EFFECT OF SOME RESPIRATORY MANEUVERS ON CEREBRAL AND PERIPHERAL CIRCULATION, WITH SPECIAL REFERENCE TO MAXIMUM BREATHING, VOLUNTARY HYPERVENTILATION AND THE VALSALVA MANEUVER

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THE present author has investigated the cerebral hemodynamics in voluntary hyperventilation and the Valsalva maneuver.¹ In this study, the effects of three kinds of respiratory maneuvers, i.e., maximum breathing, voluntary hyperventilation and the Valsalva maneuver on cerebral and peripheral hemodynamics were examined by means of a newly devised ultrasonic Doppler apparatus²⁻⁴ which is capable of multiple and simultaneous blood flow measurement non-operatively and continuously in man in situ. Further, blood pressure, heart rate and arterial gas contents (PO_2 , PCO_2 , pH) were simultaneously investigated.

MATERIALS AND METHODS

The subjects were 8 adult males, i.e., 4 normal young males and 4 healthy looking males over 60 years old.

Voluntary hyperventilation and the Valsalva maneuver were carried out in all subjects and maximum breathing in 4 subjects (3 young males and 1 elderly male).

The blood flow change in the internal carotid artery and brachial artery was continuously investigated in each subject by means of the new ultrasonic Doppler apparatus devised by the author²⁻⁴ before, during and after the experiment. At the same time, blood pressure, heart rate and arterial gas contents (PO_2 , PCO_2 , pH) were investigated.

Key Words:

Doppler Technique
Cerebral Circulation

Maximum breathing was repeatedly carried out under the condition of increased respiratory frequency and tidal volume during 1 to 5 minutes. On the other hand, voluntary hyperventilation was repeatedly carried out under the condition of no alteration of respiratory frequency and increased tidal volume during 5 to 10 minutes. Further, duration of the Valsalva maneuver ranged from 30 seconds to 2 minutes.

RESULTS

(1) Maximum breathing (Fig. 1)

Blood flow in the internal carotid artery and brachial artery was increased and the changing rate of blood flow in the internal carotid artery was more conspicuous than in the brachial artery. Blood pressure and heart rate were increased and arterial gas contents showed respiratory alkalosis, i.e., decrease of PCO_2 and increase of pH and PO_2 .

(2) Voluntary hyperventilation

Although the blood flow in the internal carotid artery was decreased, no alteration was found in the brachial artery. The blood flow in the internal carotid artery reached a minimum level immediately after the onset of the maneuver (about 1 to 2 minutes).

The change of cerebral blood flow during the maneuver was divided into the following two types. (i) Cerebral blood flow was maintained at a same level during the maneuver (Fig. 2). (ii) Cerebral blood flow tended to return to the control level during the maneuver (Fig. 3). The former type was more frequent than the latter,

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Fig.1. Effect of maximum breathing on cerebral and peripheral circulation (21 yrs.).

Fig.2. Effect of voluntary hyperventilation on cerebral and peripheral circulation (28 yrs.).

i.e., 6 : 2 cases.

The changes of blood pressure and heart rate were slight and arterial gas contents showed respiratory alkalosis, i.e., decrease of PCO_2 and increase of pH and PO_2 .

(3) Valsalva maneuver (Fig. 4, 5)

The blood flow in the internal carotid artery and brachial artery was decreased. Although the blood flow in the brachial artery returned to the control level immediately after the maneuver,

blood flow in the internal carotid artery showed a transient but conspicuous increase immediately after the maneuver.

Blood pressure and heart rate were increased and arterial gas contents generally showed respiratory alkalosis, i.e., decrease of PCO_2 and increase of pH and PO_2 .

DISCUSSION

(1) Maximum breathing

The maneuver gives rise to an increase of

Fig.3. Effect of voluntary hyperventilation on cerebral and peripheral circulation (20 yrs.).

Fig.4. Effect of the valsalva maneuver on cerebral and peripheral circulation (61 yrs.).

minute ventilation due to increase of respiratory frequency and tidal volume and increase of O_2 -uptake and CO_2 -elimination. On the other hand, arterial gas contents during the maneuver show respiratory alkalosis, i.e., decrease of PCO_2 and increase of pH and PO_2 , since O_2 -consumption in the respiratory muscle is scanty except in some severe respiratory disorders as compared with other muscles and tissues.⁵

The above findings suggest that cerebral and peripheral hemodynamics in maximum breathing

may be similar to that in voluntary hyperventilation, i.e., decrease of cerebral blood flow and blood pressure and alteration of peripheral blood flow and heart rate.^{6,7}

In the present study, however, a marked difference in cerebral and peripheral hemodynamics was observed between maximum breathing and voluntary hyperventilation, i.e., increase of cerebral and peripheral blood flow, blood pressure and heart rate in maximum breathing.

Fig.5. Effect of the Valsalva maneuver on cerebral and peripheral circulation (24 yrs.).

As for the hemodynamic difference between the two respiratory maneuvers, the following different mechanism should be considered. (i) Hemodynamics in voluntary hyperventilation may be chiefly due to an alteration of arterial gas contents, i.e., respiratory alkalosis in which a primary effect on the vessel and a secondary effect on the vessel by way of the vasomotor center are involved. (ii) Hemodynamics in maximum breathing may be chiefly due to the increment of venous return (*vis a fronte*) and cardiac output accompanying the maneuver^{8,9}

(2) Voluntary hyperventilation

It is well known that increased cerebral vascular resistance and decreased cerebral blood flow due to hypocapnic constriction of cerebral vessel is always observed during hyperventilation^{6,10}

The present author has previously investigated the relationship between cerebral hemodynamics and pulmonary function in the elderly patients with pulmonary diseases and reported the following pathophysiological relationship^{11,12}: some neurological symptoms in the elderly patients with pulmonary diseases may be due to cerebral circulatory disorders, in which the impairment of pulmonary function plays an important pathological role.

Further, it is recommended by the present author that such neurological symptoms should be classified into a new clinical entity called pulmonary encephalopathy and differentiated from other clinical entities resulting from cerebral circulatory disorders.

In a previous experiment,¹ the cerebral circulation and metabolism during voluntary hyperventilation was investigated by means of the ultrasonic Doppler technique and the cerebral circulatory effect of the maneuver, i.e., decreased cerebral blood flow, increased cerebral vascular resistance and no alteration of cerebral oxygen consumption was reported. Further, it was reported that the decreased cerebral blood flow reached the minimum level immediately after the maneuver (about one minute), then returned to the control level.

In the present study, the biphasic cerebral blood flow pattern was observed, i.e., decreased blood flow during the maneuver and increased blood flow after the maneuver. In general, the blood flow after the maneuver was larger than the control. The increased cerebral blood flow after the maneuver may be due to a kind of hyperemic reaction, since conspicuous alteration of blood pressure and arterial gas contents was not observed at this point.

As for the mechanism of decreased cerebral

blood flow during the maneuver, hypocapnic constriction of the cerebral vessel should be considered, since conspicuous alteration of blood pressure and heart rate was not observed during the maneuver.

(3) Valsalva maneuver

In a previous experiment,¹ cerebral circulation and metabolism were investigated by means of the ultrasonic Doppler technique and the cerebral circulatory effect of the maneuver, i.e., decreased cerebral blood flow, increased cerebral vascular resistance and no alteration of cerebral oxygen consumption, was reported. Further, it was reported that there was a decrease of blood pressure and heart rate and alteration of arterial gas contents, i.e., decrease of PCO_2 and increase of pH and PO_2 .

The above finding was coincident with Meyer's experiment,^{1,3} in which the decrease of blood pressure and arterial PCO_2 , especially the former, was considered as a most important cause of decreased cerebral blood flow during the Valsalva maneuver.

In the present study, the decreased blood flow in the cerebral and peripheral artery was conspicuous. In addition, alteration of the arterial gas contents was generally similar to the findings in the previous experiment.¹ As for the mechanism of the decreased blood flow in the cerebral and peripheral artery, a decrease of arterial blood supply and venous return due to the conspicuous increase of intrapleural pressure during the maneuver should be considered.^{8,9}

It is worthy of note that a transient but conspicuous increase of cerebral blood flow was observed immediately after the Valsalva maneuver. As for the mechanism of the increased blood flow, a kind of hyperemic reaction such as in hyperventilation should be considered, since conspicuous alteration of blood pressure, heart rate and arterial gas contents was not observed at this point.

The transient but conspicuous increase of cerebral blood flow immediately after the Valsalva maneuver is highly significant clinically from the view point of geriatric medicine, since cerebral hemorrhage in the elderly subjects takes place frequently under the condition of Valsalva-like maneuver, i.e., strong effort in defecation, violent talk and active movement, etc.

It is well known that the circulatory response (blood pressure and heart rate) to the Valsalva

maneuver can be divided into four phases, i.e., Phase 1 - increase of blood pressure and decrease of heart rate immediately after the onset of the maneuver. Phase 2 - rapid decrease of blood pressure and increase of heart rate 2 to 3 seconds after the onset of the maneuver. Phase 3 - transient decrease of blood pressure and increase of heart rate immediately after the end of the maneuver. Phase 4 - greater increase of blood pressure and decrease of heart rate as compared with the control (overshoot).^{14,15} In the present experiment, the alteration of heart rate was generally similar to the above.

SUMMARY

Circulatory effects of three kinds of respiratory maneuvers (maximum breathing, voluntary hyperventilation and the Valsalva maneuver) on cerebral hemodynamics (blood flow in the internal carotid artery) and peripheral hemodynamics (blood flow in the brachial artery) were examined in 4 normal young males and 4 healthy looking elderly males by means of a newly devised ultrasonic Doppler apparatus, which is capable of multiple and simultaneous blood flow measurement non-operatively and continuously in man in situ. Further, blood pressure, heart rate and arterial gas contents (PO_2 , PCO_2 , pH) were simultaneously investigated. The following results were obtained.

- (1) Maximum breathing

Cerebral and peripheral blood flow were increased and the changing rate of the former was more conspicuous than the latter. Blood pressure and heart rate were increased and arterial gas contents showed respiratory alkalosis.

- (2) Voluntary hyperventilation

Cerebral blood flow was decreased but no alteration of peripheral blood flow was found. Cerebral blood flow reached the minimum level immediately after the onset of the maneuver (about 1 to 2 minutes). The change of cerebral blood flow during the maneuver was divided into the following two types, Type 1 - cerebral blood flow was maintained at the same level during the maneuver and Type 2 - cerebral blood flow returned to the control level during the maneuver. The former type was more frequent than the latter, i.e., 6 : 2 cases.

The changes of blood pressure and heart rate were slight and arterial gas contents showed respiratory alkalosis.

- (3) Valsalva maneuver

Cerebral and peripheral blood flow was

decreased. Although peripheral blood flow returned to the control level, cerebral blood flow showed a transient but conspicuous increase immediately after the maneuver.

Blood pressure was decreased and heart rate was increased. Arterial gas contents generally showed respiratory alkalosis.

(4) Based on the results, the pathophysiology and clinical significance of each maneuver were discussed.

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