THE WORK, WAYS, AND PATTERNS OF NASAL BREATHING*
(Relevance in Heart and Lung Illness)

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The total work of lung movement when breathing through the nose is 168% greater than when breathing through the mouth. This is true for "normal" individuals breathing through "normal" noses.

In a series of volunteer patients the mean total work of mouth breathing at twenty breaths per minute with a tidal volume of 0.5 liters was 0.19 Kg. m./minute, while that of nose breathing was 0.51 Kg.m./minute, a difference of 0.32 Kg.m./minute.[1] (No figures are available in precisely this formulation for patients with abnormal noses.)

In another series of volunteers, pulmonary resistance was 50% higher when measured through the normal nose than when recorded through the mouth. As the nasal obstruction increased, the nose-mouth differential increased to 500% in some instances. Also in this series and of great importance to us, is that resistance measured through the mouth does vary a little as nasal obstruction increases. (Following surgery in some of these patients, marked decrease in pulmonary resistance was recorded when the measurements were made through the nose.) The same authors (Ogura, et al[2]) concluded that functional or relative compliance measured through the mouth decreased with increasing grades of nasal obstruction. Also, functional residual capacity increased with increasing nasal obstruction. This increase was reflected in the functional compliance, also becoming increased by the use of vasoconstrictors or following nasal surgery for the relief of nasal obstruction. The reasons for such shifts in functional compliance were thought, possibly, to be due to a nasal pulmonary reflex or to changes in surfactant substances. These investigators, as well as most others, have done their experiments using both sides of the nose for breathing and the open mouth for the same purpose.

No description of how mouth breathing is accomplished is usually given. The mouth could be wide open, it can be utilized with pursed lips like in whistling, and there can be many variations in between. It is well known that breathing under quiet conditions in the daytime through the nose is accompanied by an alternating cyclic congestion and decongestion of the mucosa of both nasal chambers, especially involving the turbinates (inferior and middle), but what is of most interest is the fact that during normal sleep in the positions that are usually assumed, the patient lies in bed with the head to one side with the other side of the nose uppermost which induces congestion of the turbinates of the lower

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nasal chamber which narrows, or even completely closes, the lumen. But the uppermost side of the fibro-cartilaginous vault falls inwards onto its lumen occluding it moderately and thereby increasing the nasal resistance to air flowing through it. As the patient moves his head from one side to the other he uses the changing upper sides of his nose, so that during the quiet of a period of sleep, breathing through the nose is really a one-sided function, a uni-lateral, or perhaps one should say, a uni-nasal breathing effort. From this it follows that studies of the work of breathing through one side of the nose are of considerable clinical significance.

Changes in posture under other circumstances will similarly affect the patency of the lumen of the nasal chambers and produce increased resistance to the air stream and, thereby, a similar increase in the work of breathing through the nose. Infections, allergies causing swelling and thickening of the nasal mucosa, polyps, mucosal hypertrophies are well known and commonly found impediments to the nasal air streams. Hard obstructions caused by deviations and impactions of septum cartilage and bone produce large and small areas of contact between the septum and the lateral walls of the nose, most usually about the inferior turbinates, the middle meatuses, and the middle turbinates. These obstructions produce not only mechanical impediments to the air streams, but also are a cause of reflex reactions not only through the well-known neurological connections between the nose and the cranial and spinal nerves, but also through the autonomic nervous system and the vasomotor structures. In a word, there are possible neurological and vascular derangements of any organ of the body from noxious stimuli arising in the nasal mucosa.

Early treatises on human physiology often took cognizance of the role played by the nose in breathing and smelling and, what is quite astonishing, they not only dealt with the existence of the nasal reflexes of sneezing and lacrimation, but also in the neurological relation of the nose to the heart and lungs. Thus, Brown-Séquard [3] as long ago as 1858 (quoted by Mink) wrote: "When the nervous action leaves the respiratory center to reach the dilator muscles of the thorax, it propels itself also into the cardiac fibers of the vagus nerve and will produce in the heart a suspension or a diminution of movement." Mink [4] noted that the blood vessels of the nose are also under the influence of breathing and cited Thiry, who noted that with an increase in respiratory function, a drawing together of the vessels and a rise in blood pressure occurred due to the action of the muscles within the blood vessels.

Nose-lung relationships were widely explored long ago. The ipso-lateral naso-pulmonary neurological connections were ascertained by Samzelius-Lejdstrom, [5] who spent at least thirty-five years in establishing the intimate involvement of each lung with the nasal chamber of its own side. Her special interest was in demonstrating that an obstruction in the nose caused a restriction of the movement of the corresponding lung and thorax -- even when breathing was through the mouth or trachea. (She was aided in pursuing her research by a financial grant and the enthusiastic encouragement given her by

body which play important roles in breathing has expanded into an enormous coordinated scientific abundance of cardio-pulmonary and cerebral physiological investigations. Studies of blood gases and the physical and neurological mechanisms regulating breathing in health and in disease have added much corroboration to the current generally accepted hypotheses of respiration.

The role of the nose in this vital function has been grossly neglected to the detriment of the welfare of our patients -- causing an impedence to progress in rhinologic diagnosis and nasal medical and surgical therapy.

It is a great relief to note that during the last ten years much of this vacuum in our knowledge was recognized and a remarkable amount of information was contributed by many in various parts of the world to fill this astounding void.

Interest in the role of the nose in respiration is not new or novel. Emil Bloch, Aschenbrandt, Mackenzie, Zwaardemaker, Mink, Goodale, Mueller are but a few who at this same time did much to further the recognition and the examination of nasal functions with an eye on their relationship to cardiac and pulmonary functions as well as on the health and homeostasis of other organs. The reports on nasal reflexes by Kratschmer and by Kuttner were remarkable pieces of cogent investigation. They were published towards the end of the nineteenth century.

At the present time many clinicians, physiologists, and physicists throughout the world are building up an enormous fund of information on the identifying and measuring of nasal activities and characteristics and it won't be long before it will become inexorably incumbent upon every doctor to include in the total evaluation of a patient's health the estimation of nasal functions disturbance. Then, as a matter of course, every rhinologist will be expected to be able to give a detailed and critical diagnostic opinion of the functioning of the nose in addition to the present day practice of just describing anatomical variations.

Rendering an objective explanation for the subjective complaints of disturbed nasal breathing is right now a much needed service and a reasonable fundamental obligation of the rhinologist.

WAYS OF BREATHING

Humans normally breathe through the nose, both sides at once or one side at a time. Mostly, however, one nasal chamber is more patent than the other at any given moment under normal circumstances as a consequence of the normal alternating congestion and decongestion of the turbinates occurring rhythmically in a two to four hour cycle.

People have the option of breathing through the mouth, an alternative most other mammals do not have. The mouth can be held fairly wide open or the lips can be pursed more or less (as in whistling). Both the nose and mouth can be used at the same time, or only one side of the nose together with an open or partially open mouth might be employed.

The position of the head and the body changes throughout the day as the person is sitting quietly, reclining, lying in bed supine or prone or resting on his left or right side. Working, walking, eating, making strenuous efforts, all influence the act of breathing. Infections, allergies, climate, pollutants, metabolic and emotional disturbance, nasal obstructions, and drugs (decongestants and congestants) affect the nasal passages and contribute materially to changing the characteristics of breathing requirements and patterns.

From the above it is obvious that there are scores of variations of the ways of breathing that are frequently used during an average day and night to meet the changing respiratory needs during the waking and sleeping hours.

The following outline (though incomplete) provides a quick survey of the many ways of breathing commonly or only occasionally employed.

A. Through the nose
   1. Alternating cyclic congestion and decongestion
   2. Through right side only
   3. Through left side only
   4. Through both sides (static)

B. Through the mouth only
   1. Wide open (or less)
   2. With pursed lips

C. Through the mouth and nose
   1. Through mouth and both nasal chambers
   2. Through mouth and right nasal chamber
   3. Through mouth and left nasal chamber

D. Manner of breathing
   1. In and out of the nose
   2. In and out of the mouth completely opened, partially closed, or alternating
   3. In through the nose and out through the mouth
   4. In through the mouth and out through the nose (as in vigorous exercise)
   5. In one side of the nose and out the other side of the nose (yogi)

E. State and position
   1. Quiet
      a. Sitting
      b. Reclining with head in midline or leaning to right or left

      c. Sleeping position
         1) On the back, head in midline, right or left
         2) On right side
         3) On left side
         4) Prone, head right or left
         5) Flat on mattress
         6) One or more pillows
      d. Conscious or unconscious of the act of breathing
   2. Active
      a. Work
      b. Walk
      c. Run
      d. Exercise which can be regular or occasional
      e. Vigorous exercise
   3. Healthy or ill with infection, allergy, etc. (see Nasal Congestion)

F. Environment
   1. Indoors
   2. Outdoors
   3. Temperature
   4. Altitude
   5. Humidity
   6. Odors
   7. Dust
   8. Windy
   9. Sunshine
   10. Pollution

G. Physiological and/or pathological forms
   1. Deep)
   2. Shallow) all with or without equal concomitant
   3. Rapid) pressure changes in the ipso-lateral antrum
   4. Slow
   5. Yawn
   6. Sigh
   7. Snoring
   8. Gasping: spasmodic inspiratory effort, usually maximal, brief, and terminating abruptly; may be rhythmic or irregular
   9. Hyperpnia: increased breathing; usually refers to increased tidal volume with or without increased frequency
   10. Hyperventilation: increased alveolar ventilation in relation to metabolic rate (i.e., alveolar $P_{CO_2} \lessapprox 40$ mm Hg)
   11. Hypoventilation: decreased alveolar ventilation in relation to metabolic rate (i.e., alveolar $P_{CO_2} \gtrapprox 40$ mm Hg)
   12. Apnea: cessation of respiration in the resting expiratory position
   13. Apneusis: cessation of respiration in the inspiratory position

14. Biot's respiration: originally described in patients with meningitis by Biot (Lyon med. 23:517, 561, 1876) as irregular respiration with pauses; today, it refers to sequences of uniformly deep gasps, apnea, then deep gasps
15. Panting
16. Cheyne-Stokes respiration: cycles of gradually increasing tidal volume followed by gradually decreasing tidal volume [7]

The evaluation, therefore, of a patient's complaint of "difficulty of breathing" is even more complex than the well known problem of comprehending "dyspnea" or breathlessness. Heart, lung, thorax, blood illnesses are always inextricably part of any consideration of this symptom and have been extensively studied in this connection, but the inclusion of the status of nasal health and illness is indispensable.

PATTERNS OF BREATHING -- UNI-NASAL BREATHING TESTS

In a discussion of the functions of the nose, the effects of the nose on the air streams and the effects of the air on the nasal mucosa, nerves and blood vessels are of equal significance and at least thirty such functions and effects have been recognized. During the last two decades they have, in fact, received considerable attention in spite of which practically no testing of any of the physiological aspects of nasal and/or oral breathing is widely performed.

Attention has, in recent years, been directed to the several ways in which studies of nasal and oral breathing pressures and flow rates of the air streams can serve as objective aids in rhinologic diagnosis and in the evaluation of nasal surgical and/or medical therapy.

From them a group of uni-nasal breathing tests were selected for extensive study. The following notes in a brief form indicate some of the data made available by the rather simple and easy available methods of examination (previously described and illustrated [8]).

A. Pressure curves graphically (electronically) recorded.
   1. Form. Variations.
      a. Irregular.
      b. Exaggerated.
      c. Diminished.
      d. Flat prolonged period of maximum expiration.
      e. Sharp short period of maximum expiration.
      f. Flat prolonged period of maximum inspiration.
      g. Sharp short period of maximum inspiration.
      h. Mid-cycle rest (inter-cycle rest).
      i. Intra-cycle rest.

   2. Ratios (normal).
      a. Inspiration <u>pressure</u> is greater than expiration pressure.
      b. <u>Time</u> of inspiration is less than expiration.
      c. There are five parts in each normal breath and they have a relationship to each other in time and amplitude.
   3. Rate: normal, 10 to 20 breaths per minute.
   4. Amplitude.
      a. Inspiratory pressure around 10 mm. water.
      b. Expiratory pressure around 8 mm. water (total amplitude about 20 mm. of water).
      c. Increase in pressure after exercise, nasal congestion, supine position, allergy, infections, obstruction.
      d. Decrease in pressure in wide noses, atrophic rhinitis, and some reflex (neurologic) conditions.
   5. Rhythm.
      a. Normally regular, even, sustained, constant.
      b. Irregular, uneven.
   6. Exercise increases nasal respiratory pressures, more so in obstructed noses.
   7. Head to one side as in sleep increases breathing pressures of uppermost nasal chamber, while the lower side normally should become almost completely closed.
   8. Head and body in sleeping position increases pressures even more.
   9. After shrinking (decongesting) of nasal mucosa and turbinates, repeat tests 7 and 8. The effect of the falling in of the lateral walls of the non-osseous nasal lateral wall can be isolated and evaluated by measuring the increase of the resistance to the air stream which the "sleep" position of the head produces.
   10. From the pressure curves, two helpful indices can be deduced:
      a. The <u>work coefficient</u>, which is the average of the height of inspiration pressure (in millimeters of water) of several consecutive breaths multiplied by the rate of breathing per minute is usually between 150 - 250.
      b. The average of 4 consecutive (highest) pressures of inspiration multiplied by the time in seconds required to take these 4 breaths gives a <u>"4 breath factor"</u>. This purely dimensional number should be in the range of the work coefficient, 150 - 300. A marked disparity in either direction points to nasal disturbance.

B. Rhino-revma-sphygmomanometry reveals the capacity of the nose to permit the inhaling or exhaling of 8 liters of air a minute (through a measuring system of tubes whose diameter is 5 mm.) without producing a resistance of more than 100 mm. of water. This can be measured mechanically or electronically.

C. Flow in liters per minute and concomitant pressures in millimeters of water are recorded synchronously (two-channel recorder), simultaneously (two single-channel recorders), or consecutively (one single-channel recorder). This can be done to give fairly true quantitative data or just good qualitative information. The latter is quite simple to accomplish and a flow over pressure calibration is employed to bring about a formulation of a Flow over Pressure equation which normally is 20 liters per minute (or more) over 20 mm. of water (or less) as a normal using an 8 mm. nozzle in the nostril of the side where the flow of air is being tested. An inversion is definitely a sign of nasal disturbance. A truly quantitative estimation calls for more selective apparatus and more demanding patient cooperation.

D. Conductance is the opposite of resistance. The conductivity as originally presented by Spoor [9] requires the flow and pressure as obtained in C to be conducted into an electronic device which integrates the data assuming a resistance of 10 mm. of water at all times, and writes out the resultant informative graph.

E. Spirometry. The determination of tidal volumes is facilitated by connecting a small (Wright) spirometer to the pneumotachometer while doing flow studies. Tidal volumes are often seen to vary from 200-1200 ml. (per breath).

F. Naso-antral pressure relationships are obtained by inserting a needle into the antrum (via inferior meatus) and placing a nozzle to the other nostril. The needle connected to the recorder transmits the same respiratory patterns as occur in its corresponding nasal chamber transmitted to the recorder by the nozzle in the other nostril. The recordings (or readings) can be made synchronously with a two-channel recorder, or consecutively on a one-channel recorder, or even monitored visually on a simple mechanical manometer.

G. The work of breathing through the nose can be roughly evaluated by multiplying the work coefficient by the volume of air breathed per breath. This work can be determined with the person in upright and reclining positions, at rest in bed, or after work or exercise (etc.) and can be compared with the work of breathing through the mouth (with the mouth, teeth, tongue and lips in a variety of positions) in the upright, recumbent, and other positions. From these studies the equivalent in changes of oxygen consumption can also be deduced, all of which in turn can be compared with the work and oxygen requirements of breathing through the mouth. In people with heart-lung conditions, important therapeutic guidance is provided.

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