laryngeal obstruction (EILO) is now recognized to be a prevalent cause of unexplained breathlessness in young athletic individuals7,8 and is best diagnosed using the continuous laryngoscopy during exercise (CLE) test.9 The latter is performed by securing a flexible laryngoscope in the nasopharynx, thus allowing continuous visualization of laryngeal movement and only one passage of the endoscope. It also offers an opportunity for biofeedback,10 and the development of battery-powered portable laryngoscope systems has now made it possible to deliver continuous laryngoscopy in challenging environments, for example, when swimming.11

Despite these developments, very little information is published regarding the optimum methodology for the assessment of laryngeal movement during environmental-type (i.e., nonexercise) provocation. Provocation agents utilized in this context typically include relatively innocuous stimuli such as household cleaning products, odors, or scents, but certain workplace environmental triggers are also relevant.12,13 Indeed, work-related irritant-induced laryngeal dysfunction remains an underrecognized and poorly diagnosed condition.14

We present a novel methodological approach to the diagnosis of ILO, utilizing a similar approach to CLE testing, to perform continuous laryngoscopy during provocation (CLP). In this report, we provide a description of this methodology and illustrative clinical cases to highlight the diagnostic and therapeutic benefits of the approach and outline its safety.

MATERIALS AND METHODS

Protocol Development
Using a portable battery-powered rhinolaryngoscopy system (CMOS laryngoscope and 8402ZX monitor; Karl Storz GmbH & Co. KG, Tuttingen, Germany), we first performed a feasibility trial. In brief, one of the authors (J.S.) had a laryngoscope placed in situ, following application of nonanesthetizing lubricating gel to one naris. The laryngoscope was then placed in specialist supporting headgear and secured with tape (Fig. 1). Simple voicing maneuvers were performed to ensure stability, and postural adjustments were made to yield high-quality images. The monitor screen was then concealed, and the subject was asked to move into an environmental challenge chamber. We then commenced our standard provocation protocol with exposure to an environmental trigger (e.g., one-spray increments of deodorant) (Table I). The challenge protocol has been utilized in our center for occupational lung disease challenge for over 15 years but differs in that previously a laryngoscope was only passed when an individual developed symptoms. Patients complete spirometric measures immediately before and following exposure, and oxygen saturation is measured. The provocation protocol is conducted by a senior speech and language therapist in a hospital setting with senior medical staff and immediate resuscitation facilities available.

RESULTS

Clinical Cases
Three female patients (aged 47–58 years) clinically suspected of having ILO and referred from the specialist...
upper airway clinic at our center underwent CLP following informed written consent and using self-selected provocation agents to elicit their typical symptoms (Table II). All patients tolerated continuous placement of the scope and confirmed that exposure in the chamber had been sufficiently concentrated to provoke their typical symptoms (i.e., wheeze, cough, breathlessness ± voice change). One patient exhibited classical paradoxical movement on inspiration at rest and following initial placement of the scope, and one developed glottic narrowing on expiration.

On provocation, two patients developed changes in their breathing pattern that led to feelings of tightness and breathlessness, and one patient performed repeated throat-clearing maneuvers. The test ended when the patient’s typical symptoms had been generated or when exposure exceeded the point of previous symptom provocation. On elicitation of upper airway symptoms, the specialist speech- and language therapist (SLT) initiated laryngeal and breathing control strategies with visual biofeedback to reduce symptoms to baseline. There were no adverse events during CLP, and the scope placement and fixation took less than 3 minutes. Two patients subsequently attended for review with the specialist SLT to consolidate understanding of CLP findings and use of control strategies. One patient declined further therapy, feeling confident of controlling symptoms independently.

**DISCUSSION**

It is now over 30 years since the first description that paradoxical (i.e., inspiratory phase) glottic closure could act to precipitate symptoms mimicking asthma. Since that time, there has been an evolving appreciation of the role of laryngeal closure in causing difficult-to-treat respiratory symptoms both in general and in workplace environments. Despite this, progress with respect to our understanding of the mechanisms ILO, variable characteristics and responses to intervention have been hampered by the lack of a valid, robust diagnostic methodology. The recent promotion of CLE to establish a robust diagnosis of EILO has facilitated considerable advances in our understanding of differing clinical phenotypes, response to treatments that include biofeedback, and surgical intervention. Continuous laryngoscopy during provocation promises similar advantages and offers unique opportunities to broaden our understanding of non-exercise ILO.

Continuous visualization of laryngeal movement offers a number of distinct advantages. Not only does it minimize the discomfort caused by multiple passages of a laryngoscope, but it also ensures that a state of laryngeal rest and adaptation can develop before commencing...
provocation. Furthermore, it affords detail regarding the time course of laryngeal reactivity and allows a comparison against control or placebo exposure. Certainly, the widespread utilization of CLE testing has facilitated a more robust determination of the epidemiology or EILO, permitted studies evaluating test–retest validity, and has been employed to assess the efficacy of interventions.

The continuous visualization approach employed by CLP also permits delivery of real-time biofeedback. This approach constitutes a promising new technique to ensure that instructions and techniques are specifically tailored to normalize laryngeal response patterns observed during the test. Visualization by the patient of laryngeal response and the effectiveness of control strategies lead to a better understanding of symptom generation and enhanced therapeutic outcomes.

The cases described align with the historical literature in that all cases had a significant delay to diagnosis and had been treated with escalating doses of asthma treatment. Moreover, despite this, the cases described frequently required acute medical care for breathing complaints underlining the healthcare implication of incorrect diagnosis. Interestingly, however, two of the three cases developed breathlessness during provocation, which appeared to be caused by changes in their breathing pattern (i.e., breath-holding, increased respiratory rate) and certainly not explained by any paradoxical vocal fold movement. Indeed, although CLP offers the opportunity to provide robust confirmation of diagnosis, prompting direct confirmation and serving to highlight other diagnoses that act to mimic ILO, in the current series both patients with breathlessness during provocation became distressed by memories of previous attacks and reported negative anticipation during the test.

Despite the promise of a more standardized approach to ILO provocation that may be afforded by CLP, further work is now needed to validate this approach. Indeed, the current approach represents a pragmatic solution to the delivery of a self-selected provocation agent, that is, as an individual would be typically exposed to in a home or work environment. We are currently unable to precisely quantify the dose or concentration of agent delivered; thus, future work should focus on establishment of a test–retest validity of this approach and development of a robust means of controlling exposure.

**CONCLUSION**

Continuous laryngoscopy during provocation is a safe and well-tolerated method for evaluating laryngeal response during provocation and negates repeated passage of the laryngoscope. Continuous monitoring throughout an environmental provocation test improves diagnostic accuracy by capturing the presence or absence of paradoxical movement.

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BIBLIOGRAPHY


