Control of the larynx in patients with obstructive and restrictive pulmonary impairment

M. Yanai, K. Sekizawa, H. Sasaki, T. Takishima

ABSTRACT: To study changes in glottic movements associated with pulmonary functional abnormalities, we measured changes in glottic resistance (Rgl) during quiet tidal breathing in normal subjects (N), patients with chronic obstructive pulmonary disease (COPD) and patients with idiopathic pulmonary fibrosis (IPF). Changes in Rgl were measured with a non-invasive method using low frequency sound [1]. Changes in Rgl were tightly coupled to changes in tidal volume and were reproducible in all subjects. Rgl was higher during expiration than during inspiration in N and COPD. COPD showed greater changes in Rgl between inspiration and expiration than did N. However, Rgl did not differ between inspiration and expiration in three of six IPF, and was lower during expiration than during inspiration in two of six IPF. We suggest that glottic movements during quiet tidal breathing change in association with the functional abnormalities of pulmonary diseases.


The larynx modulates airflow and participates in the control of ventilation during quiet tidal breathing [2, 3]. Hypercapnia [4], loading by external resistance [5, 6] and pharmacologically-induced bronchoconstriction [7] in normal subjects. In patients with chronic obstructive pulmonary disease, Higenbotiam and Payne [8] reported that the glottic width narrowed with the progression of airflow obstruction, especially during expiration. Likewise, Collett et al. [9] demonstrated that histamine-induced severe bronchoconstriction in bronchial asthma was associated with marked narrowing of the laryngeal aperture during expiration with minimal change during inspiration. Narrowing of the larynx during expiration in patients with pulmonary obstructive impairment may be beneficial by slowing expiration to prevent airway collapse and by maintaining a relatively high functional residual capacity to reduce airway resistance [8, 9].

In contrast to patients with obstructive disorders, patients with pulmonary restrictive impairment are characterized by a decrease in lung volume with an increase in elastic recoil pressure of the lung and minimal change in airway resistance. Clinically, these patients show rapid shallow breathing which differs from the prolonged expiration of patients with obstructive pulmonary disease. Therefore, behaviour of the larynx in patients with restrictive impairment during quiet tidal breathing should differ from that in patients with obstructive impairment. However, there have been no reports on glottic movement during quiet tidal breathing in patients with restrictive impairment. We therefore decided to compare glottic movement during quiet tidal breathing in patients with idiopathic pulmonary fibrosis (IPF) with that of patients with chronic obstructive pulmonary disease (COPD).

Methods

Subjects in this study were patients with chronic obstructive pulmonary disease (COPD), idiopathic pulmonary fibrosis (IPF) and normal subjects (N). Each group consisted of six subjects. The physical characteristics of each group are listed in Table 1. COPD was defined by abnormal expiratory flow that did not change markedly over several months of observation [10]. IPF patients were diagnosed by clinical, roentgenographic and physiological criteria. Transbronchial lung biopsies were performed to confirm the diagnoses histologically. These patients had no history of inhalation of inorganic or organic dusts and no precipitin antibodies when examined with eleven commercially available major antigens (Hollister-Sier Labs, USA). None of the IPF patients had received steroid therapy. The normal subjects (N) were healthy volunteers with no history of pulmonary or cardiac disease.

Changes in glottic resistance were measured as previously reported [1, 11]. Briefly, sound pressure amplitudes were detected by two microphones with flat responses in the range of 50 Hz – 10 kHz according to the manufacturer’s specifications (Nippon-Chemicon, FSM-10). The flat sensing faces of the microphones were
attached with double-sided tape to the anterior neck 1 cm above and 1 cm lateral to the laryngeal prominence, and also to the anterior neck 1 cm below the cricoid cartilage. Particular care was taken to eliminate air spaces between the microphones and the skin. Sound pressure amplitudes above (SPAA) and below (SPAB) the vocal cords were measured using a detector with a rectifier circuit and an analog filter that had a 90% response within 100 ms [12]. After the electrical signals from the two microphones had been rectified, the SPAB output at end-expiration was adjusted by an amplifier to equal that of the SPAA at end-expiration during quiet tidal breathing. Both SPAA and SPAB signals at end-expiration were then recorded as 100%. To estimate glottic narrowing, we subtracted SPAB from SPAA, and this difference at end-expiration was taken as the 0% value. The percentage increase in SPAA (SPAA%) minus percentage decrease in SPAB (SPAB%) (SPAA%-SPAB%=ΔSPAA%), during voluntary closure of the glottis from the control condition, represents the increase in glottic resistance as previously reported [1]. Conversely, a decrease in ΔSPAA% represents a decrease in glottic resistance.

During the experiment, subjects were seated in a pressure-compensated volume-displacement body plethysmograph, which was without amplitude or phase distortion up to 8 Hz [13]. During the experiment tidal volume (VT), respiratory frequency (f), and functional residual capacity (FRC) were continuously measured with the Krogh spirometer-equipped body plethysmograph. Airflow at the mouth, ΔSPAA%, VT, and the level of FRC were recorded on a pen recorder (San 6, 8s) and monitored with a storage oscilloscope (Tectronics, 5013N). All data were recorded on a data recorder (Sony Magscale, DRF 2915) for later analysis. Subjects wore a noseclip and were instructed to breathe normally through a piece of flexible tubing held firmly in the mouth. To avoid changes in tension in the skin and underlying tissue of the neck, the head position was kept vertical by fixing the height of the chair from the mouthpiece. If postural changes occur, ΔSPAA% may not accurately reflect changes in glottic resistance. Therefore, the subjects were required to keep their backs straight and in contact with the backboard of the body box. We frequently checked by observation for rotation of the neck. If it occurred, we discarded the data. A constant bias suction flow of 0.4 l/s was applied between the mouthpiece and flowmeter to minimize the instrumental deadspace.

Vital capacity (VC) and forced expiratory volume in one second (FEV1) were measured using a 13.5 l Benedict-Roth spirometer. FRC was measured with neon as a tracer gas using the gas-dilution method. Partial pressures of arterial oxygen (PaO2) and carbon dioxide (PaCO2) were measured using an IL meter 213. With all subjects, we analysed seven breaths for which VT, f, and FRC levels were stable.

Statistical analysis was performed using a one-way analysis of variance and Duncan's multiple range test. Significance was accepted at p<0.05. Data are presented as mean±SE.

Table 1 shows the physical characteristics and pulmonary function test data of the three groups. There are no significant differences in physical characteristics amongst the groups. %VC was significantly smaller in COPD and IPF than in normals. FEV1% predicted was significantly decreased in COPD and IPF. TLC% and FRC% predicted were increased in COPD and decreased in IPF. PaO2 was significantly decreased in COPD. VT was larger in COPD than in normals and f was significantly higher in IPF than in normals.

Figure 1 shows change in ΔSPAA% as a function of VT in the three groups. Each loop represents the mean±SE of seven breaths. Although the shape of the loops varied amongst the subjects, the change in ΔSPAA% with ventilation was consistent in each individual subject in all groups. The difference in ΔSPAA% between inspiration and expiration in each subject was statistically examined. For statistical analysis, mean ΔSPAA% between inspiration and expiration at VT of 20, 40, 60 and 80%, i.e. excluding end-inspiratory and end-expiratory points, were compared in each subject. In COPD and normals, inspiratory ΔSPAA% was significantly lower than expiratory ΔSPAA% (p<0.05 to p<0.01) with the exception of one patient with COPD (no. 4). In IPF, inspiratory ΔSPAA% was significantly lower than expiratory ΔSPAA% in one subject (p<0.01; no. 4) and significantly higher than expiratory ΔSPAA% in two subjects (p<0.01; nos. 3 and 5). In the other three IPF patients there was no significant difference between inspiratory and expiratory ΔSPAA%.
Figure 2 shows mean inspiratory SPA% minus mean expiratory ΔSPA% (DRgl). DRgl in COPD was significantly greater than in normals and IPF (p<0.01). In IPF, DRgl exhibited negative values and differed significantly from that of normals and COPD patients (p<0.01).

Fig. 1. – Relationship between percentage sound pressure amplitude (ΔSPA%) and tidal volume (VT) in a mean of seven breaths in each subject of the three groups; VT is expressed as 100%. Results are reported as means ± SEM. Arrows indicate direction of trace during quiet tidal breathing. 1A N: normal; 1B COPD: chronic obstructive pulmonary disease; 1C IPP: idiopathic pulmonary fibrosis.

Discussion

The results suggest that inspiratory widening and expiratory narrowing of the glottis become prominent in COPD and that the phasic movement observed in normals and COPD disappears or the expiratory glottic dimension becomes larger than on that inspiration in IPF. Since the glottic movement was tightly coupled with ventilation, and this relationship was highly reproducible in all subjects, the results obtained were not due to transient or voluntary movements of the glottis.

In a previous study [14], we directly measured upper airway resistance by intratracheal lateral pressure and mouth flow, and examined the relationship between increases in ΔSPA% and increases in upper airway resistance during methacholine and histamine inhalation in ten normal subjects. When respiratory resistance measured by the forced oscillation technique increased, the upper airway resistance increased corresponding to ΔSPA% in a manner that approximately followed the relationship observed during voluntary glottic closure [1]. Furthermore, changes in ΔSPA% reflected fairly well changes in upper airway resistance during the slow vital capacity manoeuvre in two normal and two asthmatic subjects [14]. Therefore, increased and decreased FRC or increased respiratory resistance below the larynx may not have influenced measurement of ΔSPA% in the present study.
Although we do not know the absolute resistance of the glottis, COPD patients showed larger differences in Rgl between inspiration and expiration than did normals, suggesting that expiratory glottic narrowing was intense in COPD. Glottic narrowing, particularly during expiration, has been observed in patients with low FEV₁, [8], and marked expiratory narrowings of the glottis with minimal change in inspiratory glottis areas have also been reported in histamine-induced severe bronchoconstrictions in bronchial asthma [9]. Expiratory glottic narrowing is thought to add a serial resistance to the pulmonary system, thereby controlling the time-course of lung volume changes during expiration [3, 15]. The augmented expiratory narrowing of the glottis in COPD may be analogous to expiration through pursed lips, which, by slowing expiratory flow, improves alveolar ventilation and gas exchange in such patients [16, 17]. It may also, by slowing expiration, constitute a means of reducing the contribution of the ribcage musculature to maintain hyperinflation [9].

In contrast to N and COPD patients, we showed that in IPF glottic movement during quiet tidal breathing was variable and we found no specific pattern of glottic movement. Changes in glottic movement in IPF may be related to changes in breathing pattern. Patients with IPF in the present study showed rapid shallow breathing compared to normal subjects. Since the elastic recoil pressure of the lung increases in IPF and, therefore, the work of breathing against the elastic recoil pressure increases, the rapid shallow breathing may be mechanically advantageous by enabling ventilation to be maintained with minimum increases in inspiratory muscle force and energy expenditure [18]. The mechanism responsible for rapid shallow breathing in patients with restrictive pulmonary impairment is not fully understood [19]. MARTIN et al. [20] showed that inspiratory elastic loading diminished expiratory braking by the inspiratory muscles during expiration, with the result that the rate of expiration was enhanced and its duration shortened. Therefore, changes in respiratory muscle activity, if they occur in restrictive pulmonary impairment, may be one mechanism responsible for rapid shallow breathing. Expiratory narrowing of the larynx is supposed to regulate the expiratory airflow by adding resistance to the pulmonary system [3, 15], with the result that the duration of expiration is prolonged. The lack of expiratory narrowing or widening of the glottis during expiration in some IPF patients may, therefore, reduce the serial resistance to the pulmonary system and accelerate emptying of the lung. Both changes in respiratory muscle activities and widening of the glottis during expiration may be mechanisms responsible for the rapid shallow breathing of patients with IPF.

In conclusion, we suggest that glottic movement during expiration changes in association with pulmonary functional abnormalities.

References

CONTROL OF LARYNX IN PULMONARY DISEASE


RÉSUMÉ: Pour étudier les modifications des mouvements glottiques associés aux anomalies fonctionnelles pulmonaires, nous avons mesuré chez des sujets normaux (N), chez des patients avec affection pulmonaire obstructive chronique (BPCO) et chez des patients avec fibrose pulmonaire idiopathique (FPT), la résistance glottique (Rgl) au cours d'une respiration calme à volume courant. Les modifications de la résistance glottique ont été mesurées par une méthode non invasive, utilisant des sons de basse fréquence [1]. Les modifications de la résistance glottique étaient couplées étroitement aux modifications du volume courant et étaient reproductibles chez tous les sujets. La résistance glottique est plus élevée au cours de l'expiration que pendant l'inspiration, à la fois chez les normaux et dans les BPCO. Les BPCO ont des modifications plus importantes de la résistance glottique entre l'inspiration et l'expiration que les sujets normaux. Toutefois, la résistance glottique ne diffère pas entre inspiration et expiration chez 3 des 6 sujets avec fibrose pulmonaire interstitielle, et est plus faible au cours de l'expiration que pendant l'inspiration chez 2 des 6 cas de fibrose pulmonaire interstitielle. Nous suggérons que les mouvements glottiques au cours de la respiration calme à volume courant se modifient en association avec les anomalies fonctionnelles dans les maladies pulmonaires.