PAPERS AND ORIGINALS

Prognosis in Acute Cerebrovascular Accidents in Relation to Respiratory Pattern and Blood Gas Tensions

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British Medical Journal, 1971, 3, 7-9

Summary

Respiratory pattern and arterial blood gas tensions were assessed in patients with acute cerebrovascular accidents. Hyperventilation, low PCO_2 , and high arterial pH were associated with a poor prognosis, whereas patients with normal respiratory pattern and blood gas tensions survived. Periodic and Cheyne-Stokes breathing carried an intermediate prognosis.

Introduction

Abnormal breathing patterns in cerebrovascular disease have been recognized for at least 150 years. In Cheyne's (1818) description of periodic respiration in a patient with cardiac disease the irregular breathing was recorded when the patient became "speechless and hemiplegic." Oppenheim (1900) reported Cheyne-Stokes breathing, hyperventilation, and irregular breathing all occurring in pontine haemorrhage, and Steegman (1951) described respiratory failure occurring in this condition. Plum (1966) described various disturbances of respiratory pattern occurring with lesions at specific but widely different sites within the central nervous system. There has been little discussion on the relationship between breathing pattern and prognosis beyond general remarks that respiratory abnormalities carry a poor prognosis. The present study was undertaken in order to examine respiratory pattern and blood gas tensions in relation to immediate prognosis in acute cerebrovascular accidents.

Methods

Patients admitted to hospital and studied within 24 hours of the onset of an acute cerebrovascular accident were included. A

full neurological examination, a lumbar puncture, and record of respiratory pattern were carried out. The presence of features other than cerebrovascular disease likely to influence respiratory pattern—for example, chest infection or cardiac failure—excluded patients from the study.

The tracing of respiratory pattern was made with a simple stethograph, pressure fluctuations being measured with a Statham P.M.6 transducer and recorded on an Elema Mingo-graph 61. Arterial blood was obtained by stab puncture of the brachial artery in the antecubital fossa. Blood was analysed for PO_2 , PCO_2 , and pH with standard Radiometer electrodes with direct electrical readout on E.I.L. Vibron equipment for PCO_2 and pH, and digital readout for PO_2 (Hahn, 1969). Analyses were carried out within 15 minutes, blood gas tensions being corrected for elapsed time and temperature according to the nomograms of Kelman and Nunn (1966).

Results

Respiratory pattern was recorded in 41 patients. All but nine of these patients had abnormal patterns. Hyperventilation, Cheyne-Stokes respiration, as well as other periodic, irregular, and normal patterns were recorded. Three abnormal patterns are shown in Fig 1. In seven patients hyperventilation was recorded with respiratory rates up to 53 per minute. Nine patients

FIG. 1—Examples of abnormal breathing patterns recorded (time scale in seconds). (1) Hyperventilation. (2) Irregular. (3) Cheyne-Stokes.

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had classical Cheyne-Stokes respiration with apnoeic periods varying from 4 to 30 seconds. Eleven patients showed periodic respiration without apnoeic phases, and in five the pattern was irregular.

Immediate prognosis was assessed in terms of death or survival one month after admission. Fig. 2 shows how the main respiratory patterns (excluding the small group with irregular patterns) related to this prognosis. None of the patients who were hyperventilating at the time of admission survived. Five out of the nine patients with Cheyne-Stokes respiration died, whereas eight out of the 11 patients with periodic respiration

FIG. 2—Relation between abnormal breathing patterns and prognosis for survival one month after admission. (1) Hyperventilating pattern. (2) Cheyne-Stokes pattern. (3) Periodic pattern. (4) Normal pattern.

survived. All patients with a normal respiratory pattern at the time of admission were alive one month later. The difference between these groups was significant on a χ^2 test at the 0.1% level. Of the patients with an irregular pattern, three survived and two died.

Arterial blood was analysed in 4 patients. A low arterial PCO_2 and high pH were seen in all patients showing a hyperventilating pattern and in addition, in certain patients showing

FIG. 3—Relation between arterial PCO_2 , pH, and PO_2 and prognosis for survival one month after admission.

periodic patterns (measurements being the mean of samples taken in the apnoeic and hyperpnoeic phases). The association between hyperventilation and poor prognosis was reflected in the relation between blood gas tensions and pH and prognosis (Fig. 3). A PCO_2 of less than 35 mm Hg carried a poor prognosis (16 deaths and seven survivors) as did a pH above 7.46 (11 deaths and five survivors). In the patients with both a PCO_2 less than 35 mm Hg and a pH greater than 7.46 only one survived out of 11, whereas in those patients with normal PCO_2 and pH, only one died out of 14.

Though the mean PO_2 in those who survived was slightly greater than in those who died, the difference was not statistically significant ($P > 0.05$). Patients with a normal respiratory pattern had the highest mean PO_2 levels; those with respiratory pattern abnormalities had lowered PO_2 levels but there was no significant difference between the groups.

There were clear associations between level of consciousness and both prognosis and the respiratory abnormalities (see Table). Coma carried a poor prognosis and, as anticipated, comatose patients more often showed a hyperventilating respi-

Associations between Level of Consciousness and Survival and Breathing Pattern: Figures Indicate Number of Patients

Level of Consciousness on Admission	Survival 1 Month after Admission		Breathing Pattern on Admission			
	Dead	Alive	Normal	Periodic	Cheyne-Stokes	Hyperventilation
Normal ..	0	7	5	1	0	0
Depressed ..	6	14	3	5	3	2
Stuporous ..	7	3	1	3	4	1
Comatose ..	8	0	0	2	2	4

ratory pattern and low PCO_2 . Patients with an impaired level of consciousness had a mean PO_2 significantly lower than that in those with unimpaired consciousness.

It was possible to assess the effect of a short period of hyperventilation in 15 patients. Fourteen showed periods of post-hyperventilation apnoea varying from four to 32 seconds, and in 10 of these a periodic pattern was induced which was of typical Cheyne-Stokes configuration in six.

No correlations were found between respiratory pattern and site of lesion on clinical assessment or presence of blood in the C.S.F. Insufficient postmortem data were available to draw any firm conclusions regarding anatomical site and respiratory abnormalities but in general it appeared that Cheyne-Stokes respiration was more frequently associated with hemisphere lesions and hyperventilation with brain stem lesions.

Discussion

Immediate prognosis in terms of death or survival in cerebrovascular accidents has been related to aetiology, age, sex, level of consciousness, extent and type of neurological damage, presence or absence of systemic hypertension, and presence of other diseases (Gowers, 1893; Hurwitz *et al.*, 1959; Walsh, 1966; Marquardsen, 1969). Respiratory abnormalities have generally been considered to be of serious prognostic import, but there seems to have been no systematic study of the effect of various types of respiratory dysfunction on prognosis. This study has shown that prognosis is significantly correlated with respiratory pattern. A sequence from normal pattern through periodic and Cheyne-Stokes respiration to hyperventilation carrying an increasingly poor prognosis has been found. This sequence of prognosis was reflected in arterial PCO_2 and pH values.

It might have been expected that the hyperventilating group would have had a higher PO_2 than other patients. This appeared not to be so. The PO_2 of this group was significantly lower than that in those with normal respiratory pattern ($0.02 < P < 0.05$).

Though prognosis in terms of death was not statistically significantly correlated with PO_2 in the overall analysis, there were associations between low PO_2 and depressed level of consciousness, and between depressed level of consciousness (especially coma) and the more severe disturbances of respiratory pattern. This accords with the experience of Marquardsen (1969), who found "stertorous breathing and Cheyne-Stokes respiration" to be "almost as ominous as deep coma," attributing this to the frequent association of respiratory abnormalities with coma. These findings can be explained only in terms of additional pulmonary or cardiac pathology, possibly some degree of hypostatic pneumonia in the comatose patients, even though those with clinically or radiologically obvious consolidation were excluded. It seems improbable that coma per se was responsible for the hyperventilation since under most other circumstances coma is associated with hypoventilation. The mechanisms responsible for the hyperventilation are discussed elsewhere (Lane *et al.*, 1971).

A high proportion of patients in whom it could be assessed showed post-hyperventilation apnoea. This is in keeping with the findings of Plum *et al.* (1962), who found this phenomenon in 90% of patients with bilateral supramedullary brain disease. In normal conscious man post-hyperventilation apnoea is seen only rarely, but can be induced by anaesthesia. It seems that cerebral damage and anaesthesia release the respiratory regulatory apparatus from the control of higher centres and that this leads to instability of CO_2 control mechanisms. It is likely that this instability is one of the neurogenic defects which predis-

pose to periodic breathing (Plum, 1966) and this is borne out by the frequent occurrence of periodic or Cheyne-Stokes breathing patterns following a short period of hyperventilation in the present series.

We wish to thank the physicians of the Radcliffe Infirmary for allowing us to study patients under their care, and the technicians of the Nuffield Department of Anaesthetics for their skilled assistance. One of us (D.J.L.) is in receipt of a grant from the Nuffield Committee for the Advancement of Medicine.

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Mechanism of Hyperventilation in Acute Cerebrovascular Accidents

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British Medical Journal, 1971, 3, 9-12

Summary

Lumbar cerebrospinal fluid and arterial blood acid-base state were assessed in 19 patients within 24 hours of an acute cerebrovascular accident. Those with haemorrhage into the C.S.F. showed a lower C.S.F. pH and higher C.S.F. lactate than those without haemorrhage but the PCO_2 was similar in the two groups, suggesting that this greater C.S.F. acidity was not responsible for a greater degree of hyperventilation. In those without haemorrhage an inverse relation was found between C.S.F. pH and arterial PCO_2 , suggesting that a non-chemical ventilatory drive—for example, due to central neurological damage—was responsible for the acid-base changes observed.

Introduction

Froman and Crampton-Smith (1966) described hyperventilation associated with C.S.F. acidosis in subarachnoid haemorrhage.

They attributed this acidosis to an increased lactate content in the C.S.F. and postulated from in-vitro studies that the lactate had originated from red cell metabolism (Froman and Crampton-Smith, 1967). However, hyperventilation may also occur in neurological conditions when there is no blood in the C.S.F. Plum and Swanson (1959), investigating patients with acute brain stem disease exhibiting hyperventilation, ascribed this to a central neurogenic drive. Furthermore, hyperventilation per se causes a rise in C.S.F. lactate in experimental animals (Leusen and Demeester, 1966).

We have recently shown that hyperventilation carries a poor prognosis in patients with acute cerebrovascular accidents (Rout *et al.*, 1971). The present study was designed to investigate the cause of this hyperventilation. It reports measurements of C.S.F. and arterial blood acid-base state in patients with acute cerebrovascular accidents and relates these measurements to the presence or absence of blood in the lumbar subarachnoid space.

Methods

Nineteen patients were studied within 24 hours of the onset of an acute cerebrovascular accident. At the time of lumbar puncture performed for diagnostic purposes a sample of C.S.F. was collected anaerobically for acid-base measurements. Simultaneously, a sample of arterial blood was withdrawn from the brachial artery by stab puncture. Five millilitres of the blood and 2 ml of the C.S.F. were added to 5 ml of 10% (w/v) perchloric acid.

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