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The history of paranasal sinus surgery

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Abstract. Since ancient times, paranasal sinuses' anatomy was well known, but the exhaustive exploration of this district and the treatment options for the related pathologies were limited by the complex conformation of this site. Only the introduction of increasingly advanced technological tools allowed to perform more invasive procedures with consequent better chances of healing. In this regard, the diffusion of the endoscope has represented the keystone for the development of the so-called functional endoscopic sinus surgery which, in the modern era, symbolizes the most important surgical technique for the paranasal sinuses' treatment.

Key words: endoscope, history, paranasal sinuses, surgery

The first anatomical descriptions of paranasal sinuses

From an etymologic point of view, the Latin word "*sinus*" represents the geographic term indicating a gulf, a creek or a bay, while the Greek lemma ἄντρον (ántron) is translated with "cave, cavern" (1).

The medical sources of Ancient Egypt dated between 3700 and 1500 BC, as Edwin Smith's papyrus showed (1500 BC), attest that paranasal sinuses' anatomy was deeply known at the time, as well as the related treatments (2), beginning with mummification's rituals where the brain of the dead was removed through the nostrils, presumably passing through the ethmoidal cells (3).

In the Hippocratic Corpus (460 – 377 BC), we found indications for the therapy of rhinosinusal polyps (4), while Aulus Cornelius Celsus (ca. 14 BC – ca 37 AC) extensively describes paranasal sinuses' anatomy in the 6th and in the 7th books of his treatise "*De medicina*" (5).

In the 16th century, Sansovino defined the paranasal sinuses as "*cloaca cerebri*", i.e. the cavities responsible for the drainage of the "corrupted spirits" from the head (6); furthermore, the famous Leonardo da Vinci (1452 – 1519) recognized the relationship between the maxillary sinus and the teeth, as documented by the drawings of the folio RL 19058 v, K/P 42v (7) (Fig. 1).

The first clear idea of this anatomical district was given by the great anatomist Berengario da Carpi (pseudonym of Jacopo Barigazzi, 1466 – 1530), por-

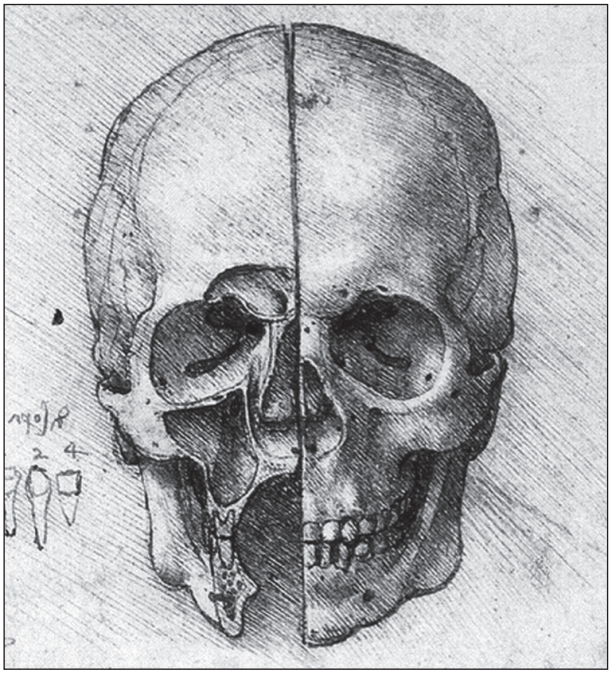

Figure 1. Folio RL 19058 v, K/P 42v, Leonardo da Vinci's sketch of human skull. The left half of the drawing shows a sagittal cross-section of the skull revealing the frontal and the maxillary sinus and demonstrating the relation of these two sinuses with the orbit and the teeth of the upper jaw, respectively.

traying the structure of paranasal sinuses with more precision than his forerunners (8). Another fundamental Renaissance anatomist was Andrea Vesalio (1514 – 1564), who composed in 1543 "*De Humani Corporis Fabrica*", one of the most important medical documents of that times (9). In his work, Vesalio described the maxillary, frontal and sphenoid sinuses, claiming that these spaces were filled with air (9). More accurate studies were then conducted by Giulio Cesare Casseri (1552 – 1616), who gave his name to the maxillary sinus ("*antrum Casserii*") (10).

Even so, the name most closely associated with the maxillary sinus remains that of Nathalien Highmore (1613 – 1685), historically speaking of "Highmore's antrum" after the publication of his "*Corporis humani disquisitio anatomica*" (1651) (11). It is worth mentioning a story about the English anatomist, who tells of a patient who, following the extraction of an upper canine tooth, scared by the continuous flow of pus from the surgical site, tried to introduce a pencil inside the opening: he was astonished to realize that the object penetrated into the gum for about two inches; he repeated the experiment with a feather which, being more flexible, entered even more. Terrified by the possibility of reaching up to the brain, he consulted Highmore, who explained the nature of the maxillary sinus (12).

The gradual improvement of anatomical knowledge over the centuries was fundamental for the evolution of surgical techniques: in 1743 in Montpellier, Louis Lamorier (1696 – 1777) gained access to the maxillary sinus through the oral cavity; this approach was then described and published in 1768 (13). Meanwhile, the dentist Anselme L.B.B. Jourdain (1734 – 1816) treated a maxillary suppurative sinusitis with irrigations of the natural ostium; unfortunately this procedure, performed between 1760 and 1765, didn't meet the expected success (8).

The first officially recognized reference text for the study of nasal cavities and paranasal sinuses was "*Normale und pathologische Anatomie del Nasenhöhle und ihrer pneumatischen Anhänge*" ("Normal and pathologic anatomy of the nose and its accessory pneumatic cavities"), published by Emil Zuckerkandl (1849 – 1910) in 1882 (14); in the treatise, the nose was considered inseparable from the surrounding structures. This work was a source of inspiration for some of the greatest rhinologists of the time, as Markus Hajek (1861 – 1941) who, after few years, published "*Pathologie und Therapie der Entzündlichen Erkrankungen der Nebenhöhlen der Nase*" ("Pathology and therapy of inflammatory diseases of the nose and the nasal passages") (15). Another fundamental treaty was "*Die Lehre von den Naseneiterungen*" ("Book on the nasal suppuration", 1893), in which Ludwig Grünwald (1863 – 1927) explained how acute and chronic inflammations were at the basis of the sinusitis (15).

The origins of paranasal sinus surgery

Already in the 1st century in Pompei, speculum-shaped nasal dilators were used for the visualization of the nasal cavities. For a long time the possibilities of interventional treatment remained limited compared to the diagnostic options, due to the peculiar conformation of this anatomical district, made by slits, recesses, reduced volumes and narrow passages restricted by bony walls. The chance of surgical drainage of the paranasal sinuses, in particular of the maxillary sinus, was considered only from the 17th – 18th century.

At the end of the 19th century, several authors proved to be attracted by the explorative puncture of the maxillary sinus: Johann von Mikulicz-Radecki (1850 – 1905) suggested to reach the antrum through the middle meatus (16); he was the first surgeon who introduced in 1886 the concept of antrostomy for the drainage of this anatomical district, recommending to create an opening of 20 mm in length and 5 – 10 mm closed to the floor of nasal cavity (16). A year later in Berlin, Hermann Krause (1848 – 1921) modified this technique adding a drainage's tube (15). On the contrary, in his "Ü*ber Bedeutung und Behandlung der Naseneinterungen*" ("On the meaning and treatment of suppurative nose", 1886), Karl K.H. Ziem (1850 – 1917) underlined how the pathology of maxillary sinus could be resolved through alveolar surgical access (15). Three years later, Ernst G.F. Küster (1839 – 1930) proposed again the validity of the sublabial approach (through the canine fossa), creating an opening not bigger than a little finger on which he used to place a rubber plug, removable if needed, to facilitate the drainage (15).

In 1893 George Walter Caldwell (1866 – 1918) resumed Lemorier's technique suggesting the possibility of creating a "window" in the lateral wall of the inferior meatus via the canine fossa (17). This approach was performed for the first time in Europe in 1896 in Breslau by Georg Boenninghaus (1860 –1945), who slightly modified the operation placing a mucous flap on the created fenestration (18). An absolutely identical procedure was described and published by Robert H.S. Spicer (19) and by Henry Paul Luc (20), respectively in London in 1894 and in Paris in 1897. What combined Caldwell, Spicer and Luc's intervention was the counter-opening of the maxillary sinus through the inferior meatus and the "*principle of irreversibly damaged mucosa*". Also the strategy of Howard Lothrop (1864 – 1928), published in 1897, comprehended a big fenestration in the inferior meatus (21); a similar surgical technique was described by Raymond Charles Claouè (1864 – ?), who adopted the intranasal antrostomy as treatment for the chronic maxillary infections, publishing his own decade experience in 1912 (22).

All these conservative treatments were set aside by the introduction of innovative radical interventions: in 1900, Gustav Killian (1860 – 1921) described the resection of the uncinate process with the enlargement of the nearby ostium (23), but perhaps Halle was the first author who can claim a large personal experience on intranasal ethmoidectomy and frontal and sphenoid sinusotomies. In his work composed in 1906 (24), the author indicated the fundamental items of this procedure, as the importance of uniting all the cells in a single common cavity, the difficulties encountered with the anterior cells, the indications in case of chronic empyema, the topic use of adrenaline and particular curved tools, the need to avoid "blind" dissection.

In 1909, Dahmer performed an inferior antrostomy cutting the anterior part of the inferior turbinate: such opening resulted so wide that the patient was able to fulfill independently the antral irrigations necessary for the treatment (25). It was well known that antrostomy carried out through the inferior meatus could run into stenosis, so an extensive opening was recommended (14, 21). Conversely, Gerber (26) and Kubo (27) expressed their preference for the antrostomy executed through the middle meatus, using a perforator designed by Onodi in 1902.

Several surgical techniques of accessing the maxillary sinus were described: Halle (24), for instance, stated that inferior meatus' approach was the most correct, while Lavelle and Harrison found a higher rate of healing and a lower frequency of complications in case of chronic sinusitis treated with an antrostomy performed through the middle meatus, pointing out how the physiologic pathway for the drainage of the antral secretions occurred via the maxillary ostium, located precisely in that district (28). McKenzie (29) described the combination of two antrostomies, until Sluder practiced the complete removal of the entire medial wall, preserving only the inferior turbinate (30). On the contrary, in 1910 Rethi recommended the amputation of only the anterior two-thirds of the inferior turbinate (31).

During the early 1920s, Harris Peyton Mosher of Harvard University studied in depth the paranasal sinuses' anatomy thanks to numerous corpses' dissections. His scientific interest was inspirited by the anatomical atlas published in 1920 in Philadelphia by Schaeffer, entitled: "The nose, paranasal sinuses, nasolacrimal passageways and olfactory organ in man" (32). During the congress of the American Academy of Ophtalmology and Otolaringology in 1929, talking about the anatomy of the ethmoidal labyrinth, Mosher said: "If it were placed in any other part of the body it would be an insignificant and harmless collection of bony cells. In the place where nature has put it, it has major relationships so that diseases and surgery of the labyrinth often lead to tragedy. Any surgery in this region should be simple, but it has proven to be one of the easiest ways to kill a patient" (33).

In 1912, Mosher himself used the intranasal ethmoidectomy for the treatment of chronic ethmoiditis (34): the subtotal resection of the middle turbinate provided a better control of the sphenoidal region and posterior ethmoidal space, making the intervention safer. This technique was then adopted by Yankauer (35), Lederer (36), Weille (37), Kidder et al. (38) and Friedman and Katsantonis (39).

While Grüenwald (40) suggested a radical amputation (with the help of particular preparations containing cocaine), Pratt (41), Davison (42), Guggenheim (43), Freedman and Kern (44), Eichel (45) and Dixon (46) emphasized the importance of middle

turbinate's preservation for the prevention of mucous dryness due to the extensive enlargement of nasal cavities' volumes. So the term "ethmoidectomy" indicated an opening restricted to few ethmoidal cells (47), while the "total ethmoidectomy" also included the opening of the sphenoid (39, 45, 47) and maxillary (42, 47, 48) sinuses.

The first approaches to the frontal sinus derived from ophthalmology (15): Alexander Ogston (1844 – 1929) was a Scottish ophthalmologist who managed to reach the frontal sinus through an horizontal incision performed under the eyebrow, drilling the bone and creating a breach sufficiently wide to allow the opening of both frontal sinuses. Afterwards, he modified this strategy executing the incision more medially, at the root of the nose (15). This technique was then described in 1894 by Luc, who used it for the insertion of a drainage tube in the frontal sinus, so the intervention took the name of Ogston-Luc procedure (15). Hermann Kuhnt (1850 – 1925) of Jena described a more aggressive alternative with the radical removal of the anterior wall of the frontal sinus: as a consequence, the skin could grow inside the hole, causing terrible malformations; to avoid these complications, in 1900 Killian performed an incision through the eyebrow preserving the supraorbital region, so he obtained a complete exposition of the frontal sinus and reached the ethmoidal cells after prolonging downward the previous incision (15).

On the other hand, Zuckerkandl focused his studies on the sphenoid sinus, stating that it was possible to reach this district via the nasal cavities, as demonstrated in 1885 by Schaeffer, draining a sphenoidal abscess through this way. These studies will represent the basis for the trans-nasal-sphenoid surgery of the pituitary gland (15).

The modern endoscopic sinus surgery

With his "*Lichtleiter, eine Erfindung zur Anschauung innerer Theile and Krankeiten. Journal der practischen Arzneykunde and Wundarzneykunst*" ("Light conductor, or description of a simple appliance and its use for lighting the internal cavities and the spaces of the living animal's body", 1806), Bozzini was the first author describing an ante litteram light source (49): two years before, he used his physics notions to create a *Lichtleiter* (i.e. light conductor), which allow him to explore the external auditory canal, the nasal cavities and the oropharynx; furthermore, he examined the female bladder, the cervix and the rectum (Fig. 2a, 2b).

Since then, several versions of endoscopes have followed, with different equipment: in some exemplars the endoscope, the mirror and the light source were separated, other types presented a stand-alone light source while the endoscope and the mirror were united, in other models the three elements were integrated in a single tool (50). At first, the endoscopes were specifically used for diagnostic procedures, including the sampling of histological specimens. About that, in 1915 Killian carried out a literature review related to the endoscopic diagnosis (51), followed by another work elaborated by Draf in 1978 (52).

In 1903, Hirschmann published the study of five ethmoids in which the middle turbinate was more or less extensively removed, being able to identify the causal site of chronic ethmoidal empyema with consequent healing after several cycles of endoscopic treatment (53). He was the first to use a real endoscope for the

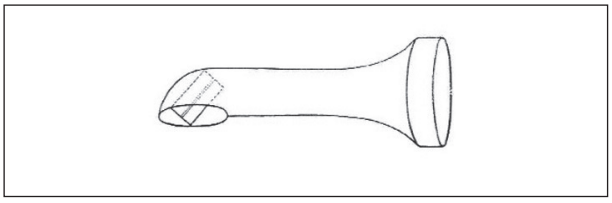

Figure 2a. Endoscopic part of Bozzini's system, with a mirror at the distal opening

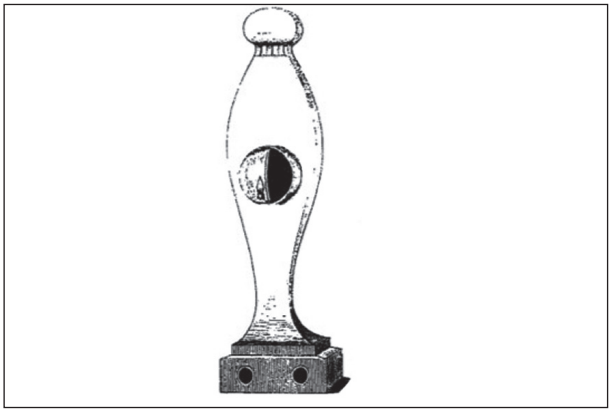

Figure 2b. Luminous component of Bozzini's system

examination of nasal cavities and paranasal sinuses; this appliance was built in Berlin by Reiniger, Gebbert and Schall on the basis of a cystoscope designed by Nitze in 1879 (54) and then used by other authors for minor procedures, as sinuses' irrigations (55), the measurement of the tubaric ostium (56) and the removal of foreign bodies (57) (Fig. 3). So, Hirschmann and Reichert introduced the endoscope in the clinical practice: Reichert published his studies on the subject a year before Hirschmann, but the latter analyzed all the paranasal cavities (15). Other authors then designed different endoscopes during the 1920s, as the "*antroskotrokar*" of von Tovolgyi of Budapest's School (15).

Probably, the first surgeon who performed an endoscopic probing of the maxillary sinus via the inferior meatus was Spielberg in 1922: he called this procedure "antroscopy" (58). Terrier et al. (59) confirmed the validity of the endoscope for histomorphologic studies of mucous lesions establishing a sinusitis' classification. In 1981, Buiter e Straatman (60) developed a surgical endoscopy-assisted method for the fenestration of posterior fontanelle, and the next year Draf (61) used the microscope matched with an angled optics endoscope.

Several specialists preferred appliances other than endoscopy for the exploration of these anatomic regions: in 1958, Heermann (62) described an intranasal operation conducted with a binocular microscope, specifically designed for a more precise cleaning of the middle and posterior ethmoidal cells and sphenoid sinus; this tool was then adopted by his homonym colleague to remove the antral mucosa through the inferior meatus (63). Bagatella and Mazzoni (64) listed the advantages of microscopic vision using lenses with a focal distance of 250 or 300 mm for ethmoidectomies fulfilled for polyposis of posterior and middle ethmoidal cells. Dixon (46) underlined how, thanks to the introduction of the microscope, the operative safety of the ethmoidal-sphenoidectomies was increased, but he admitted also that not all the rinosinusal sites were controllable through this procedure.

The integration between microscopy and endoscopy was another strategy of intervention. In 1975, Reynolds and Brandow (65) reported their technique adopted for the intranasal antrostomy: they created, milling under microscopic guidance, a small opening inside the antral cavity nearby the inferior turbinate, introducing then an endoscope through the newly built fenestration to explore more easily the maxillary sinus, irrigate it and eventually execute biopsies.

The evolution of endoscopy led to the development of increasingly advanced tools, for instance with the introduction of flexible optical fibers and better light sources, as in the case of the telescopes conceived by Storz and Wolf (the designer of the "sinusoscope" used by Maltz in 1925) (66). Successively, these aids were integrated with small clamps (67), coming to dual channel instruments as described by Hellmich ed Herberholdt (68).

The rigid nasal endoscope of Hopkins allowed to explore the nasal cavities even more in detail (69) (Fig. 4): the adoption of rigid angled optics clearly provided significant benefits for the display of the sinuses, but this also presented some drawbacks such as the tendency of the lenses to fade and soak in a bleeding operative field. Another technical progress was represented by the introduction of an endoscope equipped with irrigator-aspirator and angled optics, rotatable and interchangeable (70, 71). On the other hand, flexible endoscopes had a relevant rule in the pre- and post-operative diagnosis, not offering intra-operative advantages (72).

The modern conception of functional endoscopic nose-sinus surgery is certainly attributable to Walter Messerklinger who published his first article on this subject in 1967, stating that the anterior ethmoidal cells were the keystone of the sinusitis (15).

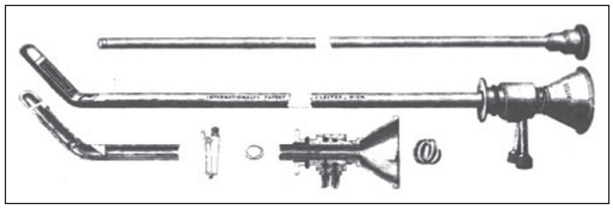

Figure 3: The first cystoscope designed by Nitze (1879)

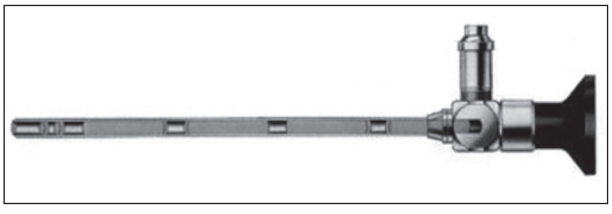

Figure 4: Hopkins' endoscope with cylindrical lenses, by Karl Storz

Starting from the pathophysiology of the mucous membranes of the upper airways, Messerklinger and Stammberger developed a step-by-step intervention of the lateral wall of the nose: "After understanding more of pathophysiology, the first surgical attempts where carried out in the lateral nasal wall… Step by step surgical procedures were developed, starting with resection of the medial infundibular wall, the lateral lamella of a concha bullosa and resection of an oversized and stenotizing ethmoidal bulla. Later we dared to approach the frontal recess and, finally, all accessible paranasal sinuses" (73).

Thanks to Messerklinger and Stammberger's movies projected during a meeting in Dubrovnik in 1984, Kennedy decided to extend his knowledge about intranasal endoscopic surgery, so the next year in Baltimore he organized with Stammberger and Zinreich the first master-class on the "Functional endoscopic sinus surgery". The acronym "FESS" will become commonly in use after the publication of the paper entitled "Functional Endoscopic Sinus Surgery, theory and diagnostic evaluation", composed by Kennedy et al. (74) (the prosecution of the paper will be signed only by Kennedy) (75).

Conclusions

Since ancient times, our knowledge of anatomy, histopathology, conservative and invasive treatments of the paranasal sinuses has progressed exponentially. All physicians of the past who developed their studies on this anatomical district, describing their observations, hypotheses and even their failings and limits, have allowed to reach the modern standards.

Starting from the beginning of the 20th century, the endoscopic sinus surgery has been widely spread, continuing in its evolution based on more and more deeper physiopathologic knowledge and on steadily improved equipments. The affluence of new offers appearing every years demonstrates the constant interest for this branch of surgery in which technical progresses and biological understanding complement each other in the development of the treatments.

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