# EFEFCTS OF PARTIAL OBSTRUCTION OF THE AIR-WAYS OF THE LUNGS AND THE INFLUENCE OF SOURCES OF HEAT

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(With 4 Figures in the Text)

A reflex narrowing of the nasal air-way occurs when the skin is irradiated with rays from a source of dull or dark heat, while an opening effect is produced by cooling the skin with a fan, and in many subjects by irradiating the skin with rays from a bright source, such as a small tungsten arc placed about 2 ft. away (Hill, 1932, 1935).

The same phenomena hold good for the air tubes of the lungs (Hill, 1936*a*) as is shown by the fact that when breathing with some labour through a short tube with a narrow orifice, e.g. 8 sq. mm., the tube being held tightly between the lips and the nose closed by a clip, the labour of breathing is increased by exposure of the face to a source of dull red heat rays, eased by a fan, and in many subjects by a bright source of heat. These effects are removed for a time after inhalation of a solution of adrenalin. Against the view that the fan produces its result by a psychological effect, e.g. through antagonizing the discomfort by other sensations, is, moreover, the fact that it is not possible to hold the breath longer with the face exposed to the fan.

The reflex congestion and narrowing of the air tubes thus resulting from exposure of the skin to the dull red or dark heat rays may have to do with that reflex mechanism by which loss of heat is increased by evaporation from the lungs, when there is diminished loss of heat from the skin. It was shown by Sonne (1921) that red and short infra-red rays, which are given off in greater amounts by bright sources of heat, penetrate beyond the skin and excite flushing and transpiration. Longer infra-red rays, which are given off in greater amounts by dull red and dark sources, will not so penetrate, but heat the surface of the skin. It is owing to this difference that bright sources are felt by many people to be the more comfortable

Using a mouth-piece with two tubes inserted in it, one for breathing through and the other connected with a water manometer, the effect on the air tubes of the lungs can be observed, that is when the orifice of the breathing tube is made narrow. If the manometer in its turn be connected with a tambour, and this be set to write on a drum, a record can be taken. Fig. 2 shows the effect of breathing through various orifices.

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Subjects vary as to the size of orifice through which they can breathe without distress while sitting at rest. Many normal subjects find difficulty in breathing through a tube with orifice of 8 sq. mm., but there are some young women of light weight who can breathe for a time even through an orifice of 2·5 sq. mm., the size of an ordinary pin's head. Asthmatic and bronchitic patients may find it difficult to breathe through a tube with an orifice of 14 or even 20 sq. mm. The size of orifice which can be breathed through without significant difficulty or alteration in pulse frequency can be used as a measure of fitness. This measure can be used in place of the well-known test of holding up by means of the breath a column of mercury 40 mm. high for as long as possible.

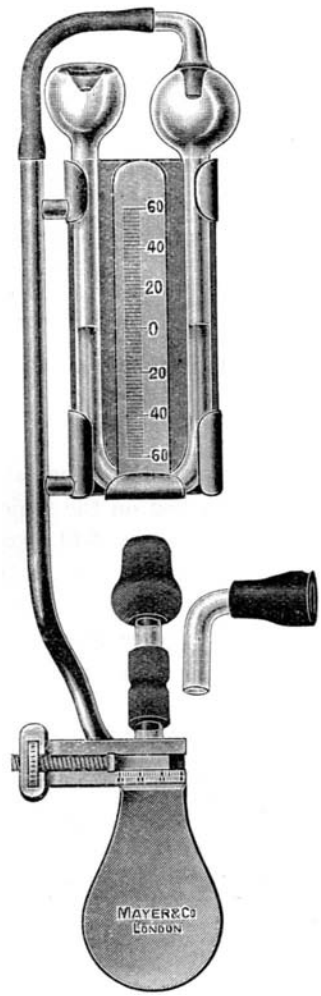

Fig. 1. Air-way gauge.

For making such measurements with ease the air-way gauge has been designed. As shown in Fig. 1, the instrument is provided with a straight tube and nipple, and a bent tube and nipple, either designed for breathing through. The former is used for measuring the size of the nasal air-way (Hill, 1936), the latter for the measure of fitness. The nipple is held tightly between the lips while the nose is closed by a clip, or by plugs of wool. The instrument is provided with a slit for breathing through, which is controlled by a screw. The size of the slit is graduated in sq. mm. The breathing tube is connected with a water manometer so that the excursion due to each inspiration and expiration can be observed. The subject sits at rest, and the operator, holding the instrument upright in front of the face of the subject, tells the latter to hold the nipple tightly between the lips and breathe naturally, the slit meanwhile being kept wide open, and the nose of the subject closed by a clip. When the subject has become accustomed to the new form of breathing and the manometer indicates a natural oscillation of about 20 mm. of water, the slit is gradually narrowed until the oscillation becomes significantly increased. If the narrowing is carried too far, the effects of respiration may blow the water out of the manometer, and this will then have to be refilled up to the (adjustable) zero mark by means of a nipple pipette. For finding the breaking point of the subject, however, the rubber tube connexion with the manometer can be closed by a clip or the end detached and closed by the insertion of a piece of pencil. The frequency of the pulse can be noted beforehand and again as the breathing

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becomes difficult. It may increase from say 5–6 in each 5 sec. up to 8–9 at the breaking point. In place of using the recording method, or the air-way gauge, a cork bored with one hole can be employed as a mouthpiece. Into this hole tubes with orifice of less and less size are inserted each in turn until the one is found through which the breathing becomes too difficult to be continued. The size of the orifices of the tubes can be approximately measured by cutting an acute angle piece out of a millimetre of squared paper, inserting the acute

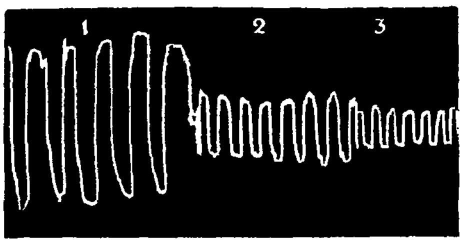


Fig. 2. 1, breathing through 5·5 sq. mm. orifice, each oscillation equalled about 100 mm. of water. 2, breathing through 9 sq. mm. orifice, each oscillation equalled about 40 mm. 3, breathing through 20 sq. mm. orifice, each oscillation equalled about 20 mm.

angle into an orifice and estimating on the inserted part by means of the millimetres marked on the paper, the diameter. Half of this, the radius, squared and multiplied by 3·14, gives the approximate surface area.

On collecting samples of alveolar air at the breaking point, i.e. when breathing could not be continued through the narrow tube, analysis gave in a number of observations 5–6 per cent of $CO_2$ and 9–10 per cent of $O_2$. The normal figures for alveolar air for the subject were 5·3 for $CO_2$ and 13·5 for $O_2$.

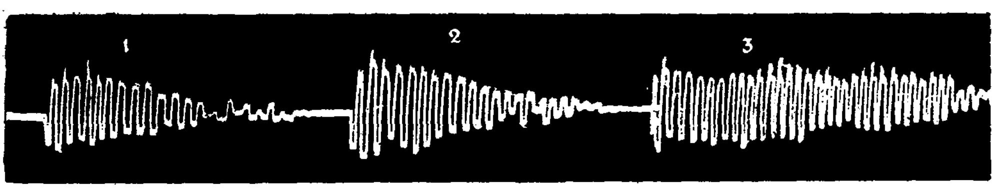


Fig. 3. 1, breathing up to the breaking point through 8 sq. mm. orifice. 2, breathing up to the breaking point through 8 sq. mm. orifice, while breathing oxygen-enriched air. 3, breathing up to the breaking point through 8 sq. mm. orifice, after breathing oxygen.

On repeating the experiment, but this time breathing oxygen-enriched air the possible period of breathing was only a little prolonged, although the alveolar air now contained 15–30 per cent $O_2$. The pulse frequency increased no less in these oxygen-breathing experiments. On taking readings of the blood pressure of the subject while he was breathing through the narrow tube it was found that at the breaking point the systolic sounds were feebler and the systolic pressure appeared to be a little lowered.

A preliminary breathing of oxygen-enriched air before breathing through the narrow tube significantly prolonged the time of such breathing, while preventing increase in pulse frequency. Fig. 3 shows these effects on the duration of breathing. This was also observed on carrying out the experiment with the fan set to blow on the face. The effect of cooling the face was notably greater than that of breathing oxygen-enriched air during the experiment. Fig. 4 shows how cooling the face lessens the labour of breathing.

Further, on inspiring through a narrow orifice and making each expiration free, breathing could be continued without difficulty and even kept up when the orifice was as small as 2·5 sq. mm. The greater ease of breathing when the expiration is free, as is the case in gas-masks, depends on the fact that as only a small time is required for expiration more time is spent in expanding the lung during inspiration.

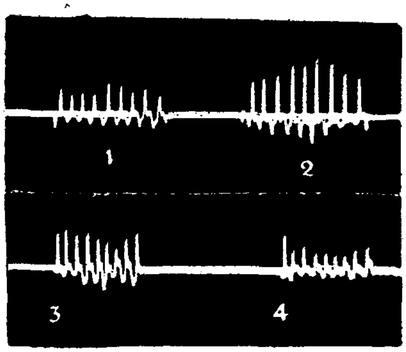


Fig. 4. 1, breathing nine times through 8 sq. mm. orifice with fan on. 2, breathing nine times through 8 sq. mm. orifice with fan off. 3, breathing nine times through 8 sq. mm. orifice while breathing oxygen-enriched air with fan off. 4, breathing nine times through 8 sq. mm. orifice while breathing oxygen-enriched air with fan on.

The suggested explanation of the results above described is that the obstruction to breathing produced by a narrow orifice impedes the pulmonary circulation; owing to this and consequent want of oxygen in the respiratory centre, breathing fails. Breathing oxygen-enriched air during the experiment does not help much, because the passage of blood through the lungs is impeded; on the other hand, breathing of oxygen beforehand is helpful, because the respiratory centre and blood which still reaches it from the left side of the heart were well oxygenated at the start. When inspiration is through the narrow tube, and expiration free, greater expansion and contraction of the lungs is allowed, and through them more blood passes.

When the subject breathes in and out through a narrow orifice the ventilation of the lung suffices to keep the more diffusible $CO_2$ from increasing notably in the alveolar air, particularly so, as little blood is passing through the lungs; the oxygen in the alveolar air is, on the other hand, lessened.

If at the breaking point a free inspiration was taken just before collecting the sample of alveolar air, the oxygen percentage was found to be only about

10 per cent; this is because the blood, allowed to pass by the free inspiration, took up more oxygen than usual. Cooling the face by reflexly widening the air tubes lessens the effect of the narrow orifice, relieves the difficulty of breathing and the impediment to the passage of blood through the lungs.

Haldane and his co-workers (1919), studying the effect of obstructed inspiration, found the alveolar $CO_2$ to be no higher than 6·5–7 per cent, and ascribed the failure of respiration to anoxaemia, resulting, as they supposed, from large parts of the lung not being expanded and ventilated during such respiration. Using a face mask, and breathing through five layers of filter paper, Killick (1935) obtained readings of alveolar $CO_2$ as high as 7·35–8·42 per cent accompanied by distress of the subject. Expiration in these experiments was free. The mask filled with expired air increased the dead space. In such experiments free expiration allowed the pulmonary circulation to continue.

Impedance of the pulmonary circulation by obstruction of the breathing tubes must be of great clinical significance. It explains why, when the obstruction is severe, oxygen may be of little help. Clinical experience has shown the benefit of bleeding in such cases. Relief is, thereby, given to the right heart.

*Respiration through tube with orifice* 4·2 *sq. mm.*

| | *Frequency of pulse* | | |
|---|---|---|---|
| | Beforehand | | |
| Subject 1: | | | |
| Heater on | 6 | 9 | At breaking point |
| Heater, fan on | 6 | 7 | Could have gone on longer |
| Heater, arc on | 6 | 7 | ,, ,, ,, ,, |
| Breathing oxygen-enriched air | 6 | 8 | |
| Subject 2: | | | |
| Heater on | 5 | 9 | After 30 sec. |
| Heater, fan on | 5–6 | 5–6 | After 1 min. could have gone on |
| Subject 3: | | | |
| Heater on | 6 | 8 | |
| Heater, fan on | 6 | 7 | |
| Heater, arc on | 6 | 7 | |
| Subject 4: | | | |
| Heater on | 5 | 8–9 | |
| Heater, fan on | 5 | 7 | |
| Subject 5: | | | |
| Heater on | 5 | 8 | |
| Heater, fan on | 5 | 6 | |
| Subject 6: | | | |
| Heater on | 5–6 | 8 | |
| Heater, fan on | 5–6 | 5–6 | |
| Subject 7: | | | |
| Heater on | 6 | 9 | |
| Breathing oxygen-enriched air | 6 | 9 | |
| Subject 8: Tube orifice 8 sq. mm. | | | |
| Heater on | 6 | 8–9 | |
| Heater, fan on | 6 | 7 | |
| Heater, arc on | 6 | 6–7 | |

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In the case of Subject 2, a powerful young man (late of the Royal Navy), breathing oxygen-enriched air enabled him to continue respiration by effective laboured breathing.

*Alveolar air*

Subject L. H.:

Inspiration through narrow tube, expiration free.

| $CO_2$ | $O_2$ | |
|---|---|---|
| 5·0 | 13·6 | 3·2 sq. mm. tube |
| 4·9 | 9·8 | 2·5 sq. mm. tube |
| 5·2 | 10·5 | 9 sq. mm. tube |
| 5·0 | 12·3 | 9 sq. mm. tube |

Respiration through narrow tube 9 sq. mm. up to breaking point, and then one deep inspiration before taking sample.

| | |
|---|---|
| 4·25 | 12·0 |
| 5·1 | 10·0 |
| 4·8 | 10·9 |

Normal after one deep inspiration before taking sample

| | |
|---|---|
| 4·0 | 15·5 |

*Samples taken at breaking point*

| | $CO_2$ | $O_2$ | |
|---|---|---|---|
| Subject B. C. | 5·0 | 12·0 | Tube 4·5 sq. mm. |
| | 5·2 | 16·5 | Breathing oxygen-enriched air |
| Subject L. H. | 5·47 | 11·0 | 5 sq. mm. tube |
| | 6·2 | 10·0 | 5 sq. mm. tube |
| | 5·8 | 8·36 | 2·5 sq. mm. tube |
| | 6·3 | 9·7 | 9 sq. mm. tube |
| | 5·3 | 10·3 | 9 sq. mm. tube |
| | 6·03 | 10·5 | 9 sq. mm. tube |
| | 5·2 | 32·4 | When breathing oxygen-enriched air |
| | 6·2 | 18·6 | |
| | 5·2 | 30·0 | |
| | 6·6 | 38·0 | |
| | 9·0 | 14·3 | Oxygen breathed before respiring through the narrow tube 9 sq. mm. |
| Subject N. | 6·3 | 12·0 | 4·2 sq. mm. tube |
| | 6·2 | 31·0 | When breathing oxygen-enriched air |
| Subject L. | 5·5 | 10·4 | 9 sq. mm. tube |
| | 5·5 | 11·1 | Heater on |
| Subject L. H. | 6·2 | 9·0 | Heater, breaking point after 15 breaths |
| | 6·2 | 10·0 | Heater, breaking point after 17 breaths |
| | 6·5 | 8·5 | Heater, fan on. After 25 breaths could have gone on longer |

## SUMMARY

Physiologists have recognized for a long time that stuffiness in a close atmosphere is not due to diminution of oxygen or excess of carbon dioxide in the air breathed, or to any other impurity in the air. Such feelings are now shown to be due to the effect of longer infra-red rays on the skin, and are accompanied by a reflex narrowing of the air-ways of the nose and lungs. These effects are set aside by cool air acting on the skin and in many people also by shorter infra-red rays from bright sources of heat. This is why some people are much more comfortable with a bright source of heat than with a dark or dull red one. When people go out of doors to get a "breather", or stand before an

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open window during physical exercises, they are instinctively using the stimulus of cold to widen their air-tubes. In open air treatment, and when sleeping with an open window, the same effect is obtained.

All rooms should be adequately ventilated with cool air to prevent stuffy feelings, and keep the air-ways open. Such ventilation will, at the same time, sweep away infection spread by "carriers".

Partial obstruction of the air-tubes hinders the passage of blood through the lungs; it is this which causes failure of breathing when the obstruction is considerable.

Bleeding is of value because it relieves to a certain extent the impeded circulation.

Breathing through a narrow tube can be used as a test of fitness. An air-way gauge has been designed for making such a test.

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