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Case Report

Forced oscillation technique to detect and monitor tracheal stenosis in a tetraplegic patient[2]

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Study design: A case report.
Objectives: To demonstrate forced oscillation technique's (FOT) utility in a tetraplegic patient with tracheostenosis.
Setting: A Rehabilitation Hospital, Brasília, Brazil.
Methods: Serial evaluations of spirometry, bronchoscopy and forced oscillation assessment.
Results: A 16-year-old male with C7 spinal cord injury, initially required mechanical ventilation and subsequent tracheostomy over a period of 4 weeks. Five months after the accident the onset of tracheostenosis was diagnosed. Flow-volume data were compatible with a fixed tracheal stenosis. FOT showed an obstructed pattern, manifested by high levels of resonance frequency and impedance. The FOT pattern returned to normal after dilatation. The FOT abnormalities recurred with two subsequent broncoscopicaly confirmed episodes of tracheal restenosis without parallel changes in spirometric parameters.
Conclusion: This case suggests a role for FOT in the non invasive detection and follow up of tracheal stenosis. FOT may be particularly useful in tetraplegic patients, in whom the restriction from muscle weakness may make interpretation of forced expiratory flow-volume data problematic.
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Keywords: quadriplegia; tracheal stenosis; spirometry; respiratory mechanics

Introduction

In patients with high spinal cord injuries (SCI), spirometric values and maximal mouth pressure are markedly reduced.[1] However, the maximum expiratory flow volume curves in such patients are commonly normal or only slightly subnormal, more reflective of respiratory muscle weakness and, consequently, providing limited information on the mechanical characteristics of the respiratory system.[2] Thus, detection of concomitant airflow obstruction can be hampered by the use of spirometry. On the other hand, cervical spinal injured patients frequently need invasive airway management, increasing the risk of later airway stenosis.[3,4]

The forced oscillation technique (FOT), proposed by DuBois,[5] permits measurement of respiratory system impedance and its components.[6] FOT consists of breathing quietly into a system in which superimposed oscillations are created by a loud-speaker or a pump. Pressure and flow are then registered in the mouth with a differential pressure transducer and pneumotachography. The driving oscillatory pressure results in flow oscillations whose magnitude and phase are determined by the resistive, elastic and inertial properties of the respiratory system.[6] The data can be collected rapidly and noninvasively. The entire examination lasts no more than 1 min. This method is easily performed in children[7] and individuals with neuromuscular disease,[8] who may remain seated in a wheelchair or lying in bed.

The present case demonstrates FOT utility in an SCI patient with tracheostenosis.

Case Report

A 16-year-old male patient suffered a C7 spinal cord injury by diving into shallow water. His injury, characterized by complete motor and incomplete sensory loss below the lesion, was classified as B by American Spinal Injury Association (ASIA B). He required intubation 7 days after admission to another hospital. The following day he was submitted to a tracheostomy and remained on a mechanical ventilator

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assistance for 15 days. His tracheostomy tube was removed 1 month later.

He was admitted to the SARAH Hospital/Brasília rehabilitation 2.5 months after the injury. He underwent a bronchofiberscopic examination because of retained secretions: the results were normal. One month later, 4.6 months after the accident, he presented with dyspnea and stridor. On this occasion, an investigation was conducted using spirometry and FOT (IOS, Erich Jaeger GmbH, Hoechberg, Germany). The spirometric values were 2.1 l for FVC (46.8% of predicted based on the spirometric standards of Knudson *et al*[9]), with FEV_1 of 1.7 l (44.3%) and a FEV_1/FVC of 74.8%. The flow-volume data suggested a fixed tracheal stenosis (Figure 1). FOT showed an obstructed pattern, manifested by high levels of resonance frequency and impedance (Zrespir), with remarkably high resistance (R) and low values of reactance (X), both at low frequencies (5–15 Hz) (Table 1). On the same day, a rigid bronchoscopy was performed which revealed a tracheal stenosis with a diameter of 4 mm, 2 cm below the tracheotomy scar. At broncoscopy the stricture was dilated. Follow-up FOT, 1.4 months after the first examination, showed a complete reversal of the previous pattern, while the flow-volume curve changed slightly (Figure 1). Later results of FOT examinations performed at 6.6 and 7.6 months post injury strongly suggested recurrent airway obstruction, without parallel modification from spirometric parameters. On both occasions he was submitted to dilatation procedures, whose effectiveness was again confirmed by FOT (Table 1). Because of these recurrences, the patient underwent a tracheoplasty with resection of the fibrous ring, 8.3 months after the accident. The histopathology report revealed tracheal stenosis with inflammation, abscess, ulcers and fibrosis. The calculated area of stenosis was 0.5 cm^2.

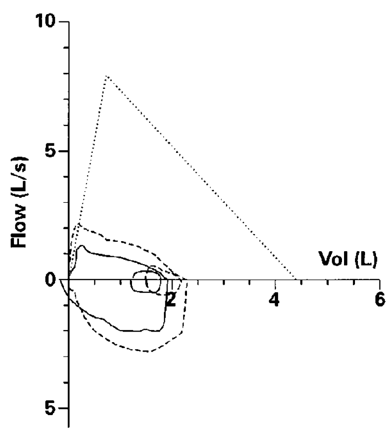

Figure 1 Forced flow volume curves before (——) and after (- - -) one of the dilatation sessions. Dotted curve (. . . .) indicates expected expiratory flow pattern

Figure 2, graph A, shows the curves of resistance and reactance of his respiratory system, obtained by FOT before and after the third dilatation. Figure 2 (graph B) demonstrates the improvement between the measurements at the onset of the upper obstructive airway and those at the time of discharge. One important characteristic of the obstruction pattern obtained by FOT was a negative frequency dependence of resistance and a positive frequency dependence of reactance, leading to an intersection of both curves at low frequency. This pattern was completely reversed after dilatation and resection. Graph C shows a pattern from an age and sex-matched individual with a normal pulmonary function, since there are no predicted values for this patient's age bracket.

Discussion

The present case shows that FOT was useful in the assessment and monitoring of respiratory mechanics and airflow obstruction, suggested by conventional spirometry. Although FOT is not yet extensively used nor is it proposed as a standard method in current

Table 1 Main parameters of respiratory mechanics measured by forced oscillation technique[a]

	Months after spinal injury						
	4.6 before	*6.0 after*[b]	*6.6 before*	*6.6 after*	*7.6 before*	*7.7 after*	*10.2 discharge*[c]
Resonance frequency (Hz)	37.01	10.93	32.11	12.49	34.35	11.43	11.79
Zrespir (kPa/L/s)	1.33	0.42	0.74	0.67	1.69	0.61	0.28
Resistence (kPa/L/s)							
at 5 Hz	1.26	0.41	0.70	0.66	1.36	0.60	0.26
at 10 Hz	0.87	0.36	0.57	0.61	0.77	0.54	0.22
at 15 Hz	0.66	0.36	0.48	0.59	0.55	0.54	0.22
Reactance (kPa/L/s)							
at 5 Hz	−0.43	−0.10	−0.24	−0.11	−1.01	−0.10	−0.10
at 10 Hz	−0.45	−0.01	−0.19	−0.01	−0.72	−0.01	−0.01
at 15 Hz	−0.37	0.03	−0.17	0.03	−0.49	0.03	0.03

[a]There are no predicted values for this patient's age bracket. [b]Before and after tracheal dilation. Patient was submitted to three sessions. [c]Last exam before discharge of patient (which was compared with the first exam in Figure 2**B**).

guidelines and reviews of respiratory system measurements,[10–12] it is being employed in children and infants[7,12] with asthma and cystic fibrosis.

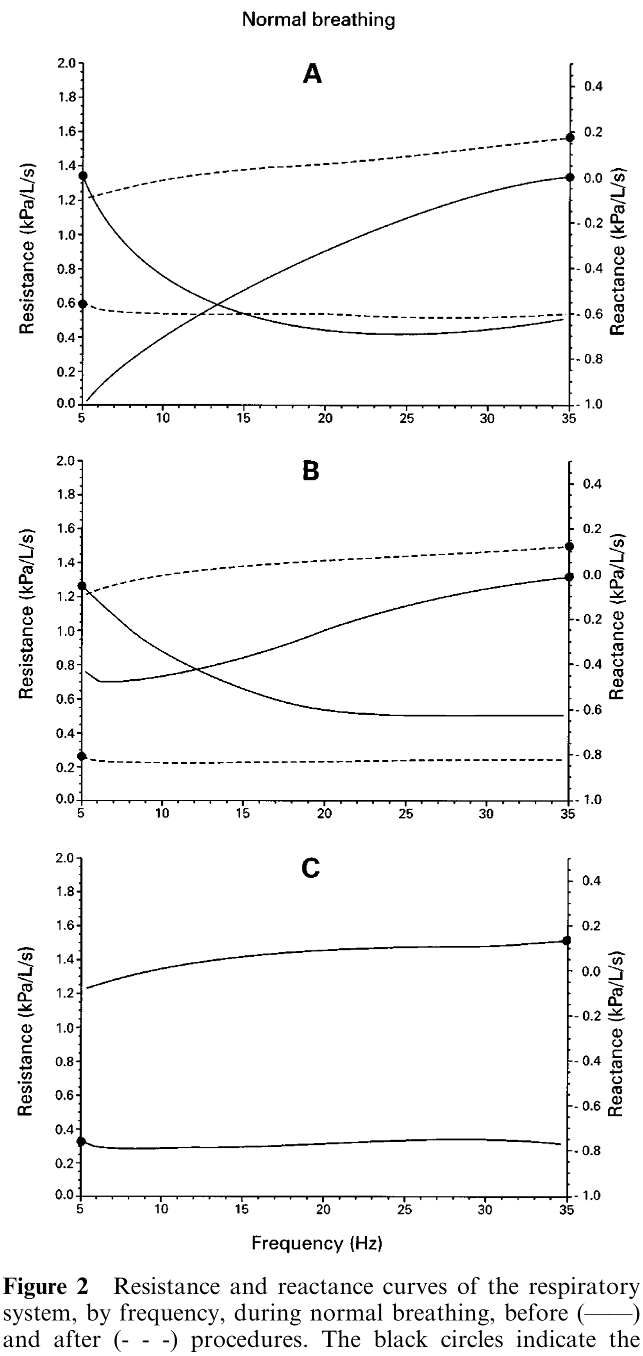

Figure 2 Resistance and reactance curves of the respiratory system, by frequency, during normal breathing, before (——) and after (- - -) procedures. The black circles indicate the origin of the resistance curve (on the left) and reactance curve (on the right). In graph **A**, the patient was submitted to a tracheal dilatation session, also documented by spirometry shown in Figure 1. In graph **B**, at the onset of upper obstructive airway status and after three sessions of dilations and a tracheoplasty. In graph **C**, the pattern from an age and sex-matched individual with normal pulmonary function

Only one study has been published in the investigation of patients with a neuromuscular disease describing the use of FOT.[8] In this study none of the patients had SCI or obstruction of upper airway, and no significant correlations were found between the forced expiratory volumes in 1 s (FEV_1) and the impedance data from the respiratory system.

Even though FOT was first described in 1956, only in the last decade has its clinical usefulness, indications, and limits been explored. The clinical significance of the measured parameters are also in the process of further evaluation, but the abnormally low values of reactance before treatment may represent the effect of tight stenosis obscuring the normally expressed low pulmonary and chest wall compliances. These compliances become expressed after the normalization of the tracheal diameter.

This case suggests a previously unreported role for FOT in the non invasive detection of airway obstruction lesions. There is a large group of previously intubated, neurologically injured patients in whom forced loop spirometry is unreliable.[2,3] The ease and quickness of FOT may enhance its utility in patients with SCI and possible tracheostenosis.

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