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Hyperventilation: Is It a Cause of Panic Attacks?

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During transcutaneous PCO_2 ($P_{tc}CO_2$) monitoring of 15 freely ambulant patients suffering from panic attacks, all the patients experienced a typical attack. Seven were identified as hyperventilators, as $P_{tc}CO_2$ fell to abnormally low levels during the attack. This group could not be distinguished on the basis of either their usual symptoms of panic or the hyperventilation provocation test. There was no apparent association between absolute levels of PCO_2 and the nature of symptoms. The anxiety ratings of hyperventilators were lower than those of non-hyperventilators. These data do not support the hypothesis that hyperventilation causes panic attacks or contributes to their severity. Hyperventilation may be better understood as a consequence of panic.

It has been proposed that hyperventilation is a common cause of somatic symptoms in patients with panic attacks (Lum, 1981; Magarian, 1982; Hibbert, 1984*a*; Ley, 1985). The validity of this hypothesis is of importance, not only for the understanding of disorders characterised by panic, but also for their treatment. The demonstration that hyperventilation is an important source of symptoms in panic attacks could play an important part in treatment for two reasons. Firstly, a variety of methods of respiratory control training has been reported to be effective in the treatment of panic attacks in patients thought to be hyperventilators (Bonn *et al*, 1984; Clark *et al*, 1985; Salkovskis *et al*, 1986); secondly, the catastrophic misinterpretation of symptoms of hyperventilation may act as a maintaining factor in panic attacks (Beck et al, 1974; Hibbert, 1984*b*; Clark, 1986) so that the recognition of this by the patient would be an important component of cognitive therapy.

In studies of respiratory control training, the diagnosis of hyperventilation has been based on symptom questionnaires (Garssen *et al*, 1983; Grossman & de Swart, 1984), or on the hyperventilation provocation test. The latter requires the patient to hyperventilate voluntarily and then compare the symptoms provoked with the symptoms of the panic attacks. Patients who find that voluntary hyperventilation provokes symptoms which are similar to their panic attacks are positive on the test and are diagnosed as hyperventilators. Both of these methods of diagnosis have been strongly criticised (Grossman & de Swart, 1984).

The present study employs a more direct method of assessing the role of hyperventilation in panic by continuously recording the transcutaneous partial pressure of CO_2 ($P_{tc}CO_2$), which is a measure of arterial PCO_2. Miniaturised apparatus has been used to monitor $P_{tc}CO_2$ in freely ambulant subjects experiencing naturally occurring attacks (Pilsbury & Hibbert, 1987).

In a healthy population, monitored while freely ambulant, the 99% confidence limit for maximum downward deflections of $P_{tc}CO_2$ from the mode (Pilsbury & Hibbert, 1988) was 1.05 kPa. This limit of normal downward fluctuation provides a working definition of hyperventilation and can be used as a cut-off point to distinguish hyperventilators from non-hyperventilators. An abnormal fall in PCO_2, defined in this way, is a correct, precise, and clear criterion for identifying an episode of hyperventilation, and is the measure that most closely approximates to pH change, which is likely to be the pathway by which hyperventilation can provoke symptoms (Okel & Hurst, 1961; Saltzman *et al*, 1963).

A series of patients has now been studied who have experienced typical panic attacks during ambulant $P_{tc}CO_2$ monitoring. This allows assessment of the frequency with which hyperventilation occurs during panic attacks.

Having distinguished hyperventilators and non-hyperventilators by monitoring $P_{tc}CO_2$, comparisons can be made which clarify the validity of traditional methods of diagnosis, and the extent to which hyperventilation is related to particular somatic symptoms or other clinically significant variables such as degree of anxiety, panic attack frequency, etc.

Method

The apparatus and its method of use have been described in detail elsewhere (Pilsbury & Hibbert, 1987, 1988).

Forty subjects awaiting treatment were recruited from psychiatric out-patient departments. All had been diagnosed as having panic disorder or agoraphobia with panic. The combination of patients with panic disorder and agoraphobia with panic is justified on the basis that there is no difference in the quality of panic attacks in the two disorders. The 15 patients who are presented here are those who experienced a panic attack which satisfied DSM-III criteria (American Psychiatric Association, 1980) during monitoring.

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Nine patients were receiving anxiolytics or antidepressants at the time of monitoring (of whom four were diagnosed as hyperventilators in the present study), and a further three were receiving aerosol bronchodilators and corticosteroids (all of whom were hyperventilators).

Subjects attended the department for attachment of the apparatus. They were instructed in the use of a diary. The instructions were to make an entry whenever they experienced symptoms, recording (a) the severity of any anxiety (a visual analogue scale, anchored at 0 by "no anxiety" and at 8 by "very severe anxiety"), (b) the extent of their physical exertion at the time (a visual analogue scale, anchored at 0 by "none" and at 8 by "extreme"), (c) what they were doing at the time, and (d) physical symptoms experienced. They were instructed to complete the diary as soon as possible after the event if they could not do so immediately. Subjects indicated that they had experienced symptoms by pressing an 'event button' on the tape recorder. Pressing the event button left a signal at that point on the tape. Reference to the diary enabled an assessment to be made of the symptoms experienced at the time of changes in ventilation.

Following equilibration of the sensor, subjects rested for an hour, after which they were encouraged to leave the department for a walk. If they indicated that an episode of severe anxiety had occurred while they were out (indicated by a score of 6 or more on the diary visual analogue scale) *and* identified this episode as a typical panic, they were questioned, on their return, in order to confirm that the event met DSM-III criteria for a panic attack. If the walk did not provoke panic they were encouraged to expose themselves to individually selected activities or situations which were likely to do so, for instance travelling by bus or eating in public. At the end of the monitoring period patients underwent two minutes of forced ventilation of room air. They were asked to compare the similarity of the sensations induced with those of their typical panic attacks (the hyperventilation provocation test). To make this comparison they completed the Similarities Questionnaire (Clark *et al*, 1985). A positive result was indicated if they found voluntary hyperventilation 60% or more similar to their typical panic attack. This procedure allowed not only an assessment of whether or not they were positive on this test, but also confirmation of the sensitivity of the ambulant equipment to changes in PCO_2.

In addition to the measures described, patients completed a number of self and observer ratings: (a) the Hamilton Rating Scale for Anxiety (Hamilton, 1959), (b) the Marks & Mathews (1979) Fear Questionnaire, (c) a symptom check-list (Clark & Hemsley, 1982), completed with reference to a typical panic attack, and (d) the Beck Depression Inventory (Beck & Beamsderfer, 1974).

Statistical analysis

The recorded data, in analogue form, were relayed, on play-back, to the analogue to digital convertor of a computer (DEC PDP 11) which sampled the signal at intervals of 1.5 seconds real time for conversion and analysis (a detailed description of the recording and play-back facilities is given by Pilsbury & Hibbert (1988)). The digitised data were partitioned into 'bins' 0.1 kPa wide to generate frequency distribution curves, indicating the frequency with which particular values of $P_{tc}CO_2$ were recorded over the whole monitoring period. The mode and range of $P_{tc}CO_2$ values were calculated from these data. Those with recorded falls of $P_{tc}CO_2$ from the mode (the most appropriate measure of central tendency because the data were not normally distributed) of greater than 1.05 kPa were classified as hyperventilators, and the remainder as non-hyperventilators. The modal value used for this calculation was the mode $P_{tc}CO_2$ value for the whole monitoring period. Hyperventilators and non-hyperventilators identified in this way were then compared on a number of variables. Student's *t*-test has been used to evaluate the significance of differences of the means when original data are analysed, and the Mann-Whitney *U* test when the data are expressed in terms of percentage change (Armitage & Berry, 1978).

Results

The mode value of $P_{tc}CO_2$ (for the whole recording) and the size of the largest deflection from the mode (referred to as the 'fall in $P_{tc}CO_2$') during monitoring of each patient is shown in Table I, along with the response to the hyperventilation provocation test. Seven of the 15 patients showed abnormal falls in $P_{tc}CO_2$ using our criteria. In every one of these and in three of the remaining eight (cases 8, 9 and 14), the maximum fall in $P_{tc}CO_2$ corresponded in time with their panic attack. The maximum falls in the other patients did not correspond in time with the panic attack. Decrements of less than 1.05 kPa in freely ambulant subjects should not be regarded as abnormal, and if they were experiencing panic at the time this should properly be regarded as a chance association. Therefore a parsimonious interpretation of the data suggests that only 7 of the 15 can be classified as hyperventilators.

As shown in Table I, five of the seven hyperventilators and five of the eight non-hyperventilators were positive on the hyperventilation provocation test. The two groups could not, therefore, be distinguished by this test.

Table II compares the demographic characteristics of the hyperventilators and non-hyperventilators and the population means for duration of illness, panic attack frequency, and scores on the Fear Questionnaire, the Beck Depression Inventory, and the Hamilton Anxiety Scale. The hyperventilators tended to be younger and to have milder disorders of shorter duration. However, because of the range of scores in the hyperventilator group, Student's *t*-test indicated that this difference was only significant for the scores on the Hamilton anxiety scale.

Three of the seven patients identified as hyperventilators (cases 1, 4, 7) had a diagnosis of asthma for which they were receiving treatment. None of the non-hyperventilators had any diagnosed respiratory disease.

Patients described particular symptoms associated with hyperventilation experienced to a moderate or severe degree during their typical panic attacks. These symptoms included dizziness, unreality, faintness, paraesthesia, tremor,

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TABLE I

The division into hyperventilators and non-hyperventilators by the size of the maximum recorded fall of $P_{tc}CO_2$ from the mode

Hyperventilators				*Non-hyperventilators*			
Case no.	*Mode $P_{tc}CO_2$ (kPa)*	*The extent of fall of $P_{tc}CO_2$ from mode (kPa)*	*Provocation test*	*Case no.*	*Mode $P_{tc}CO_2$ (kPa)*	*The extent of fall of $P_{tc}CO_2$ from mode (kPa)*	*Provocation test*
1[1]	6.9	3.9	-	8	7.9	0.9	+
2	5.8	3.3	-	9	7.4	0.9	+
3	6.6	1.4	+	10	6.7	0.5	+
4[1]	5.9	3.6	+	11	6.1	0.7	+
5	6.8	2.2	+	12	6.1	0.6	-
6	7.1	2.0	+	13	6.5	0.7	-
7[1]	7.3	1.4	+	14	8.4	0.8	+
				15	7.4	0.5	-

1. Asthmatic patients.

TABLE II

Demographic and severity variables of hyperventilators and non-hyperventilators

	Hyperventilators		*Non-hyperventilators*	
	Mean	*s.d.*	*Mean*	*s.d.*
Age	39.6	14.8	46.6	13.1
Sex ratio	4F:3M		6F:2M	
Duration of illness: years	2	2	6.8	9.3
Panic attacks per week	5.4	4.4	8.3	6.5
Fear Questionnaire	66.3	50.9	106.6	32
Beck Inventory	17.6	12.9	26.4	8.8
Hamilton anxiety scale	18.1*	4.1	26	6.5

*$P<0.05$.

breathlessness, palpitations, chest pain, choking, sweating, and nausea or abdominal discomfort. Student's *t*-test indicated that there was no statistically significant difference between the two groups in the number of these symptoms complained of. However, it is striking that both groups experienced a similar high frequency of breathlessness. There was also no apparent difference in the symptoms experienced during the particular panic attack that was monitored and it was impossible, on the basis of the reported symptoms, to predict which patients had hyperventilated.

It was of interest to know whether patients, distinguished on the basis of differences in $P_{tc}CO_2$ change during panic, also showed any such differences when at rest. Taking data only from the periods when patients were resting and neither anxious nor symptomatic, mean values for mode, maximum, and minimum $P_{tc}CO_2$ for hyperventilators and non-hyperventilators were compared using Student's *t*-test. During the resting phase the range of $P_{tc}CO_2$ values was significantly greater (1.81 v. 0.73 kPa, $P<0.05$) and the minimum values achieved were significantly lower (5.86 v. 7.09 kPa, $P<0.05$) in the hyperventilators. The mean minimum value achieved by hyperventilators during the resting period was converted to an estimated arterial value (using the algorithm reported by Pilsbury & Hibbert (1987)) of 4.1 kPa, which is at the lower limit of the normal range. The mode value of resting $P_{tc}CO_2$ for hyperventilators, however, falls within normal limits.

The rate of recovery of $P_{tc}CO_2$ following voluntary hyperventilation has been proposed by Hardonk & Beumer (1979) as an additional measure to distinguish hyperventilators from non-hyperventilators. They measured the recovery of end-tidal PCO_2 three minutes after a period of hyperventilation, expressed as the percentage of mean, pre-hyperventilation, end-tidal PCO_2 level. Recovery to less than 65% of the mean pre-hyperventilation level was suggested to indicate that the patient was a hyperventilator. Using transcutaneous measures makes impossible any attempt directly to apply Hardonk and Beumer's method and measure, but an alternative measure of the rate of recovery of $P_{tc}CO_2$ after voluntary hyperventilation is the recovery of $P_{tc}CO_2$ to pre-test values three minutes after reaching the lowest value achieved during voluntary hyperventilation. The mean percentage recovery to pre-hyperventilation level achieved by the hyperventilators was 20.3% and by the non-hyperventilators was 36.4%. The Mann–Whitney *U* test indicated that this difference was significant at the $P<0.05$ level, signifying

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that hyperventilators showed a slower recovery of PCO_2 than non-hyperventilators.

Discussion

The cut-off point of 1.05 kPa to distinguish normal from abnormal falls in $P_{tc}CO_2$ identified 47% of the patients experiencing spontaneous panic attacks as hyperventilators during the attack. In those patients who did hyperventilate, there was no evidence that hyperventilation during a typical panic attack, of which the monitored attack was representative, was connected with any particular symptoms. The hyperventilation provocation test does not predict whether or not hyperventilation actually occurs during typical panic attacks. Furthermore, hyperventilators cannot be identified by the symptoms of previous attacks.

On the other hand, those who hyperventilate during panic can be distinguished by other aspects of $P_{tc}CO_2$ change: firstly by the rate of recovery of $P_{tc}CO_2$ after voluntary hyperventilation, and secondly, by the range of fluctuation of $P_{tc}CO_2$ and the minimum levels achieved when the patient is at rest and neither anxious nor symptomatic.

These observations suggest that hyperventilation is not associated with a particular cluster of symptoms. If this is the case, it implies that, although it occurs frequently, it does not act as a cause or important component of the typical panic attack.

Table I showed three patients classified as non-hyperventilators who showed abnormal falls of 0.8 and 0.9 kPa during the attack. Although these changes are near the upper limit of normal and coincide with panic, their significance cannot be established at this stage. However, it is apparent that falls of $P_{tc}CO_2$ during panic which exceed 1.05 kPa tend to be very large indeed and do not cluster around the normal limit. This suggests that our hyperventilators are showing a distinct response.

Three of the seven hyperventilators had diagnoses of asthma. This may have been the chance association of two common disorders. However, associations between asthma, hyperventilation, and anxiety are well documented (Hibbert & Pilsbury, 1988*b*). The frequent occurrence of asthma among hyperventilators is of great interest but, in such a small population and in the absence of additional measures of airways obstruction during panic, cannot be interpreted with any confidence in this study.

The possibility that episodes of low $P_{tc}CO_2$ might be an artifact, produced either by transient detachment of the sensor or by excessive pressure of the sensor (restricting skin blood flow under the sensor) has been excluded by preliminary investigations (Pilsbury & Hibbert, 1987). A reliable method for fixing the sensor to the skin has been established, which, although increasing the time constant of the device, does not apply so much pressure as to reduce its accuracy.

Two other aspects of the study merit consideration. First, the demands of the experimental situation may have prompted some patients falsely to report panic attacks. This is unlikely in view of the distressed state of many hyperventilators and non-hyperventilators following exposure. Secondly, there may be important differences between panic attacks from occasion to occasion. Hyperventilation may occur during some attacks but not others and the symptoms of attacks may vary significantly as a consequence (i.e. there is no typical panic attack). This possibility has not been tested in the present or previous studies, but it seems an unlikely explanation of our data, especially considering that patients had no difficulty in describing a typical panic attack, and were selected on the basis that they had had what they were happy to call a typical attack during monitoring. Quite apart from this, however, the tendency to hyperventilate appears to be a consistent feature of the individual in that hyperventilators also showed a greater fluctuation of PCO_2 when at rest and asymptomatic, and a slower recovery of PCO_2 after voluntary hyperventilation.

The latter observation suggests that, although Hardonk and Beumer's diagnostic test has been seriously questioned (Wientjes *et al*, 1984; Gardner *et al*, 1986), there may yet be some value in measures of PCO_2 recovery after voluntary hyperventilation as a means of identifying hyperventilators, perhaps in combination with measures of the stability of resting PCO_2.

Finally, it could be suggested that important changes in PCO_2, and therefore important symptoms related to hyperventilation, are being overlooked by using the size of decrements in $P_{tc}CO_2$ as the only criterion for hyperventilation. Symptoms might be provoked by changes of less than 1.05 kPa if the initial PCO_2 value is already low. However, it is unlikely that this can account for our finding of a lack of association between symptoms and a change in $P_{tc}CO_2$ because the hyperventilators in this study showed significantly lower resting $P_{tc}CO_2$ values and marginally lower modal PCO_2 values over the whole recording and yet were still not distinguished by their symptoms.

Data derived from the novel technique of ambulant monitoring of transcutaneous PCO_2 have produced several conclusions about the role of hyperventilation in panic attacks which directly contradict assumptions made and conclusions drawn in the previous literature.

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The observation that approximately half the patients hyperventilated during their panic attacks is consistent with previous estimates. However, the lack of any discernible difference between the symptoms of hyperventilators and non-hyperventilators and the demonstration of the inadequacy of the conventional provocation test cast doubt on the conclusions of previous studies which have relied on symptom check-lists or the provocation test to identify hyperventilators. Our data show that hyperventilation is common in panic but is unlikely to be a significant source of symptoms in typical panic attacks. It appears to be merely a consequence of panic in individuals who may have a predisposition to hyperventilation.

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References

AMERICAN PSYCHIATRIC ASSOCIATION (1980) *Diagnostic and Statistical Manual of Mental Disorders* (3rd edn). Washington, DC: APA.

ARMITAGE, P. & BERRY, G. (1987) *Statistical Methods in Medical Research* (2nd edn). Oxford: Blackwell Scientific Publications.

BECK, A. T. & BEAMSDERFER, A. (1974) Assessment of depression: the depression inventory. In *Modern Problems in Pharmacopsychiatry, 7.* (ed. P. Pichot). Basel, Switzerland: Karger.

——, LAUDE, R. & BOHNERT, M. (1974) Ideational components of anxiety neurosis. *Archives of General Psychiatry*, **31**, 319–325.

BONN, J. A., READHEAD, C. P. A. & TIMMONS, B. H. (1984) Enhanced adaptive behavioural response in agoraphobic patients pretreated with breathing retraining. *Lancet*, *ii*, 665–669.

CLARK, D. M. (1986) A cognitive approach to panic. *Behaviour Research and Therapy*, **24**, 461–470.

—— & HEMSLEY, D. R. (1982) The effects of hyperventilation; individual variability and its relation to personality. *Journal of Behaviour Therapy and Experimental Psychiatry*, **13**, 41–47.

——, SALKOVSKIS, P. M. & CHALKLEY, A. J. (1985) Respiratory control as a treatment for panic attacks. *Journal of Behaviour Therapy and Experimental Psychiatry*, **16**, 23–30.

GARDNER, W. N., MEAH, M. S. & BASS, C. (1986) Controlled study of respiratory responses during prolonged measurement in patients with chronic hyperventilation. *Lancet*, *ii*, 826–830.

GARSSEN, B., VAN VEENENDAAL, W. & BLOEMINK, R. (1983) Agoraphobia and the hyperventilation syndrome. *Behaviour Research and Therapy*, **21**, 643–649.

GROSSMAN, P. & de SWART, J. C. G. (1984) Diagnosis of hyperventilation syndrome on the basis of reported complaints. *Journal of Psychosomatic Research*, **28**, 97–104.

HAMILTON, M. (1959) The assessment of anxiety states by rating. *British Journal of Medical Psychology*, **32**, 50–55.

HARDONK, H. J. & BEUMER, H. M. (1979) Hyperventilation syndrome. In *Handbook of Clinical Neurology, Vol. 38* (eds P. J. Vinken & G. W. Bruyn). Amsterdam: Elsevier/N. Holland Biomedical Press.

HIBBERT, G. A. (1984*a*) Hyperventilation as a cause of panic attacks. *British Medical Journal*, **288**, 263–264.

—— (1984*b*) Ideational components of anxiety: their origin and content. *British Journal of Psychiatry*, **144**, 618–624.

—— & —— (1988*b*) Demonstration and treatment of hyperventilation causing asthma. *British Journal of Psychiatry*, **153**, 687–689.

LEY, R. (1985) Agoraphobia, the panic attack and the hyperventilation syndrome. *Behaviour Research and Therapy*, **23**, 79–81.

LUM, L. C. (1981) Hyperventilation and anxiety state. *Journal of the Royal Society of Medicine*, **74**, 1–4.

MAGARIAN, G. J. (1982) Hyperventilation syndromes: infrequently recognised common expressions of anxiety and stress. *Medicine*, **61**, 219–236.

MARKS, I. M. & MATHEWS, A. (1979) Brief standard self-rating for phobic patients. *Behaviour Research and Therapy*, **17**, 263–267.

OKEL, B. B. & HURST, J. W. (1961) Prolonged hyperventilation in man: associated electrolyte changes and subjective symptoms. *Archives of Internal Medicine*, **108**, 757–762.

PILSBURY, D. & HIBBERT, G. A. (1987) An ambulatory system for long term continuous monitoring of transcutaneous PCO_2. *Clinical Respiratory Physiology*, **23**, 9–13.

—— & —— (1988) Time dependent variations of transcutaneous PCO_2 level in normal subjects. *Journal of Applied Physiology*, **64**, 1858–1863.

SALKOVSKIS, P. M., JONES, D. R. O. & CLARK, D. M. (1986) Respiratory control in the treatment of panic attacks: replication and extension with concurrent measurement of behaviour and PCO_2. *British Journal of Psychiatry*, **148**, 526–532.

SALTZMAN, H. A., HEYMAN, A. & SIEKER, H. O. (1963) Correlation of clinical and physiologic manifestations of sustained hyperventilation. *New England Journal of Medicine*, **268**, 1431–1436.

WIENTJES, C., GROSSMAN, P. & DEFARES, P. (1984) Psychosomatic symptoms, anxiety and hyperventilation in normal subjects. *Clinical Respiratory Physiology*, **20**, 90–91.

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