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Original article

Nasal Mucous Pathway after Functional Endoscopic Sinus Surgery

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Abstract:

Background: Mucociliary Clearance (MCC) is a critical respiratory system defense mechanism. It helps in protecting the airways by clearing inhaled pathogens, allergens, and pollutants. This study aimed to analyze the postoperative nasal mucociliary clearance in patient underwent FESS for chronic sinusitis. **Methods:** This retrospective comparative study was conducted on 117 subject who were divided into four groups: The first group: (control group) included sinuses tested as a control group, the second group: The sinuses tested pre-operatively, the third group: sinuses tested 8 – 18 months post-operatively, the fourth group: sinuses tested 8-18 months after the operation with residual or recurrent infection. All studied cases were subjected to E.N.T examination, diagnostic endoscopy, C.T. scan on P.N.S **Results:** The second group showed edematous mucosa, polyp or granulation tissue and when the contrast placed either delayed movement or stasis for long time, average velocity .47 mm/min, average time 21 minutes. The third group: The MCC had an average velocity of 1.1, average time 9 minutes. The fourth group showed slow of the mucociliary clearance, mucociliary stasis is the abnormal pathway, swirling and stasis of the nasal mucous, are the most observed finding among patients with recurrent and persistent sinusitis, with average velocity .4 mm/minutes, average time 25 minutes. **Conclusion:** With better sinus drainage and ventilation after functional endoscopic sinus surgery (FESS), the damaged ciliated epithelium of the sinus mucosa in chronic sinusitis has the potential to regenerate and go back to normal.

Keywords: Nasal Mucous; Pathway; Endoscopic; Sinus Surgery.

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Introduction

Mucociliary clearance (MCC) is a critical respiratory system defense mechanism. It helps protect the airways by clearing inhaled pathogens, allergens, and pollutants. The primary components of MCC are respiratory cilia and mucus. Effective MCC requires appropriate mucus production, synchronized ciliary beating, and a proper periciliary fluid layer. When foreign material (e.g., pathogens, debris) enters the nasal cavity, it gets trapped in the mucus. Cilia then propels the mucus in the direction of oropharynx to be cleared by expectoration, coughing, or ingestion [(1)].

There is a mucus layer that normally covers the nasal mucosal lining that can reach 70 µm in thickness. Mucus serves several essential functions such as preventing loss of water through diffusion. Expels foreign particles that are breathed in bacteria, viruses, inflammatory cells, allergens, and pollutants. To prevent the spread of infection in the airway, secretory cells secrete mucus and antimicrobial surfactants when infected. Every day, the nose produces around 100-200 mL of mucus. [(2)]

The direction of nasal mucus flow is unidirectional and typically moves from the front of the nasal cavity toward the oropharynx (Figure 1). Cilia plays a crucial role in this process, continuously beating in a coordinated manner to transport the mucus. After inhalation of foreign material, the mucus traps it, and cilia moves the mucus posteriorly, eventually clearing it from the nasal passages [(3)].

Restoring of the sinus mucosa and nasal physiological function, particularly mucociliary clearance is a significant mechanism, combined with the other nasal defenses, such as its aerodynamic shape and local immune system. When sinusitis patients have nasal and sinus treatments, it's crucial to note the differences in the mucociliary apparatus between the patients who had a successful outcome and those who didn't. Fortunately, cilia speed in the nose and bronchial tree may be accurately measured by observing the nasal cilia. The best part is that it's not uncommon for strategies to increase upper respiratory cilia to also help lower respiratory cilia [(4)].

Using graphite particles as an indicator to measure mucus flow time, in the nose involves observing how these particles are transported by the mucociliary clearance mechanism. Here’s how this method typically works; introduction of graphite particles: A small amount of fine graphite particles is introduced into the nasal cavity. These particles are chosen because they are visible and inert, meaning they won’t react with the mucus or nasal tissues, tracking movement: The movement of the graphite particles is tracked over time. can be done using visual methods, such as endoscopic examination or video recording. By noting the time, it takes for the particles to move from their initial placement to a specific location in the nasal cavity or to be expelled; researchers can determine the mucus flow rate, measurement and calculation: The traveled distance by the particles and the taken time are measured. From these measurements, the mucociliary clearance rate can be calculated. This rate is typically expressed in millimeters per minute (mm/min), the mucociliary clearance system. Abnormalities in the flow rate might indicate underlying health issues, such as chronic sinusitis, allergies, or other conditions affecting mucociliary function [(2)].

Mucociliary clearance is a vital respiratory system defense mechanism, where mucus and entrapped particles are transported out of the lungs. The normal velocity for this process, as mentioned, is typically between 6-12 mm per minute in a healthy individual. This rate can be influenced by several factors including hydration status, air quality, and the presence of any respiratory conditions. Maintaining a normal mucociliary clearance rate is crucial for respiratory health, as it helps to keep the airways clear of pathogens and debris [5]

This study purpose was to analyze the post- operative nasal function in a patients group that had failed appropriate medical treatment and required surgical intervention for chronic sinus infection by F.E.S.S. These items were in focus: to know the pattern of mucociliary clearance in the ethmoid labyrinth following functional endoscopic ethmoidectomy and to know the pattern of mucociliary clearance around the maxillary antrostomy created by enlarging the natural ostium.

Patients and methods

This retrospective comparitive study on 117 patient attending the E.N.T department of Benha University hospital. This was during the period from April 2019 to September 2022.

The patients' written informed consent was acquired. A secret code and an explanation of the study's goal were given to each patient. After receiving approval from Benha University's Research Ethics Committee (no. RC 2-7-2024), the Faculty of Medicine conducted the study. **Inclusion criteria were** all patients were diagnosed clinically, endoscopic ally and radiologically as having chronic sinus infection that failed to respond to appropriate medical treatment thus requested surgical intervention in the form of F.E.S.S. the regimen was adjusted doses of antibiotics prescribed according to results of culture and sensitivity of nasal discharge in the form of a minimum of one to three-week round of quinolones or similar antibiotics as (e.g., amoxicillin clavulanic acid, second generation cephalosporin, and macrolides.). Together with nasal corticosteroids and regular saline irrigation twice daily for at least one month.

Exclusion criteria were patient with chronic diseases such as diabetes, chronic renal failure and nasal granulomata. Nasal blockage, postnasal discharge, sinus headache, face discomfort, throat clearing, cough, halitosis, abnormal C.T. scan, and symptomatic failure of prior treatment led to the decision to operate.

Grouping: The first group: (control group) included sinuses tested as a control group and these sinuses were clinically and endoscopically free and imaging free of the non-operated side, there were 15 sinuses in 15 subjects and the procedure was unilateral in all cases. The second group: The sinuses tested pre-operatively in 52 patients who were manifesting of chronic sinusitis after several trials of treatment courses. The third group: The sinuses tested at 6month (3a) – and at 12 months(3b) post-operatively and those sinuses were clinically and endoscopically free, in 32 patients. The fourth group: The sinuses tested 6month (4a) – and at 12 months (4b) post-operatively with residual or recurrent infection, in 20 patients.

All studied cases were subjected to the following: Full history, Full general examination and blood investigation, E.N.T examination, Diagnostic endoscopy, C.T. scan on P.N.S. Based on the patients' medical history, the findings of a nasal endoscopic examination, and C.T. scanning, chronic sinusitis was identified in the form of maxillary effusion, mucosal thickening, or opacity of the ethmoidal cells in the patient's coronal CT scan, which indicated that the maxillary sinus cavity was implicated. (Figure 2, 7) [12].

The F.E.S.S was performed under general anesthesia with hypotensive technique; anterior ethmoidectomy and middle metal antrostomy, in some patients' posterior ethmoidectomy too were performed in patients.

Test condition and procedure: All patients and control group had done primarily the graphite test. At cut point of 6 months and 12 month months post operatively these patients were reexamined. One or two sprays of 2% lidocaine HCI and 0.25% oxymetazoline HCI will be used to anesthetize and decongest the nose. Previous studies have indicated that these agents, at this dosage and duration, are

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unlikely to affect mucociliary clearance. The patients remained in the testing room for 5 to 10 minutes, during which time the anesthetic and topical decongestant became effective. To avoid significant potential changes in the nasal physiology, no packing was used, and it was the intent of the investigator to anesthetize and decongest only the anterior nose. Sterilized, pure, natural graphite powder was chosen as the tracer medium.

Measuring mucociliary clearance velocity with graphite particles: To measure mucus velocity in the nose using graphite particles (figure 3), follow these detailed steps to ensure accuracy and safety, the graphite particles were put in different places at the nose then the distance from its application to the posterior nasal choana is measured for both distance and time of motion.

Materials needed: Graphite particles (13)**:** Finely ground and sterilized, Applicator: A small, soft brush or a sterile cotton swab, Stopwatch or Timer: For accurate measurement of time, Ruler Figure 4(13): To measure the distance traveled by the particles, Nasal speculum: Optional, for better visualization of the nasal cavity, 2.5mm 30 degrees endoscope, for better visualization of the graphite particles, Recording Sheet: To document time and distance measurements.

Calculation of mucus velocity: where d is the distance travelled by the particles and t is the time elapsed, the formula v=d/t is used to compute mucus velocity (v). Measure the distance (d) between the starting point and the endpoint using a ruler on the endoscopic picture. Use the recorded time (t) to calculate the velocity. (Song E, Iwasaki A.2020)

Data interpretation: Decreased mucus velocity: Lower velocities may indicate impaired mucociliary function, possibly due to conditions like chronic sinusitis, allergic rhinitis, or respiratory infections. Increased mucus velocity: Higher velocities are less common and might indicate hyperactive mucociliary clearance, as in acute allergic rhinitis. Figure 5 (14).

Safety and hygiene considerations: Ensure the graphite particles are non-toxic and finely ground to prevent irritation, maintain sterility throughout the procedure to prevent infections, conduct the test in a controlled environment to avoid any respiratory distress. Throughout the study, every attempt was made to avoid touching the nasal mucous or the mucosa itself with the endoscope or application, multiple sites were simultaneously studied in most subjects, often bilaterally (8).

Once the graphite was placed, repeated nasal endoscopic examination and concomitant video recordings were done to observe the movement of the tracer. The transport of the graphite particles was visualized using a 0 & 30-degree, 4 mm nasal endoscopy with a 300 W light source.

Considerations: Particle Size: Ensure that the graphite particles are of a consistent size for accurate measurement. Environmental Factors: Conduct the test in a controlled environment to avoid external factors affecting mucus flow, such as humidity and temperature. Health Status: Consider the health status of the subject, as infections, medications, or allergies can influence mucus flow (8)

Statistical analysis:

Statistical analysis was done by SPSS v28 (IBM©, Armonk, NY, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were analyzed by ANOVA (F) test with post hoc test (Tukey. Qualitative variables were presented as frequency and percentage (%) and were analyzed utilizing the Chi-square test. A two tailed P value < 0.05 was considered statistically significant. Spearman correlation was done to estimate the degree of correlation between two quantitative variables. The overall diagnostic performance of each test was assessed by ROC curve analysis. The area under the curve (AUC) evaluates the overall test performance.

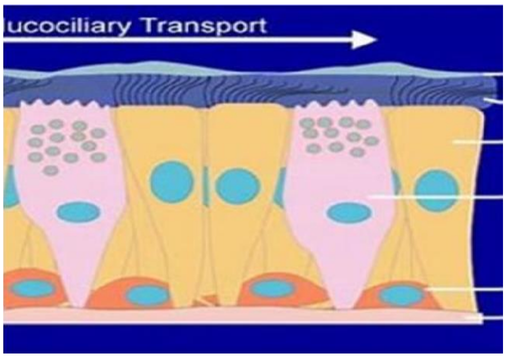

Figure 1: Mucociliary transport. (1)

Figure 2: Coronal CT scan maxillary and ethmoidal sinuses showing picture of chronic sinusitis

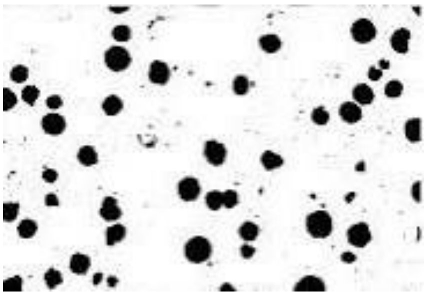

Figure 3: graphite particles

Figure 4: ruler

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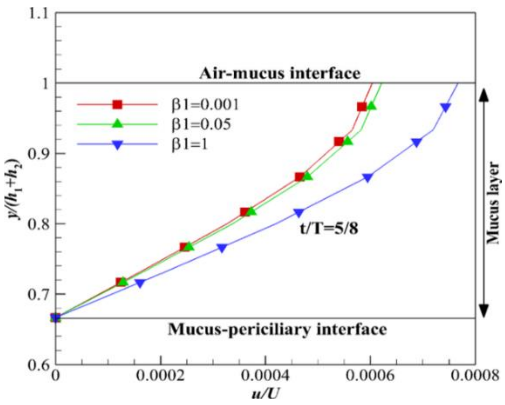

Figure 5: Mucus clearance velocity

Results

The range of patient's ages was 23 to 50 years with an average of (37.5 years). There were 22 females and 30 males. - The procedure was bilateral in 36 patients and unilateral in 16 patients. In the first group (control group), the endoscopic pattern of mucociliary clearance (M. C.C) was regular, visible and the contrast directed from anterior to posterior toward the nasopharynx. Figure 6

The second group (the sinuses were tested preoperatively) endoscopically where there edematous mucosa, polyps, or granulation tissues, there was either delay or stasis of the contrast through the whole test time. Figure 7

The third group (Included the sinuses tested postoperative at 6months 3a and at 12 months 3b. endoscopic examination of this patient was clinically free, the mucociliary clearance following ethmoidectomy, take different pattern even in the same patient when the same operation was done bilaterally. There was often a different pattern of transport on the right and left sides. In mucociliary activity following anterior ethmoidectomy, the tracer placed on mucosal surface was transported either laterally along the lateral wall or superior surface of the inferior turbinate or medially along the under surface of the middle turbinate or posteriorly to anteriorly in some cases of post ethmoidectomies. (Figure 8 Table 1,2)

In the fourth group (sinuses assessed endoscopically postoperative at 6months 4a and at 12 months 4b with residual or recurrent infection). The Mucociliary pattern takes a different pattern, where recurrent ethmoidal infection had occurred. stasis of contrast placed on the anterior ethmoidal mucosa. The contrast moved rapidly entering the sinus, these patients had recurrent ethmoidal infection after the operation. Figure 9 Table 3,4

Table 1: The average velocity and time of Mucociliary Clearance at 6 months postoperativly

	First group	No of cases	Second group	No of cases	Third group(3a)	No of cases	Fourth group(4a)	No of cases
Within normal limits	86.7%	15	0%		84.2%	32	0%	
Slow	13.3%	2	23.07%	12	10.5%	4	6%	3
Stasis	0%		76.9%	40	0%		50%	10
Abnormal pathway	0%		0%		5.2%	2	44.%	7
Average speed mm/min	1.4mm/min		47mm/min		1.1 mm/min		4 mm/min	
Average time in minutes	7 minutes		21 minutes		9 minutes		25 minutes	

Table 2: The average velocity and time of Mucociliary Clearance at 12 months postoperativly

	First group	No of cases	Second group	No of cases	Third group(3b)	No of cases	Fourth group(4b)	No of cases
Within normal limits	89.7%	15	0%		74.2%	32	0%	
Slow	11.3%	2	27.07%	12	20.5%	4	12%	3
Stasis	0%		72.9%	40	0%		60%	10
Abnormal pathway	0%		0%		6.2%	2	28.%	7
Average speed mm/min	1.5 mm/min		.42 mm/min		0.9 mm/min		0.3 mm/min	
Average time in minutes	6 minutes		20 minutes		11 minutes		25 minutes	

Table 3: The pattern and direction of M.C.C. at 6 months postoperative

Pattern of pathway	First group	No of cases	Second group	No of cases	Third group(3a)	No of cases	Fourth group(4a)	No of cases
Towards the nasopharynx from anterior to posterior	86.7%	15		52	59.3%	19		
Towards the maxillary ostium (Delayed)	13.3%	2		27	12.5%	4	30%	6
Exit from the maxillary ostium(stasis)				16	9.3 %	3	35%	7
Recycling				9			25%	5
From posterior to anterior to the nasopharynx Only after posterior ethmoidectomy					18,7%	6	10%	2

Table 4: The pattern and direction of M.C.C. 12 months postoperative

Pattern of pathway	First group	No of cases	Second group	No of cases	Third group(3b)	No of cases	Fourth group(4b)	No of cases
Towards the nasopharynx from anterior to posterior	90.7%	15		52	63%	19		
Towards the maxillary ostium (Delayed)	9.3%	2		27	10%	4	25%	6
Exit from the maxillary ostium(stasis)				16	12 %	3	45%	7
Recycling				9			15%	5
From posterior to anterior to the nasopharynx Only after posterior ethmoidectomy					15%	6	15%	2

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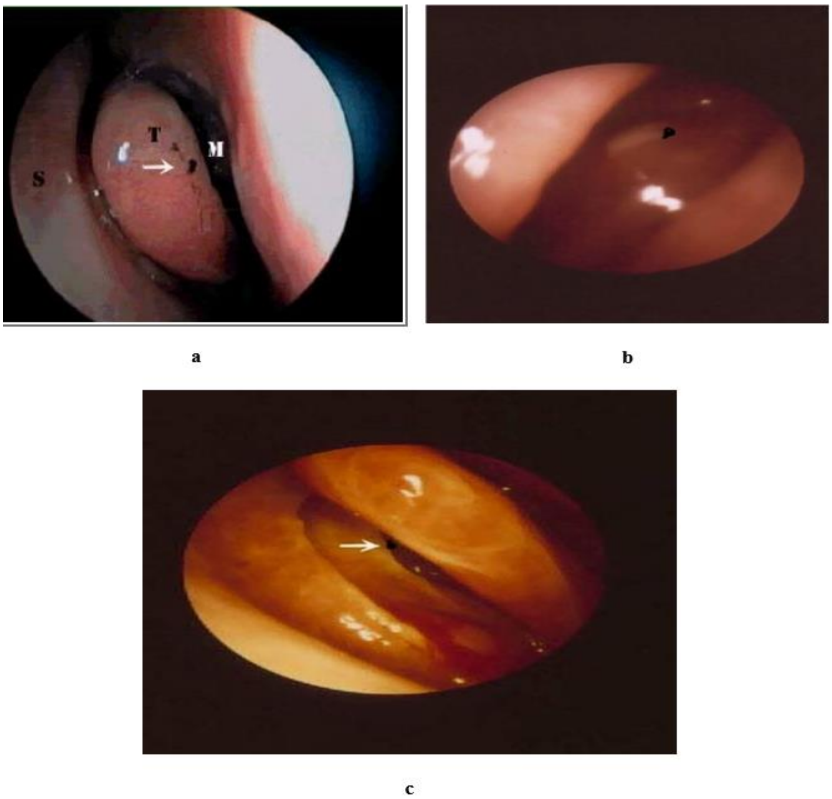

Figure 6:a) examination clinically and endoscopically was normal, the contrast on the middle turbinate moved downward and laterally toward the nasopharynx, b) examination clinically and endoscopically was normal the contrast moved rapidly from the middle meatus (M) laterally and downward to the under surface of the middle turbinate toward the inferior turbinate and finally toward the nasopharynx, C) examination was normal, the contrast seen anteriorly to the antral opening with rapid and visible movement downward along the anterior border of the maxillary ostium, the contrast moved posteriorly and downward toward the nasopharynx.

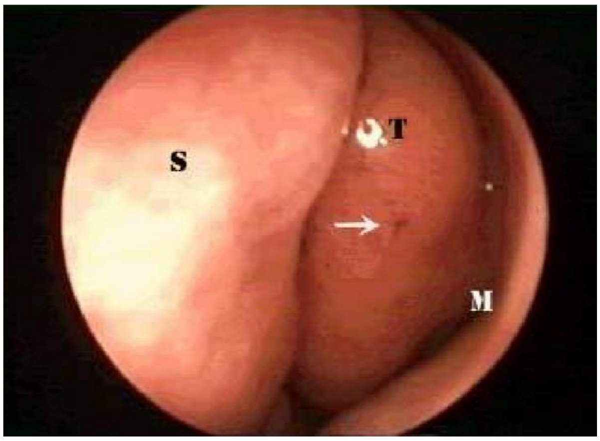

Figure 7: endoscopic examination there was edematous mucosa and mucus filled the maxillary ostium and the ethmoidal region, the contrast placed on this mucus was delayed or stopped for long time, till the end of the test, the contrast impeded within the mucus and dispersed within it but not cleared until the end of the test.

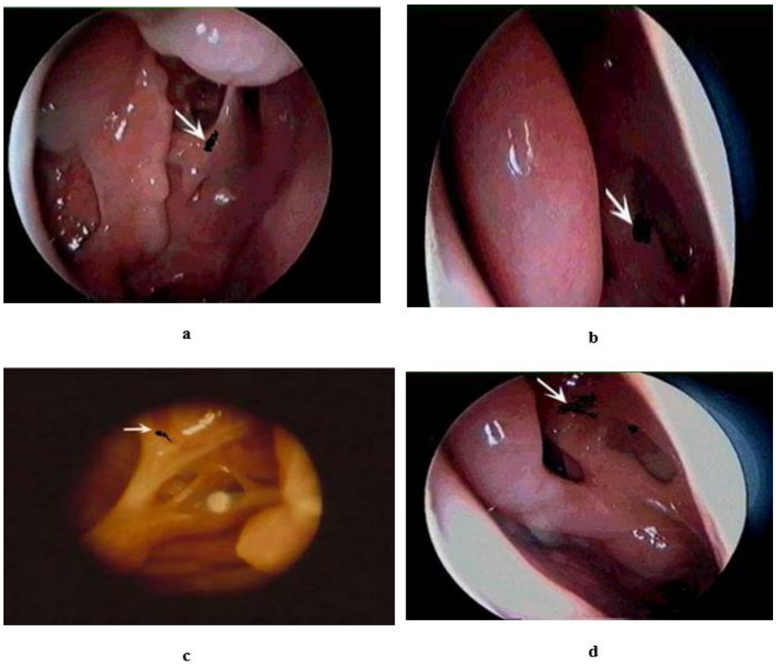

Figure 8: a) by endoscopic examination the contrast was put were it move laterally and downward to maxillary opening after the contrast disappearing from the view for some time (inside maxillary sinus), then the contrast is transported posteriorly and inferiorly from the maxillary antrostomy into the inferior turbinate for clearance into nasopharynx, b) By endoscopic examination the contrast passed on the posterior part of the antrostomy, the contrast moved downward and laterally toward the inferior turbinate, c) Another quite common pattern was the anterior transport of contrast placed into posterior ethmoidal cells. Often, the contrast moved anterior to and above the maxillary antrostomy, and then down into the lateral wall or inferior turbinate for subsequent posterior clearance. This anterograde transport was observed to be a very prominent feature in the patients who had undergoing total ethmoidectomy, d) by endoscopic examination, the contrast passed on the antrostomy, the contrast moved downward and laterally toward the inferior turbinate, there was a delay in their motility before finally going toward the nasopharynx

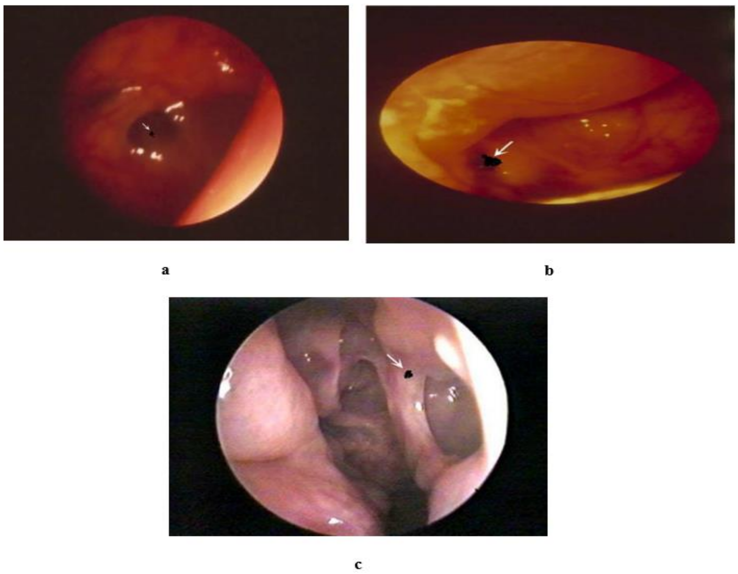

Figure 9: a) In one instance, contrast was seen entering the maxillary antrum through the antrostomy, where it remained during the study, generally impeded within a mucous droplet, b) with accumulation of droplet formation of mucus above the superior aspect of the maxillary antrostomy. The contrast swirling (moving in twisted or spiral way) within the mucous, c) However, there was truly obvious

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change in the clearance of the contrast around the antrostomies, regardless of size, there were “dead” areas where transport stopped, on a point at which stasis occurred, although the routine endoscopic examination appeared normal. One area was superior to the antrostomy, and the

Discussion

The integrity and activity of the mucociliary system are essential for the proper functioning of the sinuses [6].

The kind and degree of the operation, as well as the optimal timing for surgical intervention, may be decided by a more comprehensive understanding of the pathophysiology of the ailment and the available surgical options. There were several writers that investigated the evaluation of surgical outcomes, whether subjectively or objectively [7].

After functional endoscopic sinus surgery (FESS), the direction of nasal mucus flow can be influenced by the changes made during the surgery. FESS aims to restore normal sinuses drainage and ventilation by removing obstructions and enlarging the natural sinus openings. Improved drainage pathways, the surgery is designed to open the nasal and the sinus drainage pathways, which helps to facilitate the natural movement of mucus from the sinuses into the nasal cavity and then toward the throat to be swallowed or expelled. Reduction in obstruction, by removing polyps, diseased tissue, or other blockages, the surgery helps ensure that mucus is not trapped in the sinuses, reducing the risk of infections and improving overall sinus health.

In this study the objective evaluation using endoscopic video recording of the mucociliary clearance, using graphite powder as a marker for postoperative assessment in the four groups. These groups of sinuses were group (1): control group of normal subjects, group (2) :chronic sinusitis pre-operative group, group(3) postoperative group with no complaint which was sub divided into group3a at 6 months assessment and 3b group with assessment at 12 months and group (4) post-operative group with residual or recurrent infection which was sub divided into group 4a at 6 months assessment and 4b group with assessment at 12 months. The study purpose was to assess the mucociliary clearance velocity, time, and route pattern in the nose in order to evaluate the surgical technique objectively.

The velocity of mucus flow in the nasal passages after FESS can be influenced by several factors, ciliary function; the cilia (tiny hair-like structures) in the nasal mucosa are responsible for moving mucus. The ciliary function might improve after FESS, leading to more efficient mucus clearance. Normal mucus velocity: in healthy individuals, normal nasal mucus velocity ranges from 3 to 25 mm/min (0.3 to 2.5 cm/min). [8]

Decreased mucus velocity: Lower velocities may indicate impaired mucociliary function, possibly due to conditions like chronic sinusitis, chronic allergic rhinitis, or respiratory infections. Increased mucous velocity occurs in acute nasal allergy and some other rare conditions [8].

The first group (control group) showed normal endoscopic finding and normal, rapid and visible mucociliary, average velocity 1.4 cm/min, average time 7 minutes. The second group (preoperative group) showed edematous mucosa, polyp or granulation tissue (as shown by endoscopic inspection) and when the contrast placed either delayed movement or stasis for long time, average velocity 0.47 cm/min, average time 21 minutes The third group (post-operative group and the sinus was clinically free). The mucociliary clearance had an average velocity of 1.1cm/minute in 3a group and 1.2cm/min in 3b group , with average time 9 minutes in both. The fourth group (post – operative with recurrent or residual disease) showed slow of the mucociliary clearance, mucociliary stasis is the abnormal pathway, swirling and stasis of the nasal mucous, are the most observed finding among patients with recurrent and persistent sinusitis, with average velocity 0.4 cm/minutes in group 4a and 0.3cm/minute in group 4b with average time 25 minutes in both as shown in table1,2,3,4

Children have an average nasal mucociliary clearance time of 8.2 minutes, while adults have an average of 9.5 minutes. This is the case for healthy persons. For children, the mean nasal mucociliary clearance rate was 11.1 mm/min, whereas for adults, it was 12.7 mm/min [5].

Nasal Airflow, post-surgery, improved nasal airflow can enhance mucus movement. The velocity of mucus can be higher immediately after surgery but may vary during the healing process of edema and Inflammation, in the immediate postoperative period, inflammation and swelling might temporarily affect mucus flow. As healing progresses, the velocity should stabilize.

Shone and colleagues, mentioned that) MCC did not exhibit any substantial improvement or worsening in the entire patient population or any of the three subgroups, as of three weeks following the procedure. Post-operative stasis of secretions, crusting, secondary infection, delayed healing, and patient pain may be due to persistent mucociliary dysfunction [9].

Also Aanaes and other members of the researcher's team, has declared that by removing polyps from the nasal cavity or by correcting the natural drainage channels from the sinuses, ESS can enhance MCC. ESS has also been discovered to greatly increase the number of cilia and can decrease the amount of goblet cells in the mucosa, which may enable MCC. Furthermore, ESS can enable nasal irrigation and subsequent topical treatment of the nose and sinuses with steroids and antibiotics [10].

The mean ratio of clearance times from the patent nostril to the blocked nostril was 2.5: 1 (SEM +/- 0.5), and the ratios were statistically significant (two-tailed t-test; P = 0.039). It is evident that the mucociliary clearance patterns of the nose are significantly influenced by the nasal cycle [11].

Conclusion

This research demonstrates that the ciliated epithelium of the sinus mucosa in chronic sinusitis is capable of regeneration and may revert to its original state with the enhancement of sinus ventilation and drainage following FESS, the direction of nasal mucus flow should be more efficient and towards the natural drainage pathways, reducing the likelihood of mucus stasis and sinus infections., except in sever pathology and after aggressive surgery. One of the causes of failure to treat the chronic sinusitis patients after FESS is the abnormal pathway, swirling and stasis of the nasal mucous.

Conflict of interest

None of the contributor's declared any conflict of interest

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