

THE DRAINAGE MECHANISM OF THE NORMAL ACCESSORY SINUSES.*

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With the exception of a few sentences scattered here and there through the literature, little has been written upon the subject of the drainage of the normal accessory sinuses. This drainage is dependent upon certain physical and physiological laws, which it is the object of this communication to place before you for consideration and discussion, in the belief that a fuller knowledge and understanding of the normal drainage mechanism of the nose will help materially in solving some of the difficult problems.

Although the nose secretes daily several pints of sero-mucous fluid, only a small portion of the fluid comes from the accessory sinuses. In the nasal passages this fluid disappears by evaporation; but as the conditions for evaporation are not favorable within the sinuses, it follows that the secretion of the sinuses must be discharged into the nose. The fact that the sinuses are thus capable of draining themselves when they are in a normal, healthy condition will hardly be disputed; but that they are also capable of emptying themselves through their natural orifices when they have become diseased may not be so self-evident. Yet it is within our experience that acute inflammations of all the accessory sinuses have a natural tendency to get well without operative interference, the end of the disease being marked by a discharge of secretion into the nose, lasting for days or weeks, during which time drainage through the natural orifices goes on without interruption; so that even when the mucous membrane is diseased and the quality of the secretion altered, drainage through the natural orifices is possible, and in a large percentage of the cases is sufficient. We may, therefore, assume that in these cases the normal drainage mechanism has not been destroyed, and by following the course of the secretion in these cases some light is thrown upon the mechanism of normal drainage.

The first factor to be considered is drainage by gravitation. By this term I mean the direct outflow of the secretion by virtue of its weight. A fluid collecting in an accessory cavity naturally seeks to follow the law of gravitation, and to collect in the lowest part

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of the cavity. It cannot flow out of the cavity until its level reaches the level of the natural opening, or until the position of the head is changed so as to bring the natural opening below the level of the fluid.

The opening of the antrum is situated near the upper part of its internal wall. Hence, secretions cannot flow out of this orifice, in the upright position of the head, until the antrum is nearly full of fluid. The lower half of the antrum, however, is larger in volume than the anterior half, so that an accumulation of fluid, which is not high enough to reach the natural orifice in the upright position, may escape through this opening when the head is bent forwards. Complete emptying of the sinus can only take place when the head is bent toward the opposite side.

In the case of the frontal sinus, the opening is favorably situated when the individual is in the upright position, or when he lies upon the opposite side; but even when the naso-frontal duct is typical in arrangement, the drainage by gravitation is obstructed by the long and narrow passage through which the fluid must pass. This is equally true when the fluid must first pass through an ethmoid cell.

The anterior ethmoid cells open into the hiatus semilunaris, or between the bulla and the middle turbinate, each, according to Hajek, by a separate opening. This opening is sometimes situated near the floor of the cell, sometimes high above the level of the floor; but there are many deeper cells which open into each other and into the superficial cells in a variable manner, so that there is no position of the head in which the ethmoid labyrinth can completely empty itself. The posterior ethmoid cells are similarly situated, in reference to their outlet.

The opening of the sphenoid sinus is at the upper and outer part of its anterior wall, so that fluid can flow from this sinus only when the head is bent forward or toward the same side.

It is, therefore, evident that there is no single position of the head which is favorable to drainage from all the sinuses. During sleep, drainage from one-half of the sinuses would be favorably affected if the individual rest upon the side. During waking hours, in the occupation of most individuals, the position of the head varies sufficiently to cause frequent changes in the position of the fluid in the sinuses, and in this way the drainage of one or another of the sinuses may be temporarily affected in a favorable manner.

On the other hand, even when the head happens to be in such a position that the natural orifice of any particular sinus is at its

most dependent portion, the escape of any contained secretion can, at best, be only slow and intermittent. For, when a liquid flows from a vessel with a narrow outlet, it escapes in jets. Each jet is followed by the entrance of a bubble of air into the vessel. If the surface tension of the liquid is low, the jets and bubbles follow each other in rapid succession; but if the liquid is thick and viscid, like glycerin, for instance, or like the nasal secretions, its escape will be very slow; in fact, if the opening is very small, there may be no escape of liquid at all.

Now, there is but one small opening into each sinus. Hence the escape of secretion from the sinuses is slow, each drop being succeeded by an intermission, during which a bubble of air enters the sinus. In persons who have excessive secretion in their sinuses, this bubble of air may give rise to a sensation, or to a noise of which the individual is distinctly conscious.

Considering these facts, and bearing in mind that the secretion of the healthy sinuses is a mucous fluid, and that of the diseased sinuses a still more viscid one, it is evident that gravitation, as such, plays a very small part in the drainage of the normal accessory sinuses, as well as in the drainage of those diseased cavities in which restoration to health takes place without operative interference. On the other hand, the explanation of the manner in which these cavities *are* drained, must be sought in a study of the character of the mucous membrane over which this drainage takes place, and of the physical properties of the secretion.

With the exception of the olfactory tract proper, the mucous membrane of the nose and its accessory cavities is covered with ciliated epithelium. The cilia are in a state of constant motion, which has been compared to the lashing of a whip. Each cilium moves through an arc of from 20 to 30 degrees, at the rate of about 12 times per second, the forward movement being about twice as rapid as the return movement. All the cilia of a single cell move in the same direction at the same time, but the cilia of all the cells do not move simultaneously, but the motion is carried over the mucous membrane in a wavelike manner. The movement of the cilia is maintained and governed by the nucleus of the cell. It is favored by heat, by a proper degree of fluidity, and by an alkaline reaction of the secretions; it is retarded by cold, by dryness, by viscosity of the secretions, and by various chemical reagents. The direction of the ciliary motion is always toward the external orifices of the body; in the accessory cavities it is toward their natural

orifices. The power exerted by the combined action of the cilia is said to be very considerable.

By means of this ciliary motion, the secretion covering the mucous membrane is kept constantly moving toward the natural openings and into the nasal passages. Ciliary activity is therefore an important factor in maintaining the drainage of these cavities. The fact that diseases, in which the cilia are destroyed, such as the various forms of atrophic rhinitis, are frequently associated with accessory sinus diseases, would be an instance.

In some of the sinuses, and in favorable positions of the head, the activity of the cilia is in a downward direction, and is favored by gravitation; but in other sinuses, and in many positions of the head the fluid must be driven uphill, and in such cases the upward motion of the fluid is favored by the fact that the secretion is exuded from all parts of the mucous membrane in small quantities at a time. For some of the secretion is exuded near the natural orifice, so that the distance which it must be moved is small; but this fact also brings into play a certain law of physics, as follows: When a fluid is present in large quantities the law of gravitation prevails, and the fluid flows downwards; when the quantity of fluid is small, so small that it is measured in drops, its gravity may be counteracted or even overbalanced by other properties, such as adhesion, surface tension or tenacity, capillary attraction and syphonage. These physical properties are common to all fluids alike; they are therefore true of the secretion of the normal sinuses, and of the diseased sinuses as well. Their influence in determining the drainage of the sinuses has not been touched upon in the text-books nor in other literature. We have, therefore, collected the results of clinical observation of these phenomena, and will present them in the order in which they seem to exert their action in the nose.

By adhesion we mean the power of attraction existing between bodies. Not every liquid can adhere to a solid, as, for instance, mercury and glass; when, however, adhesion between a liquid and a solid exists, as between water and glass, the liquid is said to have the power of wetting the solid. If a drop of liquid is placed upon a surface which it is capable of wetting, it does not remain stationary, but spreads over the surface; if the surface be vertical, it will rise upwards, contrary to the direction of gravitation, as well as downwards; this creeping of the fluid takes place more readily if the surface has been previously wetted with the liquid, for when it is dry, the adhesion of the

atmosphere to the solid must first be overcome. In consequence of this power, a liquid contained in a vessel which it moistens, will rise along the sides of the vessel, so that the upper surface of the liquid is not flat, but is concave, presenting what is familiarly known as the meniscus. The height of the meniscus depends upon the degree of adhesion existing between the liquid and its container, and is greater when the surface of the container has been previously moistened with the liquid.

Now, in the nose the adhesion between the secretion and the surface of the mucous membrane is very great, for one of the main functions of the secretion is to keep the mucous membrane moist. Any secretion formed in the sinuses therefore tends to spread over the walls of the sinus. If secretion has accumulated within one of the sinuses, its surface will present a high meniscus, so that the level of the fluid where it comes in contact with the walls of the sinus will be much higher than in the middle, and the actual dimensions of the sinuses are such that the height of the meniscus is generally sufficient to bring the fluid up to the level of the natural orifice. In like manner the secretions rise out of the various depressions and pockets in the floor of the sinuses, and are able to surmount the obstructions presented by the partitions and septa which are often encountered. The rise of the meniscus is favored by the cilia; for the area of the mucous membrane is greatly increased by these numerous projections from its surface, and consequently the adhesion is greater. Moreover, as the direction of the ciliary motion is toward the natural orifice, the two forces always act in unison to bring the fluid to the outlet of the sinus.

If a liquid is contained within a tube the surface of which it can moisten, and whose diameter is sufficiently small, the adhesion of the liquid will overcome its gravity, and instead of flowing out of the tube, the liquid will rise in the tube contrary to the direction of gravitation. This phenomenon of capillary attraction is directly dependent upon adhesion and is subject to the same laws. In a tube of given diameter the height to which the liquid will rise depends upon the degree of adhesion between the liquid and the tube. With a given liquid and tube, the capillary attraction depends upon the diameter of the tube, the narrower the tube, the higher the liquid will rise. It is not necessary, however, that the capillary space be tubular in form; for these phenomena will manifest themselves equally well between any two surfaces which are near enough

to each other. If the surfaces are parallel to each other, the liquid will rise to a certain height and its upper border will be horizontal. As the height to which the liquid will rise depends upon the distance between the surfaces, it follows that in a wedge-shaped space, the liquid will rise higher along the narrow side of the wedge. In fact, in a horizontal wedge-shaped space which is open below, a drop of fluid introduced into the open part of the space, below, will flow upwards until it forms a narrow band along the line where the surfaces meet. Capillary attraction is always greatest in the immediate neighborhood of points of contact.

Now, as soon as the secretion of the sinuses reaches the natural outlet, it encounters the capillary attraction due to the conformation of the outlet. The outlet of the frontal sinus is tubular in form; in this form the capillary force is greatest, and it is by virtue of this fact that the resistance due to the unusual length of the naso-frontal duct is overcome. The orifices of the antrum and of the anterior ethmoid cells, as well as the naso-frontal duct, open into the semilunar hiatus, a narrow space with parallel walls, which exerts a not inconsiderable degree of capillary suction upon the secretion which presents itself in these orifices. The sphenoid sinus and the posterior ethmoid cells open into the very narrow superior meatus, whose walls are sufficiently close together to exert similar attraction upon their secretion.

When the semilunar hiatus is visible, the secretion may be seen; for it accumulates in the wedge-shaped space formed between the rounded edges of the lips of the hiatus. The secretion does not necessarily accumulate in the lower part of the hiatus, but flows readily along its entire length, quite independent of gravitation. By virtue of its adhesion and its power of spreading over the moist surface of the mucous membrane, it flows downwards over the uncinate process and upwards over the bulla, and will next be found accumulating in the wedge-shaped space or groove between the uncinate process and lower turbinal, or between the bulla and middle turbinal. In this way the secretion is spread over the entire surface of the middle meatus, and as this is the main respiratory channel, the secretion will, if its quantity is not excessive, disappear by evaporation. On the other hand, when the quantity of secretion is excessive, its further course is of interest. If the middle turbinal is large, the space between it and the outer nasal wall, and between it and the lower turbinal, becomes a capillary space. Owing to the rounded outline of the turbinals, this space is a wedge-

shaped space, the angle of the wedge becoming more acute above. As the secretion must follow the law of capillary attraction and accumulate in the narrowest part of a wedge-shaped space, it will sometimes happen that the only visible accumulation of secretion will be found high up in the angle between the middle turbinal and the agger nasi. The fact that secretion is present in this locality, and that it reaccumulates here after it has been wiped away, does not indicate that it comes from the frontal sinus, for it may reach this locality from the antrum as well as from the frontal sinus. It is only when the space between the middle turbinal and the outer nasal wall is so large that capillary attraction between them is impossible, that the location of the secretion is of value in the differential diagnosis between the sinuses of the anterior group; for, under these circumstances, the secretion from the frontal sinus is apt to accumulate in the anterior part of the middle meatus, that from the antrum in the posterior part.

The secretion of the sphenoid sinus is apt to flow into the nasopharynx; but it usually flows, together with the secretion from the posterior ethmoid cells, over the middle turbinal into the olfactory fissure. The mere presence of secretion in this region, however, is not pathognomonic of diseases of the posterior group of cells. For the secretion from the anterior group, which is drawn by capillary attraction to the outer surface of the middle turbinal, may accumulate along the edge of this structure in the form of a hanging drop or band. The secretion is not limited, however, to this hanging drop or band alone; for upon closer examination it can be seen that a thin film of secretion extends upwards on both sides of the turbinal, having been drawn up into this position by virtue of its wetting power, i. e., by adhesion. The thin film corresponds to the meniscus in a hollow space or cavity. If, now, the middle turbinal is in contact with the septum, or near enough to it to enable the drop of secretion to bridge the gap, the secretion will be readily drawn up into the angular space between the two structures, according to the law of capillarity which has been quoted. The presence of secretion in this region is, therefore, pathognomonic only when disease of the anterior group has been excluded, or when the secretion can be seen in the superior meatus by posterior rhinoscopy.

The secretion which flows from the hiatus semilunaris over the uncinate process reaches the inner surface of the lower turbinal, and may accumulate along its lower border and reach the septum in the same manner as described above for the middle turbinal. From

both turbinals the secretion of the entire nose is carried over to the septum, along which it can easily flow down to the nasal floor, to be discharged from the nose.

Between the two turbinals and the septum there is a triangular space, around the edges of which secretion is held by capillary attraction; but in many individuals this space is filled up by a slight elevation, thickening or spur of the septum, which converts this triangular space into a space with parallel walls, so that capillary attraction is equalized over this area. Such a slight elevation of the septum in this region may, therefore, be an aid to drainage, and its removal a distinct detriment.

It is evident from the above facts that the nasal passages may be regarded as a series of capillary spaces, which are in direct communication with the sinuses through the natural orifices, and that the secretion which lies in these capillary spaces is in direct continuity with the secretion which lies within the sinuses. It therefore follows that when the secretion which has entered the nasal passages through one of the natural openings, has reached as far down as the level of the fluid within the sinus, a new factor in drainage is called into play, namely, syphonage; for under these conditions, the weight of the fluid within the sinus is balanced by the weight of the fluid in the nasal passages. As the capillarity of the nasal passages is exerted between the turbinals and the septum, its effects must be co-extensive with these structures. Hence, as the area of the septum is very great, both in height and in length, especially in comparison with the corresponding dimensions of any one of the sinuses, the nasal passages must be considered as the long arm of the syphon, which has several short arms, each represented by one of the sinuses. The fact that the combined area of the sinuses is much greater than that of the septum and nasal passages does not enter into consideration at all; for syphonage depends upon the relative pressure in its two arms, and is independent of the number of vessels which may feed the syphon. When the amount of secretion is normal, the effect of syphonage upon each sinus is the same as if the other sinuses did not exist. When, on the other hand, the amount of secretion in one sinus is excessive, the increased volume of fluid may choke the long arm of the syphon, i. e., the nasal passages, and interfere with the flow from the other sinuses. The secretion may even back up into another short arm of the syphon, i. e., into another sinus, and so we note the clinical fact that when one sinus is diseased the others are endangered. The po-

sition and shape of the natural orifices have no effect upon syphonage; for the natural orifice corresponds to the bend of the syphon, and it is quite immaterial whether it happens to be high or low, angular or rounded. Syphonage is independent of the position of the head; for the area of the septum is so great that it is equally effective in every position.

In order to maintain the efficiency of the syphon, it is necessary that the continuity of the fluid from within the sinus, through the natural orifice and into the nasal passage be unbroken. This continuity is favored by the tenacity of the secretion, which is supplied by its mucous constituents. A break in the continuity of the fluid, and a consequent interruption of the syphonage, may undoubtedly occur from various causes, but in the healthy nose such a break would be readily repaired by the activity of the cilia; for the direction of the ciliary movements corresponds exactly to the direction of the syphonage.

It has been supposed that ordinary quiet respiration aids the drainage of the sinuses by exerting a suction action during inspiration, the return of the fluid being prevented by a valve-like action of the semilunar hiatus. This theory would leave out of account entirely the posterior group of sinuses, as very little air passes through the superior meatus during quiet respiration.

It has also been supposed that expiration empties the sinuses in a way similar to the manner of emptying the middle ear by poltitization. That the ordinary movements of quiet respiration have no such effect may be proven by the observation that during quiet respiration a drop of mucus held in any of the capillary spaces of the nose, executes only a very slight to and fro movement. On the other hand, forced expiration, as in sneezing and blowing the nose, and forced inspiration, as in the act called sniffing, act very powerfully to clear the nose of accumulated secretion, and by keeping the long arm of the syphon clear, aid in maintaining proper drainage. In like manner swallowing, gagging and gargling, by causing a reflex contraction of the superior constrictor of the pharynx, help to keep the posterior nares and naso-pharynx clear of secretion.

Atmospheric conditions have a marked effect upon the state of the nasal mucous membrane, and hence exert a secondary influence upon the drainage of the sinuses. The inhalation of cold and dry air causes a swelling of the venous channels, both upon the turbinals, and upon the septum, thus narrowing the respiratory

channels, in order to expand, warm and moisten the inspired air. Under these conditions the outlets of the sinuses may become obstructed, and so we find that cold weather favors the occurrence of acute sinus affections, as well as exacerbations of chronic affections. When the atmosphere is warm and contains the proper amount of moisture, this engorgement of the mucous membrane disappears. This physiological reaction of the turbinals to changes in the surrounding atmosphere is very prompt, and is effected through the agency of the vaso-motor nerves.

By accentuating the favorable conditions of the atmosphere, i. e., by making the inspired air excessively warm and excessively moist, as is the case when the individual is subjected to the inhalation of steam, this physiological action is intensified. Such inhalations may therefore be used therapeutically, for under their use swollen mucous membrane shrinks, the engorged turbinals contract, the capillary spaces are restored to their normal size, and the openings of the accessory sinuses are made patent. Their therapeutic value may be enhanced by adding to the boiling water one of the volatile oils or balsams, such as menthol, eucalyptus, or the compound tincture of benzoin. The vapor of these drugs, probably by stimulating the activity of the ciliary movements, starts the flow of the nasal syphon, and aids materially in draining the sinuses.

Steam inhalations should not be administered from any of the face steaming apparatuses or croup-kettles which are sold for this purpose, as the steam emerges from such an apparatus in a forcible jet, which carries with it a fine spray of hot water, which may scorch the face. They are best administered from a broad open vessel, such as an ordinary basin, set up over an alcohol lamp. The head and entire apparatus are covered with a towel or blanket. After a few minutes the face begins to perspire and a discharge from the nose occurs. Within ten minutes thereafter the full benefit of the inhalation is obtained.

The value of steam inhalations in acute accessory sinus disease has been known for a long time; their persistent and repeated use is also distinctly beneficial in the palliative treatment of those chronic affections which are associated with thickened secretion and crust formation. The writer wishes, however, to call especial attention to the hitherto unknown fact that such inhalations may be used for diagnostic purposes in a certain class of cases.

One of the most common symptoms of sinus disease is headache, which, in the chronic cases takes the form of recurrent neuralgia.

Such headaches are caused by a temporary occlusion of the natural orifice of the affected sinus, and can generally be quickly relieved by the use of steam. *When, therefore, a patient with a recurrent headache of long standing, whether nasal symptoms, such as discharge, etc., be manifest or not, is subjected to the action of a steam inhalation as above described, if the headache be relieved, even though the relief be only partial or temporary, it can be definitely stated that the cause of the headache will be found in one of the accessory sinuses of the nose, or in the neighborhood of their natural orifices.*

The fact that this procedure, which may be called a test for the nasal origin of headache, gives reliable information only when the result is positive, and that failure of the inhalation to relieve the headache does not necessarily exclude accessory sinus disease, does not invalidate the test; nor does the fact that it gives us no information as to which sinus is affected. The fact that the specialist has more accurate and more definite means of diagnosis renders it less useful to him than to the general practitioner, who is unprepared for, or unskilled in the more exact diagnosis of intranasal conditions. For the general practitioner, this test constitutes a simple and harmless procedure, which will enable him to determine the cause of many a persistent headache, which has long resisted his efforts at internal medication. (And the fact that a headache which is caused by accessory sinus disease, can be cured by appropriate surgical treatment, is one of the triumphs of which the modern rhinologist may justly be proud.)

These observations upon the drainage of the sinuses, which are the result of a study of the course of the secretions in patients convalescing from acute sinus disease, in private practice, and in a large variety of clinical material in the service of Dr. Emil Mayer at the Mount Sinai Hospital Dispensary, with whom I am associated, may be summarized as follows:

The drainage of the accessory sinuses is influenced by gravitation to a slight degree in certain positions of the head. It is chiefly effected by ciliary activity, by the power of the secretion of creeping over the surface of the mucous membrane, i. e., adhesion, by capillary attraction at the natural orifices of the sinuses, and by the syphonage exerted by the nasal passages. The combined action of these forces is favored by the respiratory air currents, and by certain atmospheric conditions.

By exaggerating the favorable atmospheric conditions, as in the use of steam inhalations, a valuable therapeutic agent is obtained, by means of which the drainage of the sinuses can be improved in diseased conditions, and which action is so pronounced that its effects may be used for diagnostic purposes in a general way in a certain class of cases.

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Treatment of Innocent Laryngeal Growths by the Galvano-Cautery. A. WYLIE, *Lancet*, Nov. 23, 1907.

The advantages of the galvano-cautery are:

- (1) That very minute growths can be obliterated and that, as far as experience shows, they do not return;
- (2) That small vascular growths can be removed without the risk of haemorrhage.
- (3) That it is far superior to chemical caustics; the dangers of local reaction arising from chromic and lactic acid are always considerable.
- (4) That the technique is more reliable, more precise, and involves less risk of damage to adjacent structures.
- (5) That the whole operation is in view of the surgeon, which is not the case with forceps.
- (6) That by it small sessile growth on the mesial surface of the vocal cords are more thoroughly treated than by the forceps.
- (7) That the stumps of growths already removed by other instruments can be obliterated by the cautery.
- (8) The galvano-cautery cuts off the blood-supply and thus kills the growth, while the forceps often only removes the superficial parts; and
- (9) That it diminishes the liability of local infectivity of papillomata.

THOMSON.