INFRA-RED RADIATION AND NASAL OBSTRUCTION

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(With 3 Figures in the Text)

In the years 1931 to 1934 Sir Leonard Hill published a series of papers in which he shed new light on the well-known relation between the heating and cooling of the skin and the width of the nasal airway, as conditioned by the congestion of the nasal mucous membranes. In this work a dominant part was ascribed to the radiation energy of the infra-red spectral region, as the effector of the nasal troubles. And further it was maintained that the radiating effects of different wave-lengths had no simple additive action, but that a distinct antagonism was present between the influence of the 25,000–30,000 Å. and the rays on either side of this range. According to Hill's theory it is not the visible part of the spectrum which is important but especially the infra-red regions; consequently every illuminating source of heat as the tungsten arc having the properties of a nose-opener can be changed into a nose-shutter as the electric fire by means of a suitable filter. Thus window glass converts an arc, or the sun, into a nose-shutter. On the other hand, glass protects the subject from the nose-shutting rays of the electric fire. He maintains that the ultra-violet or visible radiation is not important for the intranasal volume changes. These investigations have been subjected to a severe criticism by Dufton and Bedford (1933) and later on by Winslow, Greenbury and Herrington (1934), who have made an extensive research on this problem. The nose-closing phenomenon caused by heating of the skin was generally confirmed, but an opening effect caused by short infra-red radiation could not be demonstrated by these authors. Artificial cooling of the skin will have an opening influence according to Dufton and Bedford, but this effect too is denied by Winslow and collaborators. It is clear that the reason for the large deviation of opinions between these investigators will be partly given by differences in the experimental procedure. At first L. Hill's results were completely based on the subjective sensations of himself and of others. Later, to meet his critics, he carried out objective measurement of the phenomenon, and to this end registered the respiratory movements of his subjects by means of a pneumograph. A rhinomanometric procedure as used by Dufton and Bedford, and in the main by Winslow, is rejected by Hill as being not sensitive enough. Both methods, however, the rhinomanometric and the pneumographic, have the drawback that the expiration pressure is very irregular without any radiation at all. "All kinds of influences, especially psychical ones, will disturb the constancy of experimental conditions" (Zwaardemaker, 1914, and Mink, 1933). In my opinion both methods do not permit sufficient steadiness of the controls in

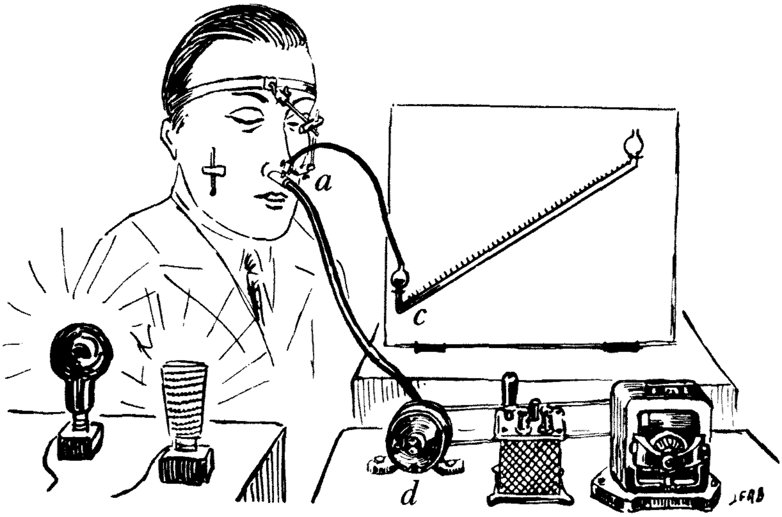

Fig. 1.

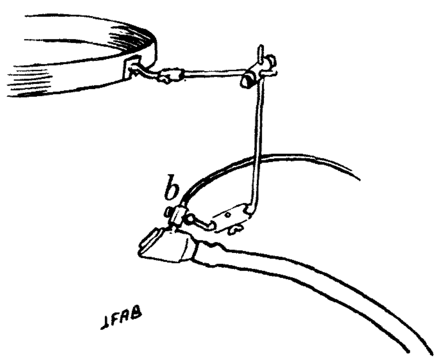

Fig. 2.

relation to the wanted degree of sensitivity. Hill maintains that by use of the nose-clip he is able to overcome the difficulties and secure results, while the conditions are sufficiently constant, which show the nose-opening effect.

Method

In order to have a method which was able to give an objective measurement of the intranasal pressure, it was necessary to make the estimation independent of the patient's respiratory activity. To this end a constant stream of air was blown through a nasal orifice into the pharynx; the outlet was possible through the mouth, or, if the mouth were closed, through the other

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nostril. The input pressure of the air is measured by an inclined water manometer (Fig. 1, *c*), which is connected to the air tube (Fig. 1, *a*, also Fig. 2), just before the orifice. Decrease in diameter of the air passage will give increase in input pressure. The end of the air tube is olive-shaped and fits very well in the nasal orifice, so that a special tightening with adhesive plaster is not needed. By the use of spherical joints the olive-shaped inlet keeps always in position; the complete apparatus is fixed to the skull by means of a head band. The air pressure is brought by a small rotating pump (*d*) which gives a pressure of 400 mm. of water when the nose is completely closed.

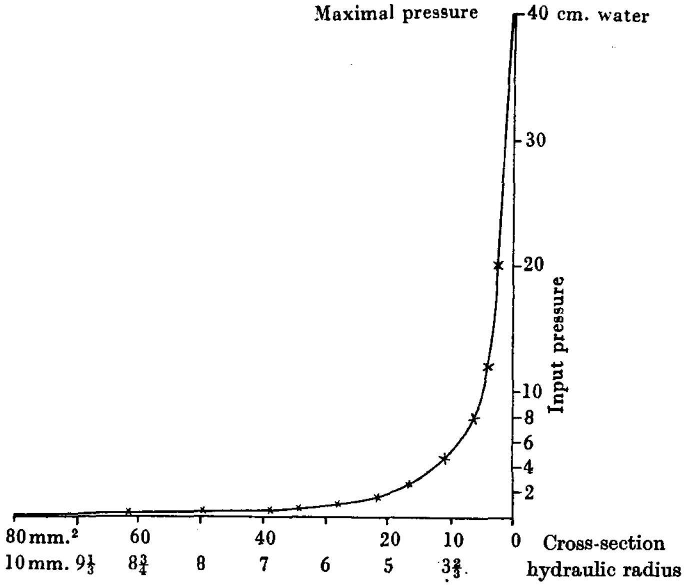

Fig. 3.

With normal passability the input pressure does not exceed 4 mm., which corresponds to the normal inspiration pressure at the nasal orifice. For estimation of nasal passability only a few seconds are necessary. In this time the air is blown through the nose, whilst the patient holds his breath in the expiratory position.

Some nervous patients have difficulties with palatinal movements, which cause a partial or complete obstruction of the nasopharynx; the outlet is then given by the free nostril. This difficulty can be overcome by closing the free nostril with adhesive plaster; then every palatinal obstruction shows itself at once in the manometric tracing. If independence of palatinal movements is wanted the patient is told to blow with force through a narrow tube placed between his lips; simultaneously the air pressure is applied through one nostril so that the total resistance of both nasal passages is measured whilst the way to the pharynx is closed.

It is permissible in the case of septum deflection to equalise this total resistance to the resistance at the narrowest cross-section of the nasal passage. If no air pressure is applied it is possible to make the usual rhinomanometric estimations, so that the results of both methods can be compared.

In order to calibrate the apparatus and to determine the relation between input pressure and intranasal passability, I have made measurements with various diaphragmatic holes and with small glass tubes of about the length of the nasal passage. Fig. 3 shows the calibration curve of the apparatus with 6 cm. tubes: maximal input pressure of the blower 40 cm. of water.

This curve shows that there is no linear relation between the decrease of cross-section and the increase of intranasal pressure. Decrease of the cross-section from 80 to 40 mm.^{2} gives only a slight increase in intranasal air pressure, but under 40 mm.^{2} of cross-section the sensitivity becomes much larger, so that, at a cross-section of 20 mm.^{2}, a decrease of only 1 mm.^{2} raises the manometer pressure over 2·5 mm.; while at a cross-section of 5 mm.^{2} a decrease of 1 mm.^{2} raises the manometric value over 50 mm. of water.

The main reason for this change is the fact that the pressure increases inversely with the square of the cross-section according to Poiseuille's law. The determination of the intranasal input pressure gives an approximation of the real air passage by first reading from the calibration curve, the so-called hydraulic radius, that is the diameter of the corresponding tube with circular cross-section. The relation between this hydraulic radius d' and the true nasal cross-section is given by the formula $d'=4\frac{F}{U}$, in which F is the cross-section to be calculated and U is the circumference of this cross-section (F. Rohrer, 1915). Close agreement between the determined cross-section and the real one will be the better obtained, the greater the swelling of the mucous membranes becomes, and the more the passage narrows to a circular cross-section. The average pressure found in many cases of normal passability is 3–4 mm. of water. This corresponds to a normal cross-section of ± 50 mm.^{2} A higher intranasal pressure corresponding to a smaller passage is found in cases of septum deflection, rhinitis, polyps, etc. Pressure smaller than the above mentioned is never found, not even in very wide noses, where the conchae have been removed. This remarkable limit of 50 mm.^{2} is caused by the fact that the air blown from the olive-shaped inlet into the vestibulum nasi has to pass through the narrow cross-section of the ostium internum (the fissure between the plica vestibuli and the septum). This fissure is the narrowest place of a normal nose and the input pressure is mainly determined by this constriction. In the general rhinomanometric observations by which the pressure in the pharynx is measured, the results are also determined by the ostium internum. Only when there arises in the nasal passage a constriction smaller than the ostium internum will the respiratory tracings become larger. I must lay stress upon this remark, because this phenomenon has a great importance for the interpretation of rhinomanometric estimations and is often neglected.

As a further determination of the experimentally found cross-section of the ostium internum I have performed direct measurements on several patients in whom I have found, in normal respiration, also a value of about 50 mm.^{2} Now the average cross-section of the nasal passage itself is 200 mm.^{2} and that of the choanen 450 mm.^{2} In normal inspiration therefore the air sucked through the narrow aperture comes into a relatively large hole. From the total lumen of this hole only one-fifth is used as air passage. *In order to act as an increase of the resistance formed by the constriction at the ostium internum, the swelling of the mucous membranes must fill up no less than four-fifths of the total lumen.* Of course the localisation and form of the obstruction will be important too, in relation to the extra resistances caused by turbulation of the air stream.

For a further experimental demonstration of the reflections mentioned above, I have measured the pressures directly before and at the back of the internal ostium in patients having a circular perforation in the anterior part of the septum. To this end a connecting tube with a suitable small rubber plate was brought into contact with the perforation; this arrangement permitted measurements of the air pressures directly at the back of the internal ostium without causing any artificial stenosis. The figures obtained thus with the patient breathing through one nasal passage are compared to Zwaardemaker's figures from experiments in which the air was breathed through both nasal passages.

	Own experiments mm. water	Zwaardemaker mm. mercury
Pressure in vestibulum	−5	−0·1
Pressure directly behind ostium internum	−15	—
Pressure in nasal cavity	—	−0·37
Pressure in nasopharynx	—	−0·38
Pressure in trachea	—	−1·9

An analogous diaphragmatic resistance is caused by the glottis which lowers the pharyngeal pressure of −0·38 to −1·9 mm. of mercury at the trachea.

From the above considerations it can be concluded that the condition to be fulfilled for the study of intranasal changes of volume must be carried out with suitable patients having a nasal airway of about 50 mm.^{2} diameter (that is equal to or smaller than the normal cross-section of the internal ostium). One must look for such patients among the people with septum deviations. Moreover, by investigation of these persons one finds air pressures which lie in the sensitive region of the apparatus (see Fig. 3). According to L. Hill it is also possible to use normal cases if a suitable nose-clip is put on the cartilage laterale. This clip obstructs the internal ostium but it does not constrict the air passage in the region of the conchae, where the cavernous tissue is located. For this reason I did not use the clip in experiments of this type.

Now the initial determination of the nasal passability is not sufficient for the choice of a suitable experimental subject. For instance, the airway might be maximally constricted already, so that only dilatation can occur and also an important dilatation may not be detected if the 50 mm.^{2} limit is surpassed. In addition pathological conditions may have changed the concheal reactivity. In order to know their swelling capacity I have sprayed the mucous membranes with a 1/1000 histamine chloride solution. The cases in which histamine did not effect a well-demonstrable constriction were rejected. In order to test the dilatating possibility it was required that after spraying with adrenaline 1:1000 the input pressure should remain above 4 mm.^{2} In this way one is sure that a swelling or dilatation can be registered. Anticipating my results, I add Table I, showing the nose-shutting effect of an electric fire for comparison.

By means of the calibration curve the cross-section, which corresponds to the experimentally found input pressure, is calculated, in order to give an idea of the changes which occur really in the nose. On the other hand, the input pressure will indicate the trouble which a patient will suffer in consequence of a nasal obstruction.

Table I gives a survey of some experiments.

Table I. *Some examples of the histamine-adrenaline test*

No. of exps.	Maximal pressure 40 cm. of water. Input pressure in mm. water and corresponding cross-section in mm.² — Initial pressure and cross-section	Electric fire during 10 min.	1:1000 HCl histamine	1:1000 adrenaline	Remarks
21	4 = 36	4 = 36	4* = 36	4 = 36	Nose too spacious, cross-section of internal ostium being the limit
12	4 = 36	4 = 36	4* = 36	4 = 36	
44	4 = 36	4 = 36	7 = 27	4 = 36	Spacious nose, constriction by heat not observable
48	4 = 36	4 = 36	6 = 28	4 = 36	
32	65 = 7	65 = 7	65 = 7	23 = 15	Maximal obstruction from the start
46	11 = 21·5	18 = 17·5	34 = 12·2	10 = 22·5	Well suited for experiments
51	13 = 21	24 = 15	33 = 12·5	7 = 27	
45	12 = 21·2	18 = 17·5	50 = 9·0	10 = 22·5	
39	8 = 25·5	35 = 12·0	87 = 5·0	8 = 25·5	
29	25 = 14·6	36 = 11·8	35 = 12·0	6 = 28	
Average last 5 exps.	20·8 mm.²	16·8 mm.²	10·2 mm.²	25·1 mm.²	

* Patient feels pulsations in the nose as a sign of active hyperaemia.

The average nose-shutting by histamine is 51 per cent. of the average initial cross-section. The average nose-shutting by electric fire is 19 per cent. of the average initial cross-section. The average nose-opening by adrenaline is 21 per cent. of the average initial cross-section.

Results

Whereas various investigators found nasal obstruction caused by radiating heat or by overheated rooms, they interpret this as the direct consequence of an increase in skin temperature. Conversely L. Hill suggests that of infra-red radiation the region on either side of about 30,000 Å. has a nose-closing effect, the 25,000–30,000 Å. region causing the inverse reaction. In order to form an opinion on the relation between nasal obstruction and increase in surface temperature, I have chosen a series of experiments in which the skin of the face, breast or back was radiated with various combinations of heat sources. Surface temperature was measured by a very small thermometer or by thermoelectric means.

These experiments have been divided into three series:

I. The effect of long infra-red rays on nasal passability.

II. The same effect of short infra-red rays at the same or higher surface temperature.

III. Effect of short infra-red rays on the heat-obstructed nose at the same surface temperature. In addition the effect of artificial cooling was investigated.

I. *Long-wave infra-red radiation*

The first series of experiments was designed to find out how the mucous membranes react on radiation of the skin with a dull electric fire, having a maximal emission in the region of 45,000 Å. According to Hill this radiation should have a nose-shutting effect. In fifty-five cases which are recorded in

Tables I, II and III this effect was studied. *In nearly every case a distinct closing effect was present.* Three cases only showed no reaction on heat radiation. The average initial cross-section of 19·6 mm.² was narrowed by the electric fire to 13·6 mm.² *That is a nose-shutting effect of* 31 *per cent.*

Table II. *The influence of short-wave infra-red radiation, directly followed by long-wave infra-red radiation on the nasal passability*

Maximal pressure 400 mm. water. Distance from source of heat 50 cm. Room temp. 17–18° C.

Input pressure in mm. water and corresponding cross-section in mm.²

No. of exps.	Initial pressure and cross-section	Change from no radiation to Georgsun during 10 min.			Surface temp. 0° C.	Change from Georgsun to electric fire during 10 min.			Surface temp. 0° C.	Radiation applied to
		Opening	No change	Shutting		Opening	No change	Shutting		
52	38=11·5	37=11·5	—	—	40	—	38=11·5	—	40	Face
54	5=31	—	5=31	—	40	—	—	10=22.5	37	,,
30	15=19·5	—	—	17=18	43	—	—	21=16·3	34	,,
32	65= 7·2	—	—	115= 3	46	—	—	165= 2	35	,,
34	12=21·3	—	—	23=15·5	42	—	—	38=11·5	36	,,
38	11=21·5	—	—	17=18	42	—	—	38=11·5	36	,,
53	20=17·3	—	—	24=15	39	—	—	27=14	37	,,
Average	18·5 mm.²		16 mm.²		43		12·8 mm.²		36	
		Sollux lamp during 10 min.								
		Opening	No change	Shutting						
27	10=22·5	8=25·5	—	—	37	9=24	—	—	34	Back
23	32=12·4	—	—	36=12·2	37	—	—	36=12·2	36½	Face
24	6=28	—	—	12=21·3	37½	—	—	23=15·5	37	Back
26	9=24	—	—	15=19·5	37½	—	—	30=13·2	33	,,
29	25=14·6	—	—	35=12	38	—	—	40=11·3	34	,,
30	15=20·5	—	—	23=15·5	35½	—	—	21=16·3	34	Face
Average	20·3 mm.²		17·7 mm.²		37		13·2 mm.²		35	
		Electric fire and tungsten lamp during 10 min.								
		Opening	No change	Shutting						
11	6=28	5=31	—	—	36½	—	—	10=22·5	36	Face
15	6=28	4=35	—	—	35	—	—	10=22·5	34	,,
18	16=19	15=19·5	—	—	37½	—	—	17=18	36½	,,
20	55= 8	48= 9·3	—	—	37	—	—	64= 7	36	,,
55	10=22·5	7=27	—	—	38	—	10=22·5	—	38	,,
17	10=22·5	—	10=22·5	—	36	—	—	18=17·5	35½	,,
13	6=28	—	6=28	—	37	—	—	12=21·3	36	,,
16	6=28	—	6=28	—	36	—	—	10=22·5	34	,,
14	17=18	—	—	24=15	36½	—	—	42=10·5	36	,,
Average	22·4 mm.²		23·9 mm.²		36·6		15·8 mm.²		35·8	

II. *Short-wave infra-red radiation*

In a second series of experiments the effect of short-wave infra-red rays on the nasal passability was studied. In order to prevent any influence of cooling of the skin, every experiment was made at the same or even at higher surface skin temperature than was present in the first series.

As a source of radiation I have chosen:

(1) The *Georgsun*: a clinical lamp which has nearly no visible radiation, but a heat radiation in the shorter infra-red region of 95 per cent. of the total

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output, as stated by the manufacturer. This lamp at a distance of 50 cm. is able to increase the surface temperature to 48° C. in a couple of minutes.

(2) *The Sollux lamp* (Hanau): which is a very powerful tungsten lamp, also used as a clinical radiation lamp.

(3) A 300-watt tungsten lamp in combination with the electric fire. In every case radiation was applied during 10 min. In comparison with the former experiments the effect of radiation by an electric fire was recorded immediately afterwards as a control. The results are shown in Table II.

In Table II a nose-opening effect by the short infra-red rays is shown in seven cases; it is an *opening effect of* 15 *per cent.*

A nose-shutting effect by these rays is present in eleven cases; it is *a shutting effect of* 20 *per cent.*

In four cases there is no change in passability produced by the short rays, but a shutting effect by the long infra-red rays of 24 per cent.

The average initial cross-section in these twenty-two cases was 20·6 mm.^{2} The average cross-section in these twenty-two cases after short-wave infra-red radiation is 19·7 mm.^{2} *That is a shutting effect of* 5 *per cent.*

The initial cross-section was narrowed by the long infra-red rays to 14·1 mm.^{2} *That is a shutting effect of* 31 *per cent.*

Taking this second series of experiments alone it does not affirm the existence of a nose-opening effect of short infra-red rays.

An opening effect occurs in one-third of the cases only. It must be pointed out, however, *that the shutting effect is very much smaller* (5 *per cent.*) *than that caused by the long infra-red rays* (31 *per cent.*) in the controls. So there is in these experiments a great difference in the two kinds of radiation.

The fact that the *tungsten lamp in combination with the electric fire prevents the shutting effect* of the latter to a great extent is very remarkable. Instead of a nose-shutting, even a nose-opening or no change at all resulted in eight out of nine cases with the above-mentioned combination. In these cases it might be allowed to speak of an antagonistic action of the long- and short-wave infra-red radiation, as described by Hill.

III. *Nose-opening effects*

From the second series of experiments it is seen that at a normal condition of the nasal mucous membranes, the nose-opening effect is present in one-third of the cases only. It is possible, however, that the demonstration of a nose-opening effect will be much easier if the airway is partly obstructed already. For this reason the influence of short-wave infra-red radiation was investigated on the heat-obstructed nose in a third series of experiments. This is the only type of experiments performed by Dufton and Bedford and Winslow. Therefore I studied the nose-opening effect on the heat-obstructed nose:

(1) With the Georgsun at the same or higher surface temperature.

(2) With a 300-watt tungsten lamp at decreasing temperature.

(3) In addition the effect of artificial cooling of the skin by means of water or fanning was recorded.

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Table III. *Nose-opening effect of short-wave infra-red radiation and of artificial cooling on the heat-obstructed nose.*

Maximal pressure 400 mm. water. Distance from source of heat 40–50 cm. Room temp. 17–18° C.
Input pressure in mm. water and corresponding cross-section in mm.²

No. of exps.	Initial pressure and cross-section	Change from no radiation to electric fire during 10 min.: Opening	No change	Shutting	Surface temp. 0° C.	Change from electric fire to Georgsun during 10 min.: Opening	No change	Shutting	Surface temp. 0° C.	Radiation applied to
35	25 = 14·6	—	—	35 = 12	37	30 = 13·2	—	—	44	Face
57	47 = 9·5	—	—	53 = 8·4	35	47 = 9·5	—	—	35	,,
58	50 = 9	—	—	110 = 3	35	75 = 6	—	—	35	,,
59	33 = 12·5	—	—	55 = 8	34	42 = 10·5	—	—	34	,,
60	40 = 11	—	—	62 = 7	34	40 = 11	—	—	34	,,
62	13 = 21	—	—	25 = 14·6	35	15 = 19·6	—	—	35	,,
63	7 = 27	—	—	30 = 13·2	34	—	—	36 = 11·8	34	,,
39	8 = 25·5	—	—	35 = 12	37	—	—	37 = 11·6	37	,,
51	13 = 21	—	—	24 = 15	38	—	—	26 = 14·3	44	,,
Average	16·8 mm.²		10·4 mm.²		35½		12 mm.²		37	
						Tungsten lamp during 10 min.: Opening	No change	Shutting		
2	10 = 22·5	—	—	14 = 20	36	12 = 21·2	—	—	28	Face
4	74 = 6	—	—	86 = 43	35	78 = 5	—	—	28	,,
5	38 = 11·4	—	—	50 = 9	35	42 = 10·5	—	—	22	,,
66	46 = 9·6	—	46 = 9·6	—	35	30 = 13·2	—	—	23	,,
7	34 = 12·2	—	—	48 = 9·3	36	40 = 11	—	—	26	,,
9	18 = 25·5	—	—	10 = 22·5	35	6 = 28	—	—	26	,,
11	6 = 28	—	—	10 = 22·5	35	5 = 31	—	—	26	,,
3	80 = 5	—	—	100 = 4	36	—	100 = 4	—	29	,,
1	4 = 36	—	—	6 = 28	36	—	—	8 = 25·5	28	,,
8	12 = 21·2	—	—	16 = 19	34	—	—	18 = 17·5	22	,,
Average	17·7 mm.²		14·8 mm.²		35·3		16·7 mm.²		25·4	
						Cooling of skin: Opening	No change	Shutting		
25	6 = 28	—	—	36 = 11·8	37	25 = 14·6	—	—	—	Back water
26	9 = 24	—	—	30 = 13·2	37	15 = 19·5	—	—	—	,,
29	25 = 14·6	—	—	36 = 11·8	36	7 = 27	—	—	—	,,
34	12 = 21·2	—	—	38 = 11·4	36	25 = 14·6	—	—	—	Face water
38	11 = 21·5	—	—	23 = 15·5	36	20 = 16·6	—	—	—	,,
39	11 = 21·5	—	—	23 = 15·5	36	8 = 25·5	—	—	—	Open air
40	6 = 28	—	—	27 = 14	34	21 = 16·3	—	—	—	Face fan
46	11 = 21·5	—	—	18 = 17·5	36	12 = 21·2	—	—	—	Face water
37	23 = 15·5	—	—	27 = 14	40	—	27 = 14	—	—	Back water
Average	21·8 mm.²			13·9 mm.²	36		18·8 mm.²			

The results are shown in Table III, the first part of which shows that the short-wave infra-red radiation of 25,000 Å. can partly antagonise the nose-shutting of 45,000 Å. In six out of nine cases the *Georgsun is able to open the closed nose but not to the initial passability.* The shutting effect of the long infra-red rays is 40 per cent. and it is decreased by the short infra-red rays to 30 per cent. This phenomenon cannot be ascribed to decreasing surface temperature, because the temperature was maintained at the same or higher level.

The second part of Table III shows that the tungsten lamp is able to dilate the obstructed nasal passages in seven of ten cases; in three cases the dilatation exceeds the initial value. This effect might be ascribed to the tungsten lamp radiation, but possibly the decrease in surface temperature will play a part too. Controls have shown me, however, that the opening in the dark after removing of the heating source wants an appreciably longer time (15 min.), whereas the visible radiation sometimes gives a very rapid reaction (1–3 min.).

The third part of Table III shows *that the opening effect of artificial cooling is distinctly present in nearly every case.* In most cases there is a larger dilatation than can be obtained with short-wave infra-red radiation.

The shutting effect of the long infra-red rays is 38 per cent., and it is decreased by artificial cooling to 14 per cent.

With the exception in the case of artificial cooling, *the opening effect is generally not so constantly and distinctly present as the shutting phenomenon is.*

In some noses the shutting initiated by the electric fire continues even when there is no radiation at all.

Discussion

As previously stated Winslow and also Dufton and Bedford started their investigation with the rhinomanometric technique. Winslow confirms the nose-closing effect, but he denies the possibility of nose-opening by suitable radiation as well as by artificial cooling, and this on the basis of measurements on thirty-one nasal passages.

Winslow's general procedure is 10 min. of radiation with electric fire followed by 10 min. of combined radiation by electric fire and tungsten lamp. In my opinion the experiments of this author are not very well suited for an investigation of L. Hill's suggestions. For the giving of too irregular tracings five of the thirty-one nasal passages should be excluded, while thirteen normal passages proved to be too wide for giving any measurable influence of heat treatment. It was observed, however, that in these thirteen cases large variations of respiratory pressure occurred caused by irregular breathing without any radiation at all. In the thirteen cases of septum deviation, where sensitivity to heat radiation was present, this respiratory irregularity was much larger still, because all kinds of psychical influences could not be excluded. Also the purely physical effect of stenosis caused by the increased resistance must be reckoned with, according to Poiseuille's law and its physiological consequences. It will be evident that a slight increase in swelling of the mucous membranes in air passages, which are very narrow already, will increase the intranasal resistance very much more than the same degree of swelling would have done in a wider nose. With narrow passages one is in the sensitive part of the calibration curve (see Fig. 3), so that large oscillations of the rhinomanometer are not necessarily due to important intranasal volume changes. One has to reduce the experimentally found pressure variations with the aid of the calibration curve. Further, it must be taken into account that the physiological responses to the stenosis will exaggerate the rhinomanometric reactions still more. The last-mentioned difficulties are excluded in the insufflation method as described in this paper. Winslow himself states that "in patients with the narrowed air passage the variation in the degree of nose opening (as shown by the variation in manometric tracings) is very large without any radiation at all".

The author fails, however, to conclude from this that such irregularities do not permit him to conclude anything from the experimental results of heat radiation, the influence of which is certainly not larger than the spontaneous variations which occurred in his controls.

A second source of difficulty in Winslow's experiments is his examination of patients in the horizontal position. It has already been shown by Gevers-Leuven (1904) and Zwaardemaker

(1914) that this position intensifies subsequent nasal obstruction by producing swelling of the mucous membrane. *For a study of increase or decrease of this volume, the lying position is wholly unsuitable.* Winslow has not realised this, notwithstanding that he himself writes: "in control experiments conducted as ours were, by causing the subject to recline on a couch with one nostril connected to the recording apparatus, such susceptible subjects may show a marked increase in nasal obstruction even when no heat or light treatment is used".

Using the mentioned experimental conditions which must be considered as not optimal for this research, Winslow had thirteen cases at his disposal which were heat sensitive. These patients were treated with the combination heat and light. In three cases the opening effect was present, and the author concludes that the Hill effect does not exist. In my opinion this result does not justify the author's conclusion, especially because Hill himself found the opening effect in 50 per cent. of his cases only. It is very probable that by sufficient variation of the experimental conditions Winslow might have come to a higher percentage of nose-opening effect. In later experiments Winslow and his co-workers have substituted the rhinomanometric method by an insufflation method which is not dependent on respiratory movements. Curiously enough the authors have not changed their method because of the reasons mentioned above, but because of the supposed respiratory disturbance by an increased basal metabolism.

The method consists of a spirometer which blows 1 litre of air through the nose of the patient, the necessary time being taken as an estimation of the nasal passability. A calibration was not carried out. The result was, that in four of the six heat-sensitive patients the nose was closed during the heat + light period and that in two patients an opening occurred; but again in these experiments the fault is made of experimenting with patients in the horizontal position.

Contrary to all other investigators Winslow and his collaborators state that the nose-opening by artificial cooling does not exist. We are inclined to describe this result also to the insufficiency of the experimental procedure, because a good method of research must surely have revealed this phenomenon.

Dufton and Bedford have made use of the rhinomanometric method exclusively, so that many of the above-stated remarks can be applied to their research. In order to exclude the eventual effects of suggestion, they studied in addition to a large number of normal persons about thirty blind ones. The patients were studied in the sitting position. There was no selection in relation to the nasal passability. The method used was similar to Winslow's heat compared to light + heat. In my opinion this is not the optimal order of experimentation as is shown in my experiments. Moreover, this method is not refined enough to come within the scope of exact rhinomanometric measurements.

Hence the closing effect was demonstrated by Dufton and Bedford, but the short infra-red radiation opening effect was not. Contrary to Winslow, however, the effects of superficial heating and cooling were distinctly present in the rhinomanometric curves.

The phenomenon as described by Hill is essentially affirmed by my own investigations. I must, however, lay stress upon the fact that my experimental conditions are chosen in a manner to exaggerate the effect of radiation on the skin. The small energy quantities which reach the skin through a selective screen, which are perceived by Hill, are not studied in my experiments; neither have I had the opportunity of studying the infra-red region below 25,000 Å. to which Hill ascribes a shutting effect similar to the range above 30,000 Å.

With a view to the theoretical explanation of the antagonistic action of longer and shorter infra-red radiation it is natural to look for a difference in cutaneous absorption. It was shown by Sonne (1921) and by Argyll Campbell and Hill (1923) that the red and short infra-red radiation (the nose-opening rays) penetrate rather deeply into the superficial tissues, give rise to active hyperaemia and transudation in a relatively short time, and cause a bearable sensation of heat, even when the temperature in the deeper part of the skin rises to 48° C.

Contrary to this the longer infra-red rays (the nose-shutters) give a much more superficially localised heating of the skin and cannot be tolerated when the surface temperature rises to 42° C. Evidently the heat receptors in the surface layers of the skin are kept cool by the active hyperaemia excited by the penetrating short infra-red radiation.

The absorption of infra-red radiation by the tissues of the eye was studied by A. Vogt. Here, too, it appeared that the longer heat radiation damaged the superficial structures, whereas the 7000–12,000 Å. radiation was especially noxious to the lens and retinal tissues. Hardy and Muschenheim (1934) and also Hill found that *the short heat radiation penetrated deeply into the skin, but that radiation above* 35,000 Å. *was completely absorbed in the Malpighian layer.* As any radiation can only influence those tissues in which it is absorbed, one has to suppose that the nose-shutting must originate from that layer, either by reflex or in a humoral way. A humoral cause is made probable by the long latent period (6 min.) of the shutting phenomenon. In so far as the short-wave infra-red radiation is absorbed in the Malpighian layer, it would have a shutting effect too; this is confirmed by my experiments. So there is no qualitative but only a graduated difference in the two kinds of radiation.

In addition to this an antagonistic action of the infra-red short waves must be pointed out. It is obvious that these rays are capable of preventing the shutting effect of the longer rays and are also able to reopen the nose when closed by the influence of surface heating. This action may be explained by the excitation of an increased circulation which cools the overheated Malpighian layer. It has been shown that the long-wave infra-red radiation causes a capillary dilatation with stagnation, resulting in overheating by the absorbed energy. The effect of the short infra-red rays is an arteriolar dilatation causing an increase of the circulating volume. This effects an increase in the flow of heat and is the cause of a relative cooling of the Malpighian layer. Of course the same condition can be reached by artificial cooling of the skin.

According to Spiesmann (1933) a change of surface temperature corresponds to a change in intranasal temperature. It will be interesting to find out whether the intranasal temperature will be different during the heating of the skin with long-wave or short-wave heat radiation, especially if the localised temperature of the Malpighian layer is measured thermoelectrically.

It would be premature to say much about the practical hygienic consequences of Hill's discovery. In normal man there is so large a range in nasal passability that a small degree of closing does not necessitate oral respiration. It is, however, a matter of common experience that many people complain of nasal obstruction, headache or a stuffy sensation when they find themselves near hot stoves, in overheated railway compartments, etc. Such reactions are important in regard to human well-being. Rhinologically these complaints are explained by swelling of the mucous membranes and obstruction of the nasal sinuses. Possibly the said conditions are a cause of chronic rhinitis and sinusitis. It is well known that rhinitis is a rare occurrence in open-air sanatoria. Possibly the refreshing effect of a cold wash after sleep is due to the decrease of swelling of the nasal mucous membranes and opening of the sinuses. Again, the want of ventilation in a warm closed room is felt much more than in the same cool room. This might be explained by the fact that the nose-shutting does not occur in low-temperatured rooms (Hill). In the construction of clinical radiation lamps these researches must be taken into account; the therapist has already hit upon the most efficient treatment, for the head-light bath of Brünings, and lamps like the Georgsun give almost only short-wave infra-red radiation.

Finally there are already laryngoscopic observations (Mudd and Grant, and Hill) of analogous changes in the lower parts of the air passage caused by surface radiation. This would give a still greater extension to the importance of the phenomenon.

Summary

For the investigation of the Hill phenomenon, viz. the antagonism of short- and long-wave infra-red radiation in their influence on nasal obstruction, the commonly used rhinomanometric technique is not well suited. In this paper a new procedure is described, in which an air current is blown through the nose. In this way the nasal passability may be estimated, independent of respiratory movements. It proved to be desirable to make a selection of suitable experimental subjects with the aid of adrenaline and histamine tests; only those persons in which the opening by adrenaline and the narrowing by histamine sprays were clearly demonstrable were chosen.

Long-wave infra-red rays constantly caused nasal obstruction.

The shorter waves were much weaker in their shutting effect, and also decreased the narrowing of the nose when they were given in combination with the long-wave rays of an electric fire.

A nasal passage closed by long-wave infra-red radiation may be partly opened by the short-wave rays; the possibility of surface cooling being the opening factor was excluded.

Artificial cooling of the skin has a very marked opening influence.

It is suggested that nose-opening and nose-shutting are correlated with cooling and heating of the Malpighian layer. Long infra-red rays will be completely absorbed in the layer and cause capillary stasis with local overheating. The shorter waves for the greater part penetrate more deeply; the skin reacts by an active hyperaemia, which, by relatively cooling the overheated Malpighian layer, has the same effect as a cooling from without.

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