ABSTRACT

Post-polio patients sometimes complain about the occurrence of breathing difficulties after the polio infection. We have examined 40 post-polio patients who have had respiratory or non-respiratory poliomyelitis for at least 50 years in an attempt to elucidate whether hyperventilation is common and to what extent certain symptoms and simple lung function tests are related to hyperventilation or incidental hyperventilation. We measured arterial blood gases, vital capacity (VC), maximal expiratory and inspiratory pressures (NEP, MEP) and CO2 rebreathing response. Symptoms were assessed by a yes/no questionnaire. Six patients required respiratory assistance at the onset of the disease. At present, two require nocturnal assisted ventilation. Two patients showed manifest hyperventilation; one of which required night-time ventilator, whereas the other patient had not required ventilatory assistance even at the onset of the disease. Significant correlation (p = 0.05) was found between arterial carbon dioxide tension (PACO2) and VC, MEP and ventilation increase during CO2 rebreathing. A significantly higher a-PACO2 was found among those who required respiratory assistance at the onset of the disease, who admitted headache and who felt through ineffective, low VC and low ventilatory increase during CO2 rebreathing and the presence of headache explained 45% of the variation in a-PACO2 in a multiple regression analysis. We conclude that manifest hyperventilation is rare in this unselected material of post-polio patients and that a vital capacity below 45–50% of predicted normal and the presence of frequent headaches indicate an increased risk to develop hyperventilation.

KEY WORDS: arterial blood gases, hyperventilation, post-polio syndrome, respiratory function.

Late effects from the muscle-skeleton system of post-polio patients have been referred to as the "post-polio syndrome" (6–10). These patients had their infection more than 30 years ago and they experience increased tiredness, lack of strength and/or pain. Hyperventilation may occur as a consequence of increased weakness of the breathing muscles and could explain why some patients complain about breathing difficulties. These symptoms may, however, represent physiological changes which are only partly understood (13).

To be able to recognize which hyperventilation or run an increased risk to develop hyperventilation is important for the care of these patients.

Symptoms like headache, tiredness and dyspnoea have been considered to be associated with the occurrence of hyperventilation (9, 10). These symptoms are unspecific however, and may be explained by many other causes than hyperventilation. It is therefore unclear how useful these symptoms are in the assessment of hyperventilation in post-polio patients.

Simple lung function tests indicating developed hyperventilation would also be clinically useful for the recognition of risk patients.

This study was aimed to study whether hyperventilation is common among post-polio patients and to what extent certain clinical symptoms and/or simple lung function tests are related to hyperventilation or incidental hyperventilation. Abnormally high arterial carbon dioxide tension (a-PACO2) indicates hyperventilation and we have assumed that a-PACO2 within the normal range (12) is related to the risk to develop hyperventilation. For example, a patient with a-PACO2 close to the upper normal limit, is assumed to run an increased risk compared to someone with a lower a-PACO2. Thus, symptoms and lung function measurements have been related to a-PACO2.

MATERIAL

We aimed at including all post-polio patients in the age of 40–66 years, living in the region of Göteborg (approximately 450000 inhabitants). From the Association for Traffic and Polio Injured Patients we got the names of 42 patients. Twenty patients dropped out (seven patients did not contact after repeated requests and seven did not want to participate). Thus, 32 of these patients took part in the study. Through the registrar of the Epileptic Hospital in Göteborg we identified 37 eligible patients, who had been taken care of at the hospital in the years 1910–1954. Twenty of these patients were asked to
participate (the others could not be found in data register, had died or were living outside the region of Göteborg). Nine patients did not answer the offer, while four patients did not want to participate. Thus, seven patients from the register of the Epidemiology Hospital took part in the study. Two additional patients were found and included. One patient was found to suffer from rheumatic arthritis and was excluded. Accordingly the present study is based on 40 patients.

Mean age was 56 years (range 42-66 years). The mean duration of illness was 40 years (range 30-62 years).

METHODS

Routine physical examination was performed. Scoliosis, if present, was graded in small, medium and severe. A questionnaire with most answers in yes/no form was constructed and sent out together with the invitation to participate in the study. The questions concerned the occurrence of infec tions, dyspnoea, tiredness, chest pain, headache, symptoms of gastritis, change in appetite, and smoking habits. An attempt to rank dyspnoea was made. Slight to moderate dyspnoea was defined as dyspnoea walking or driving wheel chair on plain level or on a slight slope. Medium to severe dyspnoea was defined as dyspnoea at primary ADL (dressing and undressing, washing) and at rest.

Arterial oxygen tension (a-P02), arterial carbon dioxide tension (a-PC02) and standard bicarbonate (SB) were measured in samples of blood obtained from the radial artery. Hyperventilation was defined as a-PC02 > 6 kPa. Lung function examination was done with the patients in sitting position. Three acceptable recordings of vital capacity (VC) and forced expiratory volume in one second (FEV1) were obtained and the maximum value of each variable was used in the further analysis. Normal values were predicted according to Becklund et al. (3). Maximal inspiratory pressure (MIP) reflecting the strength of the diaphragm and maximal expiratory pressure (MEP) reflecting the strength of the abdominal muscles were obtained at functional residual capacity, according to the technique previously described (3). Normal values were predicted, according to Decramer et al. (9) and Larie et al. (11).

The CO2 rebreathing technique, according to Read (14), was used as a possible way to test the ability to increase ventilation. End-tidal PC02 and ventilation in l/min were registered in two runs with a few minutes’ interval. The slope of the curve relating PC02 to ventilation (AIV/AVPC02) was calculated after exclusion of the initial curved part and expressed in l/min/kPa.

RESULTS

Six patients required respiratory assistance at the onset of the disease. Eleven patients were smokers, 17 ex-smokers and 12 non-smokers. Four patients showed slight scoliosis, eight moderate, and ten severe scoliosis. Table I presents working capacity and means of assistance. One patient had a Cuariss ventilator and another had a Dallhorn respirator.

Symptoms

Cooperation in answering the questionnaire was 100%. Fig. 1 illustrates the prevalence of various symptoms. Headache was reported by 14 patients, most of whom (11 patients) now and then used analgetics. Abnormal tiredness was admitted by 12 patients. Ankle swelling had been noted by 20 patients. None complained of bad appetite. Gastric symptoms were admitted by 17 patients and 13 of them used antacids. Chest pain at effort was admitted by eight persons. One of these used β-adrennergic blockers but none of them used nitroglycerine. Mild dyspnoea was found in 21 patients and moderate to severe dyspnoea in eight. Eleven patients did not complain of dyspepsia. Feeling of adequate cough function was reported by most patients but ten reported the sensation of inadequate cough.

In the extended questionnaire answered by the eleven patients who had the lowest VC's and were examined during sleep, the following was noted: night mares 1/11, experienced memory deterioration 1/11, day time drowsiness 1/11 and the feeling of thoroughly rested in the morning 9/11.

Fig. 1. Prevalence of various symptoms among 40 post-polio patients according a questionnaire results.

Long function

Two patients showed increased a-PC02, one patient required night-time ventilator, whereas the other patient had not required ventilatory assistance even at the onset of the disease. Mean a-PC02 in the group as a whole was 5 kPa. Spirometric and respiratory muscle strength results are illustrated in Fig. 2. VC was less than 50% of predicted normal value in five of the patients and was within the predicted normal range in 30 patients. All patients had a normal FEV1%. As a rule, MEP was within the normal range as only four patients showed reduced pressures. Regarding MEP, twelve patients (30%) showed values below the predicted normal range.

In an attempt to find factors predicting the risk to develop hyperventilation correlations against a-PC02 were calculated. Significant correlation (p < 0.05) was found to VC, MEP and ventilation increase during CO2 rebreathing (Fig. 3). MEP, however, was not significantly correlated to a-PC02.

Among those who had admitted headache and the feeling of ineffective cough, a significantly higher a-
METHODS

Routine physical examination was performed. Sc Oakland, if present, was graded in small, medium and severe. A questionnaire with most answers in yes/no form was constructed and sent out together with the invitation to participate in the study. The questionnaire concerned the occurrence of infections, dyspnea, tiredness, chest pain, headache, symptoms of gastritis, change in appetite, and smoking habits. An attempt to rank dyspnea was made. Slight to moderate dyspnea was defined as dyspnea walking or driving wheel chair on plain level or on a slight slope. Medium severe dyspnea was defined as dyspnea at primary ADL (dress and undressing, washing and at rest).

Arterial oxygen tension (\(P_{\text{aCO}_2}\)), arterial carbon dioxide tension (\(P_{\text{aCO}_2}\)) and standard bicarbonate (\(\text{SB} \)) were measured in samples of blood obtained from the radial artery. Hyperventilation was defined as \(P_{\text{aCO}_2} \geq 5.0 \text{kPa}\). Lung function examination was done with the patients in sitting position. Three acceptable recordings of vital capacity (VC) and forced expiratory volume in one second (FEV\(_1\)) were obtained and the maximum value of each variable was used in the further analysis. Normal values were predicted according to Bøe and Merker (2). Maximal inspiratory pressure (MIP) reflecting the strength of the diaphragm and maximal expiratory pressure (MEP) reflecting the strength of the abdominal muscles were obtained at functional residual capacity, according to the technique previously described (3). Normal values were predicted, according to Decramer et al. (3) and Larie et al. (11).

The \(P_{\text{ACO}_2}\) breathing technique, according to Roed (4), was used as a possible way to test the ability to increase ventilation. End-tidal \(P_{\text{CO}_2}\) and ventilation in 1/min were registered in two runs with a few minutes' interval. The slope of the curve relating \(P_{\text{ACO}_2}\) to ventilation (AV/VE/\(\text{ACO}_2\)) was calculated after exclusion of the initial curved part and expressed in 1/min/kPa.
PCO₂ was found (Fig. 4), whereas there were no such differences regarding the other symptoms. Furthermore, those patients who required respiratory assistance at the onset of disease, showed significantly higher a-PCO₂ than the others.

Low VC and respiratory increase during CO₂ re-breathing and the presence of headache explained 45% of the variation in a-PCO₂ in a multiple regression analysis.

Nocturnal oximetry showed no signs of obvious hyperventilation as none of the patients showed arterial oxygen saturation (a-SO₂) <30% for more than 3% of the sleeping time.

**DISCUSSION**

**Patient selection**

The population of post-polio patients in the Göteborg area is unknown. In a previous survey in Sweden (Malmö/Lund) the prevalence is estimated to 70/100,000 (16). In the present study, we have found 15/100,000 individuals but we do not know the number of eligible patients that we were unable to trace. Furthermore, there was a substantial drop-out from those eligible patients who were traced (25/88). Thus, the representativeness of the present material is unknown. It seems likely, however, that patients with severe hypoventilation would have been known to us and that those with minor disease tend not to participate. In our opinion, therefore, the present material is probably weighted towards over-representation of those patients with the more severe involvement. Anyhow, those who were examined demonstrated large variations in distribution of paresis/paralysis. Also working capacity, as well as need for aid, varied considerably in the group.

**Symptoms**

Answers about symptoms like headache and tiredness are difficult to interpret, since these symptoms are non-specific. For example, the feeling of tiredness might be influenced by several factors, one of which is mental well-being. Headache can be influenced by anxiety as anxiety can give increased muscle tone and eventually develop tension type headache. Thus, when interpreting these symptoms the patients total situation and signs of mental insufficiency should be considered. This was not done in the present study.

Dyspnea is a symptom also hard to interpret. The degree of effort producing dyspnea was hard to estimate due to variations in the degree of disability. Dyspnea, however, turned out to correlate to an objective variable, i.e. VC. In the group complaining of headache more patients with high level of a-PCO₂ were found (p<0.02). Among members of Association for Traffic and Polio Disabled, from where a majority of patients were recruited, discussion about the post-polio syndrome and the risk of hyperventilation had been active and strong consciousness was noted. It is possible therefore that worry-avoidance might have strengthened some of the unspecific components in the syndrome. Furthermore, among those eleven patients who had the lowest VC’s a local frequency of symptoms was noted.

**Lung function**

In a previous study from Sweden (1) in an area of 750,000 inhabitants a questionnaire was answered by 267 post-polio patients. Eighty-four of these polio patients, who were supposed to be most handicapped, were offered a control of their lung function. Twenty-nine patients were examined, supposedly represent-
PCO$_2$ was found (Fig. 4), whereas there were no such differences regarding the other symptoms. Furthermore, those patients who required respiratory assistance at the onset of disease, showed significantly higher a-PCO$_2$ than the others.

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**DISCUSSION**

**Patient selection**

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**Lang function**

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scoliosis present in some of the patients is likely to have contributed to the reduction of VC (5).

It is important in neuro-muscular diseases to get objective measurement of the strength of the muscles engaged. The test method employed in the present study to assess the respiratory muscles is simple but the normal values show wide variation (9, 10). MEP was not correlated to a-PCO₂ and in the multiple regression analysis MEP did not contribute to explain the variation in a-PCO₂ presumably because of the rather strong correlation to VC (r = 0.60). The assessment of the strength of the respiratory muscles by MEP and MEP measurements appear therefore not to be helpful in assessment of the risk to develop hypventilation. Respiratory muscle endurance might have been more useful but is hard to measure.

We speculated that an inability to increase ventilation might be related to the risk to develop hypventilation in post-polio patients. We chose to provoke increased ventilation by CO₂ breathing rather than by ordinary physical exercise due to the various handicaps. The results showed a significant negative correlation between a-PCO₂ and ΔVE/ΔPCO₂ and that ΔVE/ΔPCO₂ contributed to explain the variation in a-PCO₂ in the multiple regression analysis. The mechanisms can, however, not be fully explained on basis of the present results. Reduced dynamic force in respiratory muscles combined with reduced endurance capacity is a possible mechanism. Alternatively, a high a-PCO₂ per se causes a lowered central drive to increase in ventilation when intracerebral PCO₂ is rising.

In order to reveal possible concealed hypventilation we added nocturnal oxymetry among those with the lowest VCs. No obvious signs of hypventilation were found.

In conclusion, hypventilation seems to be rare among post-polio patients. In clinical practice, low VC (below 40-50% predicted normal) and the presence of frequent headache should motivate repeated a-PCO₂ determinations and result in an awareness of increased risk to develop hypventilation. Adequate information to the patient concerning respiratory capacity is of importance and consecutive measurements may be helpful. Continuous assessments of a-PCO₂ during daynight would probably be a useful diagnostic method, especially for patients who are thought to be in the risk zone.

ACKNOWLEDGEMENT

The study was supported by grants from the Konung Gustav V:s 80-årsfond.

APPENDIX

Some questions selected from the questionnaire which were answered by the participants

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td>Do you have more than five respiratory tract infections per year?</td>
<td></td>
<td></td>
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<tr>
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<tr>
<td>At rest?</td>
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<tr>
<td>Walking or driving wheel chair on plain ground?</td>
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<tr>
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<tr>
<td>Have you felt augmented tiredness last months years?</td>
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<tr>
<td>Do you feel tired more than normal in relation to age and life situation?</td>
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<tr>
<td>At what time of the day do you feel tired?</td>
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</tbody>
</table>

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    try). Lund-Malmö SYCOR. Series. Swedish Central Com-
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- At rest?
- Walking?
- Walking fast or in a slope?
- Do you need to stop to breathe when you walk/drive wheelchair on flat ground?
- Do you have felt augmented tiredness last months years?
- Do you feel tired more than normal in relation to age and life situation?
- At what time of the day do you feel tired?

Have you felt chest pain?
- During day-time?
- During night?
- At rest?
- Stress?
- Do you regularly suffer from headache?
- In the morning?
- In the afternoon?
- Is the headache of such intensity that you must use analgetics?

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