Resistive load detection during passive ventilation

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Summary

1. By using standard psychophysical techniques resistive load detection was estimated in five normal subjects during spontaneous breathing and during passive ventilation in a Drinker respirator.

2. During assisted ventilation a gross deterioration in resistive load detection occurred.

3. The findings imply that active respiratory muscle contraction plays an essential role in the detection of added resistive loads.

Key words: dyspnoea, loaded breathing, respiratory sensation.

Introduction

Normal subjects, patients with neurological abnormalities and subjects with altered respiratory mechanics have all been studied in an attempt to elucidate the mechanism of resistive load detection (Bennett, Jayson, Rubenstein & Campbell, 1962; Wiley & Zechman, 1966; Newsom-Davis, 1967; Noble, Frankel, Else & Guz, 1971; Burki, Mitchell, Chaudhary & Zechman, 1978; Howell & Shahid, 1979). Campbell and his colleagues (Campbell, Freedman, Smith & Taylor, 1961; Bennett et al., 1962; Campbell & Howell, 1963) postulated that detection of an externally added load occurs because the change in volume or rate of change of volume (flow) is inappropriate or less than expected for the applied muscular force or pressure. They further suggested that the primary afferent information arose in the chest wall. If information essential to the genesis of resistive sensation arises in muscle receptors, activation of which depends on muscular contraction, then the acuity of resistive load detection might be reduced by passive ventilation. By studying resistive load detection during passive ventilation, we were able to test the role of active muscular contraction in the generation of resistive sensation.

Methods

Subjects

Five subjects (age 20–52 years) were studied. All had normal spirometry. Two were familiar with the purpose of the experiment and all were familiar with respiratory and sensory studies.

Apparatus

The experiment was performed in the supine position with the subject completely enclosed in a Drinker respirator. The subjects breathing through a mouthpiece and one-way valve were connected to the outside of the ventilator by corrugated tubing (3 cm internal diameter). The inspiratory port of the valve was connected to a resistance circuit, which allowed the addition of a series of resistances (range 0.15–3 cm water l−1). The pressure–flow characteristics were linear to a flow rate of 1.5 litres. The basal resistance of the circuit was 0.4 cm water l−1 and the dead space was 50 ml. Flow was recorded by means of a Fleisch no. 3 pneumotachometer and volume was recorded by integration of the flow signal. Mouth and box pressure were recorded with Hewlett Packard no. 267 pressure transducers. All recording equipment was calibrated by using standard techniques.

Detailed procedure

After entering the Drinker respirator the subject breathed quietly through the resistance...
circuit for 5 min. During this time, the respirator was turned on but the side port of the respirator was open and no pressure was developed around the thorax. The subject was given a short familiarization procedure in which he was presented with each of the loads in succession. He was instructed in the cueing and signalling procedure, which was as follows: on the breath before the test breath, a buzzer sounded and remained on until the presentation was complete. In his hand the subject held a response button which he was to press if he detected the presence of a load. He was informed that the cue would be followed by a load or a blank (zero load). Five loads, spanning the range of detection in addition to a zero load, were presented randomly 10 times. Each load was present for one breath and the interval between presentations varied from two to five breaths.

Experimental protocol

Two experiments were performed and were alternated on successive subjects. (1) Detection of externally added resistive loads while subjects breathed actively (with the ventilator on but no pressure generated across the chest). (2) Detection of externally added resistive loads while subjects were passively ventilated by the Drinker respirator.

Analysis of results

Each detected load scored one point. The probability of detection was thus estimated as the score obtained divided by the total possible score. The results were then expressed as the probability of detection ($P$) plotted against the added loads ($\Delta R$) (Fig. 1). Threshold detection is defined as the added resistance detected with a 50% probability ($\Delta R_{50}$).

Results

The mean threshold resistance $\Delta R_{50}$ during active breathing of subjects was $0.77 \pm 0.16$ (SEM) cm water s$^{-1}$ l$^{-1}$. This slightly high value can be explained by the increased internal resistance in the recumbent position (Wiley & Zechman, 1966). The detection threshold during assisted ventilation was not within the range of our resistance circuit (0.15–3 cm water s$^{-1}$ l$^{-1}$). In four subjects, resistances of the order of 10 cm water s$^{-1}$ l$^{-1}$ had to be added before reliable detection ($P > 50\%$) occurred. One subject did not reliably detect total occlusion. The minute ventilations were similar under both conditions (approx. 15 litres/m).

Discussion

We have shown that the detection of added resistive loads grossly deteriorates during assisted ventilation. These results suggest that active respiratory muscle contraction plays an essential role in load detection, implying that the kinaesthetic properties of active respiratory muscle contraction is similar to that shown for the limb muscles (McCloskey, 1978; Roland & Ladegaard-Pederson, 1977).

It could be argued that we have no proof that the respiratory muscles were inactive during passive ventilation. Although this could be a cogent argument had there been no effect, it is difficult to sustain in the light of our findings. Inspiratory assistance produces a distracting stimulus which might lead to impaired detection. However, the control run was also carried out with the same distraction making this an unlikely explanation for our results.

Increased background elastance or resistance are both known to cause a reduction in resistive acuity (Wiley & Zechman, 1966; Burki et al., 1978; Gottfried, Altose, Kelsen, Fogarty & Cherniack, 1978; Howell & Shahid, 1979). We cannot rule out an increase in background resistance due perhaps to incomplete abduction of the vocal cords or an increase in elastance due to increased expiratory muscle tone such as has been shown to occur with positive pressure breathing (Bishop, 1964). The increases in background elastance or resistance necessary to
reduce detection to this degree would have to be very large. Analysis of the pressure–volume and pressure–flow characteristics across the thorax obtained during the study showed a mean elastance of only 13 cm water/l and a mean resistance of 5 cm water s⁻¹ l⁻¹ during passive ventilation. This background load would not be sufficient to account for the deterioration shown.

In the original paper on resistive load detection, Bennett et al. (1962) forwarded the hypothesis that it was the inappropriate relationship between pressure and flow on the loaded breath that generated the sensation. They further suggested that this information originated from the chest wall (spindle, tendon organs and joint receptors). Passive ventilation by altering information from muscle (McCloskey, 1978) might be expected to lead to a deterioration in resistive acuity. In summary, we have shown that the detection of externally added resistive loads deteriorates dramatically with passive ventilation. Our findings strongly support the hypothesis that active respiratory muscle contraction is an important source of resistive sensation.

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References


