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## The Maxillary Sinus

### PRESIDENT'S ADDRESS

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*History.*—The history of the maxillary sinus, its discovery and early description is of considerable interest. There is reliable evidence in the medical writings of the ancient Egyptians, between 3700 and 1550 B.C., that the structure of the superior maxilla was known to them. In most anatomical publications dealing with the skull, particularly those printed in Great Britain, it is customary to credit Nathaniel Highmore (1613–1685) with the first description of the maxillary sinus, now commonly called the antrum of Highmore (Fig. 1). There is, however, little doubt that this structure was known to Claudius Galen (A.D. 130–200) a Greek physician who dissected and practised in Rome and whose writings provided the basis for anatomical studies for the next thousand years. It was, however, the quite remarkable Italian genius Leonardo da Vinci (1452–1519) who first accurately described and beautifully illustrated that antrum named after Highmore. Leonardo's accomplishments were so varied and so astounding that his proper place in the history of science is apt to be missed. Accounts of his achievements are sufficiently absorbing to provide the material for a complete address. But as this would disturb the proper balance of my subject it is necessary to confine my remarks about Leonardo to some of the more interesting and instructive generalizations.

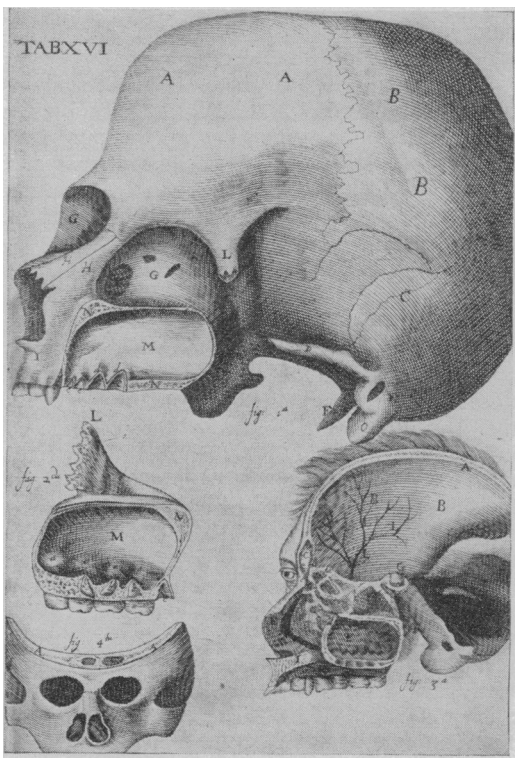


FIG. 1.—Maxillary antrum as illustrated by Highmore 1613–1685.

Leonardo, in general regarded as an artist, was born on April 15, 1452, the natural son of a peasant girl, his father being Ser Piero da Vinci, a well-known young notary. Following this affair Ser Piero was quickly induced to marry into a good Florentine family but a few years later, finding his wife childless and the young Leonardo a beautiful and promising child, he introduced his natural son into the esteemed family as an accepted member. Little is known of Leonardo's early education but it was not extensive and he was taught neither Latin nor Greek. During his youth there appears to have been ample opportunity to pursue those interests for which he had such remarkable aptitude. From the first he exhibited the biological approach, the essence of which is minute scrutiny of the parts of living things and of their workings. From 1466 to 1481 he worked most of the time in Florence with Verrocchio, a self-made all-rounder who approached the artistic problems of the human body from an anatomical point of view. In 1472, at the age of 20, Leonardo was admitted to membership of the Company of Painters in Florence.

In 1483, disguised as a musician, Leonardo took the road to Milan to take up a position as military engineer to Ludovico, then Duke of Milan. For the next four years nothing is recorded of his activities but these must have included many anatomical dissections. The first

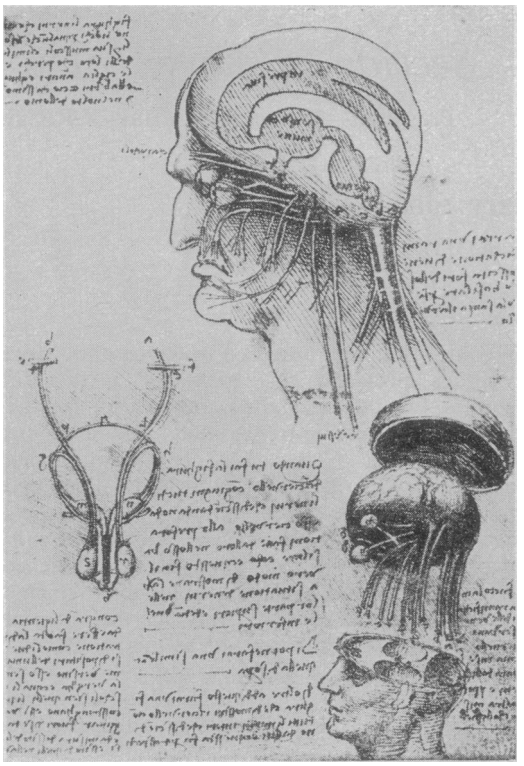

FIG. 2.—Ventricles of the brain demonstrated by the introduction of wax (Leonardo da Vinci).
[From the Schloss Museum, Weimar]

dated reference in his notebooks was "On 2nd April, 1489, the book entitled 'Of the Human Figure'." This book has never been found.

Leonardo's approach to anatomy was one that can with advantage be studied and followed even to-day. During the years spent in Milan he performed a large number of anatomical dissections. Most were done in secret and at night. He decrees that it is better to look at an anatomical demonstration than to see drawings. It is necessary to proceed by stages with sufficient bodies to render knowledge complete. Then repeat twice over in order to discover the differences. Skill in drawing is essential for representation and this combined with a knowledge of perspective. Also one must be versed in the methods of geometrical demonstration and of estimating the forces and strength of muscles. One must not be found wanting in patience.

Leonardo was well aware of the insufficiencies of contemporary methods of anatomical demonstration which were not much more than a post-mortem examination of the main viscera. He put forward his own idea of how dissection should be performed and illustrations made: "I counsel you not to cumber yourself with words unless you are speaking to the blind. Do not busy yourself in making enter by the ears things which have to do with the eyes."

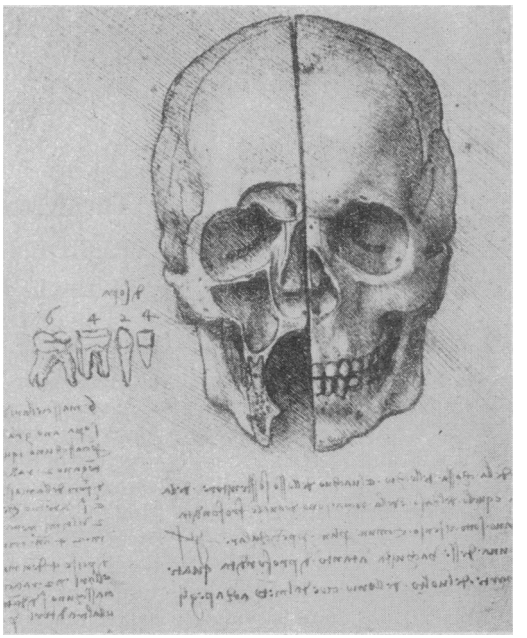

FIG. 3.—Teeth, orbit and nasal sinuses as illustrated by Leonardo da Vinci 1452–1519.
[Reproduced by gracious permission of H.M. The Queen From the Royal Library, Windsor Castle.]

These utterances are worthy of the first illustrator of anatomy and their application in teaching is only being realized in our own century. It must not be imagined that the accuracy of Leonardo's drawings appeared straight away in their full perfection. Part of the fascination of studying his manuscripts lies in following their evolution from the crudities of contemporary conventionalism, to their final naturalist form.

While Leonardo's greatest contribution to anatomical knowledge was by illustration from dissection, with this alone he was not content. As the artistic motive gave way to the scientific he increasingly occupied himself with the interpretation of the function of the organs he drew. In his investigations of the muscles Leonardo was especially concerned with the discovery of their action. He laid down his first general principle, "The function of a muscle is to pull . . . When a muscle contracts its counterpart expands." With this generalization he anticipated the law of reciprocal excitation by the nerves, elaborated less than forty years ago by the late Sir Charles Sherrington, one of my teachers and one to whom I have, for many reasons, to be grateful.

Leonardo extended his anatomical research into the field of comparative anatomy. His motives for so doing were mixed. Dissection of

the horse was a basis for the equestrian statue of Duke Francesco. Dissection of birds was his way of beginning his enquiry into the problem of flight.

His interest in the anatomy of man and animals necessitated the development of methods for making his investigations and many ingenious techniques are described in his manuscripts. An example is the introduction of melted wax into the ventricles of the brain (Fig. 2). Exploring the nose and cheeks Leonardo decides "I wish to take away that part of the bone, the support of the cheek and to show through the opening revealed the breadth and depth of the two cavities which hide behind it. In the cavity above is hidden the eye, the instrument of sight, and in that below is the humour which nourishes the roots of the teeth" (Fig. 3).

Thus we can be left in no doubt to whom the credit for the first accurate description of the antrum of Highmore should go—Leonardo da Vinci.

*Embryology and development.*—In the human fœtus at the end of the fourth week five processes begin to sprout from the base of the primitive cerebral capsule. The central one of these, called the frontonasal process, has symmetrical right and left halves, each in turn having medial and lateral portions which project beneath the forebrain. Immediately on the caudal side of the frontonasal process is the first pair of processes, namely the right and left maxillary, and behind these again the right and left mandibular processes.

During the sixth week the maxillary process on either side grows inwards against the median and lateral portions of the frontonasal process thereby forming the anterior nares. By the end of the seventh week the anterior nares and the nasal septum are recognizable.

The maxillary process springs from the base of the mandibular process about the end of the fourth week and rapidly grows forward below the eye which it thus separates from the mouth. In addition to the easily visible surface growth the maxillary process forms the palatal plate which appears in the sixth week and grows inwards to fuse with its fellow of the opposite side about the tenth week. In this manner the two palatal plates form the whole of the hard palate, except the premaxilla, and in so doing separate the nasal and buccal cavities.

The maxilla at birth consists of a plate of bone in the floor of the orbit which is separated from the mouth by the tooth crypts. Each maxilla rests on the outer aspect of the lateral nasal process and helps to form the outer wall of the nasal cavity. In the third month of fœtal life the mucosa on the lateral wall of the nose starts to bud outwards, penetrates the cartilage of the lateral nasal process and begins to distend the maxillary process. At birth the sinus is only a shallow recess on the outer wall of the middle meatus of the nose and it continues to expand up to adult life. The other nasal sinuses are non-existent at birth. As the maxillary sinus expands backwards the posterior border of the maxilla, which contains the buds of the permanent molar teeth, undergoes a rotation downwards. In this way the teeth, which at first are in the back wall of the antrum, come to lie on the alveolar border (Fig. 4). Thus the normal development of the antrum has a direct bearing on the position and subsequent eruption of the upper teeth and in particular the last molar.

*Anatomy.*—In adult life the cubic capacity of the maxillary sinus is extremely variable ranging from 5 to 25 ml with an average of approximately 15 ml. Although roughly pyramidal in shape its outline in normal maxillæ shows wide variations as does both the thickness and density of its bony walls. Viewed from inside, the walls of the maxillary sinus are seen to be irregular and exhibit projections ranging from small ridges to large crescentic septa. These irregularities occur mostly on the floor and are much more frequent and conspicuous in large sinuses. Their presence results in the formation of pockets which often interfere with drainage. When the antral cavity is very large it extends into all parts of the maxilla and even into the premaxilla. In these instances the walls of the sinus are reduced to a thin layer of compact bone and the roots of many teeth form projections on its floor. Apart from this closer association with the upper teeth it is not my experience that the larger sinus is more prone to infection than the smaller one.

*Physiology.*—The maxillary sinuses, to some extent, participate in all the functions of the nose except that of olfaction. The resonance of the speaking and singing voice is greatly influenced by the state of the nasal cavities and the accessory sinuses and the most important of these latter are the maxillary sinuses. The antra are likewise concerned in the process of preparing the inspired air for reception into the lower respiratory tract which entails cleansing, warming and humidification. These processes, which are basically physical, depend on four important factors: (1) Air currents, (2) capillary blood flow, (3) cilia, (4) mucus.

The separate functions of each of these are well known. The normal physiology of the maxillary sinuses depends upon the integrity and activity of the microscopic cilia together with the healthy overlying mucous blanket. This is a fundamental requirement and one always to be remembered when considering the management

of any abnormality. It must be obvious, for example, that a maxillary antrum whose ostium is partially obstructed, as by a deformity of the nasal septum, is deprived of normal ventilation and in consequence cannot function properly. Similarly any general dyscrasia, such as a blood or liver disease, may alter the biochemical and physical properties of the antral mucus and so change adversely its physiological action.

*Signs, symptoms, causation and diagnosis.*—Time will not permit me to discuss the general clinical aspects, ætiology, symptomatology, radiography and diagnosis of the many abnormalities found in connexion with the maxillary sinus. I shall, however, consider in some detail certain aspects of pathology and treatment which have evolved from personal experience and which may be of assistance to others.

*Pathology.*—One of the first essentials when considering sinus disease is to appreciate the many variable factors that may play a part. It is common knowledge that some individuals are prone to catarrhal infections while others seem to exhibit a natural immunity. The differences between these two groups cannot be defined in terms appertaining either to the causation or the pathology of sinusitis. The vast number of organisms, virus or bacterium, the resistance of the patient and the many factors influencing the nasal physiology are only a few of the variables responsible for the complexity of the complete clinical picture and its accompanying pathology. The generally accepted macroscopic and microscopic alterations described in the textbooks cannot be more than a yardstick with which to measure pathological changes and broadly to classify cases. It is the meticulous consideration of every aspect of each individual case which will determine the success or failure of any particular procedure in the management of patients.

Perhaps the commonest pitfall and certainly a very frequent difficulty is allergy. Twenty-five years ago nasal manifestations of allergy were relatively uncommon whereas to-day it is the exception to find any current number of an ear, nose and throat journal which does not contain one or more articles on this subject. Out-patient clinics in this country and most others in the Western World, are full of allergic patients. This means that allergy has become increasingly important, and is an ætiological and pathological factor in an ever-expanding number of E.N.T. patients. It is, however, my belief that because of its common occurrence there is now a strong tendency to fix the label too readily and thereby permit other and equally important factors to be overlooked. For convenience the diagnosis "allergic rhinitis" is constantly made. I submit that there is no such entity as "allergic rhinitis" or "allergic sinusitis". The correct description is an allergic subject with symptoms of sinusitis or rhinitis.

It is generally accepted that allergic individuals tend to escape the common virus infections of the nose and in consequence are less susceptible to infective sinusitis. Personal experience has led me to doubt the accuracy of the latter part of this generalization. The pathological changes in the nasal and sinus mucous membrane which result from persistent allergic attacks eventually hamper and finally prevent the normal physiological functions. The first to be impeded is ventilation and if this is long continued ciliary action will be interrupted thus facilitating infection. It seems to me that not infrequently this superadded infection is in the first instance due to a virus rather than one of the better known non-filter-passing organisms. Not until we know more about the habits of viruses in the nasal sinuses and are able to isolate and cultivate them from the sinuses can a final answer be given to this hypothesis. At the present time our knowledge is so limited that in certain cases it is not possible to decide whether or not the pathological changes observed are: (1) Entirely due to allergy, (2) the result of infection superimposed on an allergic mucosa, or (3) primarily caused by an infection which produces symptoms indistinguishable from those found in allergic subjects.

It is well known, but occasionally forgotten, that maxillary sinusitis from whatever cause and whether acute or chronic is a mucosal disease. Strictly speaking any spread beyond the lining mucous membrane is a complication. Consequent upon the numerous ætiological factors, the pathological changes which occur, such as œdema, hyperæmia, hyperplasia, fibrosis or necrosis are well recognized. The secretory cysts found in the antrum and the antrochoanal polyp are equally well known. It is also generally accepted that in most patients whose antral lining is subjected to persistent irritation polypoid degeneration will ultimately develop. What is not so generally known is that in many of these cases collections of encysted pus or mucopus occur in the antral mucosa immediately deep to the superficial epithelial layers. Many of these are only microscopic in size but often they are clearly visible and contain up to one or two millilitres of frank pus. Cultures of this pus usually grow one of the variety of cocci commonly found in the nose. Quite often organisms will be visible in stained preparations but fail to grow on culture, a very usual experience with specimens aspirated from any nasal sinus and due to the bacteriostatic properties of the mucous secretions.

By far the most important feature of pathology in its relationship to treatment is whether or not

the changes which have taken place are irreversible spontaneously. That is to say the pathological condition is one which, if unaided surgically, will persist.

*Treatment.*—It has always been my firm conviction that the most important basic principle in treatment is that the method selected for any case should be that which is calculated to afford nature the maximum assistance in bringing about recovery. I count myself fortunate for having been guided by teachers who believed that without assistance from the natural defences complete success in treatment was virtually impossible. Equally it was repeatedly stressed that no surgeon, however brilliant as a diagnostician or operator, could kill organisms with a knife. This is not intended to imply that wonders cannot be achieved and lives saved by judicious therapeutics or skilful surgical intervention. It is, however, meant to stress that when deciding upon a method of treatment the most important consideration after the saving of life should be the restoration or preservation of function.

I now wish to apply these principles in the management of some of the abnormalities occurring in the maxillary sinus. Firstly, it is common knowledge that the antrum is affected to some extent in many cases of acute coryza, and that in nearly all these cases the catarrhal inflammation of the antral mucosa resolves completely without any form of treatment. On certain occasions simple measures designed to assist the natural defences—that is to say the normal physiology already referred to—will relieve unpleasant symptoms and also effect a more rapid resolution.

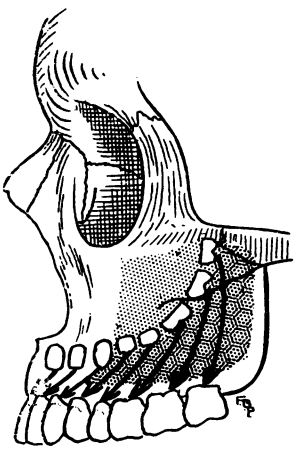

FIG. 4.—Diagrammatic representation of rotation of teeth as the maxilla develops.

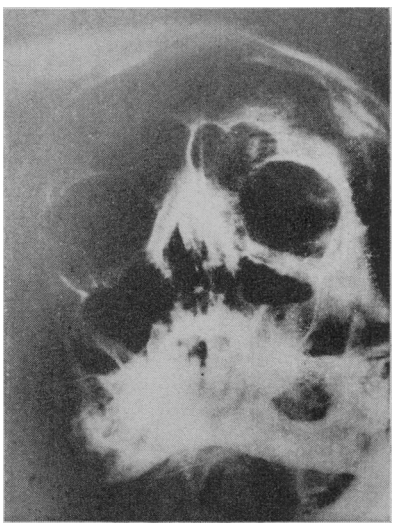

FIG. 5.—Fluid in left antral cavity. Note the concave upper surface characteristic of a fluid level.

The next type of case is that in which the main defence mechanism, namely ciliary action, has ceased to function. This can occur as the result of the toxins produced by the invading organism, but more commonly is due to the bulk of material accumulated in the antral cavity (Fig. 5). In these cases, in addition to the antibiotic therapy necessary to overcome toxæmia, mechanical aid to the cilia is required. This can best be provided by simple lavage, the frequency of which has to be determined for each individual case. In the majority only one wash-out is needed. When dealing with children, or if for any particular reason such as previous attacks or a prolonged history, it is felt that several wash-outs will be necessary, it is my practice to introduce a polythene tube. This procedure enables the antral cavity to be cleared two or three times daily and with a minimum of discomfort to the patient.

Finally, surgical intervention in the management of sinus abnormalities is considered only when non-operative treatment has been unsuccessful. All aspects of the so-called conservative measures cannot be covered, but broadly these include: (1) Removal of any obstruction to normal sinus ventilation, e.g. deformity of the septum or polypi. (2) Reduction of the turbinates where these are causing constant blockage of the airway. This can be accomplished by outfracture and compression, submucosal sclerosing, ionization, cautery or partial submucous resection. (3) Complete allergic investigation and treatment. (4) Dental examination and treatment. (5) Treatment of any systemic disease. (6) Proetz displacement. (7) Antral irrigation.

On more than one occasion antral puncture and lavage has produced surprising and lasting improvement in a case considered to be entirely allergic. One cannot help wondering if such cases may not in reality be due to a virus infection of the antrum. By the process of exclusion the cases requiring surgical intervention are those: (1) Where non-surgical methods have failed. (2) Where cysts are present in the antrum or an antro-choanal polyp has formed. (3) With an antro-oral fistula. (4) With malignant disease.

The subject of malignancy is deliberately excluded from this Address. Taking the remaining three groups in reverse order it need only be said

FIG. 6.—Large simple cyst in the right antrum. Note the characteristic convex upper border.

that an antro-oral fistula is nearly always of dental origin. In all, some 10% of diseased antra are due to dental causes, and as a group they are the most satisfactory to treat. As has already been mentioned, the first essential is elimination of the dental infection. Following this all irreparably damaged antral mucosa should be carefully cleared, any diseased bone excised and adequate drainage into the inferior meatus of the nose provided. The fistula itself is closed at the time of the antral operation, a procedure which requires special consideration for each case, and varies with the site and size of the opening.

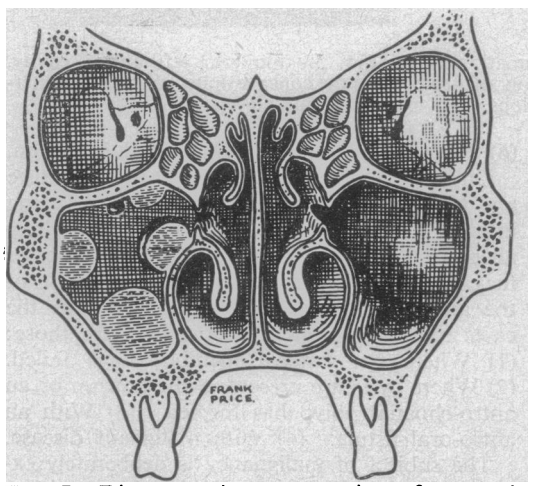


FIG. 7.—Diagrammatic representation of encysted pus and polypi in the right antrum.

Cases of antro-choanal polyp or simple cysts in the antral cavity (Fig. 6) causing symptoms should in my opinion be treated by the Caldwell-Luc operation.

Finally we are left with patients where non-surgical methods, which include the use of polythene tubes, have failed. In these the lining mucosa of the antrum has undergone irreversible pathological changes (Fig. 7). The correct treatment for these cases is the Caldwell-Luc operation. It must be admitted that there are examples where this radical operative procedure should if possible be avoided. This is particularly true in children. It is equally true that in general any operative procedure should be the last resort in treatment. My contention is that where surgery is inevitably the correct method of treatment the operation for chronic maxillary sinusitis is the Caldwell-Luc (Fig. 8). To-day

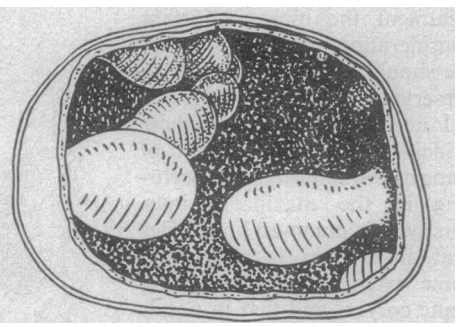

FIG. 8.—Multiple polypi in an antrum as seen through the Caldwell-Luc approach.

there is no place for the intranasal antrostomy. The advantages of an approach which affords easy access to and a clear view of the diseased tissues cannot be denied. It must also be accepted that the contraindications to the Caldwell-Luc approach are a legacy of the pre-antibiotic era. The post-operative symptoms to-day are few, and the complications extremely rare. If due attention is paid to the extent and position of the incision, the minimum amount of bone removed and no unnecessary trauma inflicted, the occurrence of cellulitis, osteitis, neuralgia or anæsthesia is extremely rare. It is admittedly an undesirable operation in childhood, but there are few, if any, cases of maxillary sinusitis in children and young adults which do not respond to non-surgical treatment.

In conclusion I must stress that unless polypi, encysted pus and areas of chronically diseased mucosa are removed from a diseased sinus, a normal and physiologically active lining will not reform. It is also important that the underlying antral periosteum should not be damaged.