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The effect of a new ostium and sinus mucosal flaps on mucociliary flow of the maxillary sinus*†

Metin Önerci[1], Tülin Aras[2]

[1] Department of Otorhinolaryngology, Hacettepe University, Ankara, Turkey
[2] Department of Nuclear Medicine, Hacettepe University, Ankara, Turkey

SUMMARY

To evaluate the effect of a new ostium upon the mucociliary flow of the maxillary sinus, a window in the lateral wall of the sinuses was made and left open in New Zealand rabbits. The contralateral sinuses were used as controls. No change in mucociliary flow was observed, except for a shorter clearance time in sinuses with a new ostium. In the second group of rabbits the maxillary sinus mucosa was elevated at the floor, lateral and medial walls and rotated about 80-90°. The other side acted as control, the mucosa was elevated and put in place again. The mucociliary flow of sinuses with rotation decreased significantly.

Key words: maxillary sinus, ostium, mucociliary clearance

INTRODUCTION

The presence of cilia on epithelia of the respiratory tract was reported more than 150 years ago, and it has been found of interest since then. Advances in many areas of science have contributed to increased understanding of ciliary movement and mucociliary clearance mechanisms in the respiratory tract. Physiologically, transport is directed towards and through the natural ostium. Sinus mucociliary transport mechanism is dependent from a complex interaction of cilia motility, characteristics of mucous, glandular secretion and absorption and the sino-nasal environment as described by Sleigh et al. (1988).

The aims of this study have been: 1) to evaluate if a newly created ostium would have any effect on mucociliary flow, i.e. on the direction of the flow and, also, on the mucus flow rate; 2) to investigate whether ciliary beating is direction-fixed or not. In other words, if the direction of the cilia is changed by rotation of mucosal flaps in the maxillary sinus, will they continue to beat towards the natural ostium or not.

MATERIAL AND METHODS

New Zealand rabbits were used in all experiments. Twenty-two maxillary sinuses were operated in both experiments. Eleven of the sinuses served as controls. All of the animals were healthy at the beginning of the operations and remained so throughout the experiments, except for two which died during the experiments and were discarded.

All operations were performed under general anaesthesia with xylazine and ketamine. Ketamine and xylazine were administered intramuscularly combined with a local injection of xylocaine over the bridge of the nose. All operations were carried out with aseptic precautions having been taken, such as used in clinical surgery.

The fur was shaved off the head and a mid-line incision was made down the bridge of the nose through the skin and the periosteum (Figure 1). The periosteum was stripped off over the sinus and the lateral wall of the sinus was opened. The bone of the lateral wall was removed only widely enough to make a hole, through which the intrasinus manipulation could be carried out enabling elevation of mucosal flaps.

In four rabbits, at the lateral wall a new ostium was made on one side and left open (Figure 2). Care was taken to preserve the mucosa and epithelium to cover the bony margin of the operation window. The contralateral sinuses were used as controls and after making a hole the incision was sutured and nothing else done.

In five sinuses, the mucosa was elevated with extreme care not to damage it and the elevated mucosa at the floor, lateral and medial wall of the sinuses was rotated about 80–90° after excision of some mucosa cephalic to the flap (Figure 3). On the contralateral site the mucosa was elevated and some mucosa cephalic to this flap was excised, but the flap was not rotated and left in place.

The next day the rabbits were taken for radionuclide study. The dynamic sinus scan was obtained immediately after bolus injection of 150 μCi ^{99m}Tc-nanocolloid (Solco Nuclear, Basel, Switzerland) into the maxillary sinuses of the rabbits through newly-made operative windows. Images were obtained with the large field of a gamma camera (Toshiba GCA601 E) equipped

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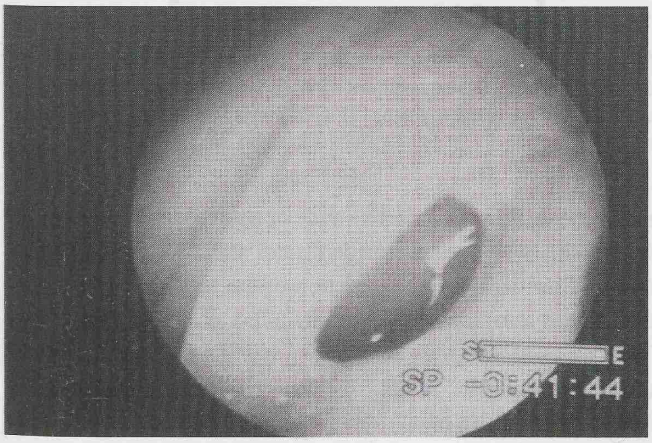
Figure 1. Mid-line incision through the skin and periosteum.



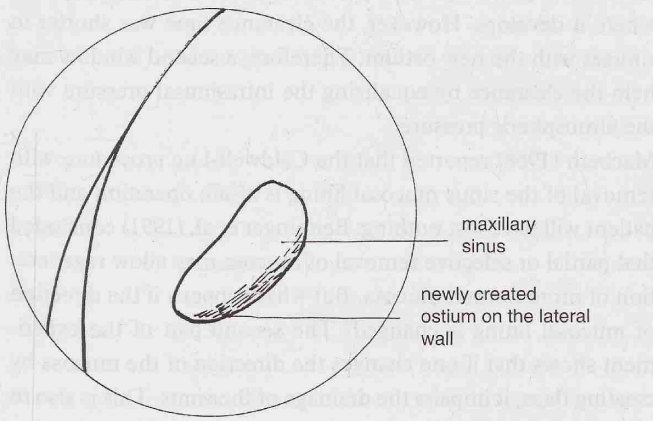
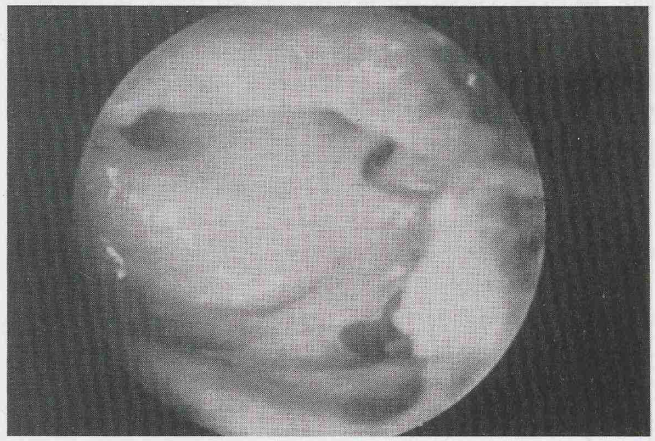


Figure 2. After elevation of the periosteum, the bone of the lateral wall of the maxillary sinus is removed by drilling and Kerrison's forceps, and a new ostium is made in the lateral wall of the maxillary sinus.

with a pinhole collimator and linked to a computer. A dynamic series of analog and digital images (15 1-min images, 64×64 matrix) were acquired in the anterior view. Additionally, the anterior, right and left lateral views were obtained after 15 and 30 min (256×256 matrix).

We computed the time-activity curves of the sinus scan. From these fitted curves, the respective sinus clearance was derived. The tracer retention, the drainage side and time-activity (clearance) curves were interpreted visually and quantitatively without the knowledge of the experiment by the experienced nuclear medicine physician.



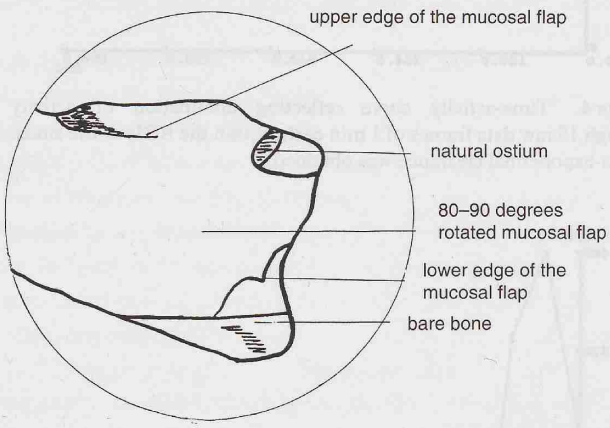


Figure 3. After removal of the bone to allow intrasinus manipulation enabling elevation and rotation of mucosal flaps, the mucosa of the lateral wall, floor and medial wall of the maxillary sinus are elevated and rotated about 80–90° after excision of some mucosa cephalic to the flaps.

RESULTS

The drainage of the maxillary sinuses of the rabbits were obtained bilaterally. The mean drainage of the maxillary sinus was 52±14% (in 15 min) in four sinuses with newly made operative windows. The mean drainage of the control side was 48±15% (in 15 min). When this group was compared to the controls, the sinus drainage of the tracer was similar by visually and quantitatively. Figure 4 shows the time-activity curve of the studied and control group. The curves are characterized by an initial rapid clearance of the tracer. The newly made operative windows do not affect the maxillary sinus drainage.

The time-activity curve in five sinuses with mucosal elevation and rotation was different when compared to the control group. The mean drainage of the control group with only mucosal elevation was 63.6±28% (in 15 min; Figure 6A). It was in the form of a bio-exponential curve (Figure 5), and is characterized by an early fast and the late slow clearance phase of the sinus. The main part of the drainage was in the early fast clearance phase. The mean time of the clearance was in the first five minutes. The amounts of the last slow clearance phase were 2.6±1.5%. The mucociliary drainage of the studied side with both the mucosal elevation and rotation showed retention of the tracer and impaired drainage (Figure 5). In this group, only 6.7±4.9% sinus drainage was obtained. The time-activity curve is characterized by an initial tracer retention and partial delayed

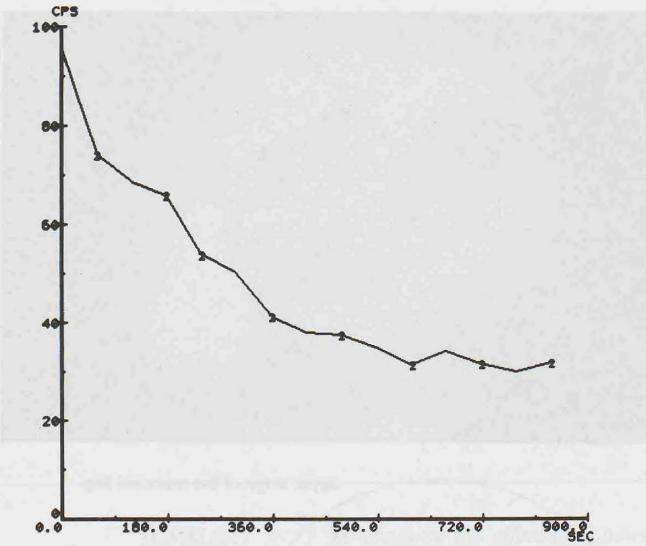


Figure 4. Time-activity curve reflecting elimination of activity through 15 raw data frames of 1 min each, within the ROIs of the sinus. Mono-exponential clearance was obtained.

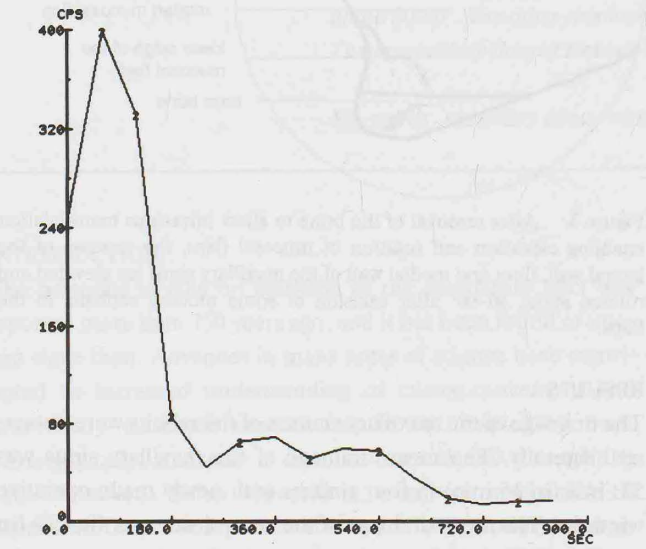


Figure 5. Bio-exponential curve of the drainage in the group with only elevated mucosal flap. It is characterized by an early fast and the late slow clearance phase of the sinus.

drainage. Comparison of the curves of both sides revealed a significantly decreased drainage on the studied side.

DISCUSSION

King (1935) has showed that mucociliary clearance continues towards the natural ostium despite creation of an inferior meatal window. In 1941, Hilding has concluded that in humans all of the sinuses drain with a spiral motion centering at the ostium. The direction of the flow in the maxillary sinus is not altered by making a window into the inferior meatus; however, in the presence of large quantities of secretion much of it flows out of the window in the inferior meatus. And it is gravitation-dependent, as reported by Friedman and Toriumi (1989). But we do not know the effect of a window on the lateral wall of the maxillary sinus just contralateral to the natural ostium, instead of a window inferior to the natural ostium. This part of the

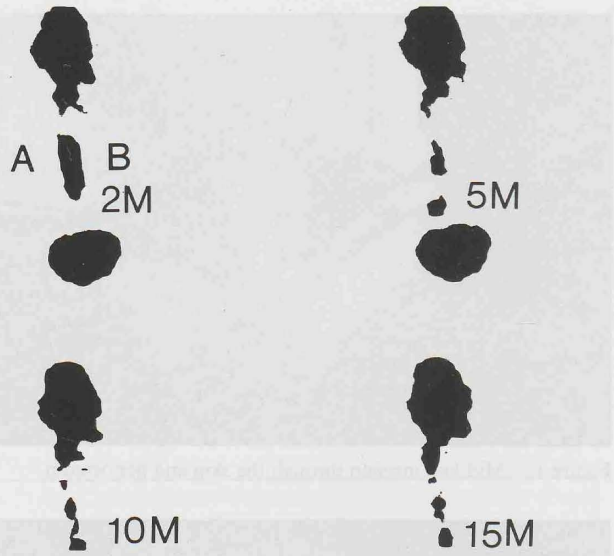


Figure 6. Clearance of the maxillary sinus on the control side with only elevated mucosa but without rotation is very fast (A), however the clearance of the maxillary sinus in which the mucosa was elevated and rotated about 80–90° is significantly decreased (B).

experiment shows that newly-made operative windows between the maxillary sinus and outside do not affect mucociliary flow, and no flow occurs in the direction of the new ostium. Oxygen application also does not have any effect on mucociliary flow. This supports the idea that ciliary beating is direction-fixed, always towards the natural ostium. The sinus mucosa is an invagination of the nasal mucosa and for this reason the direction of ciliary beating is always towards the natural ostium, from where it develops. However, the clearance time was shorter in sinuses with the new ostium. Therefore, a second window may help the clearance by equalizing the intrasinusal pressure with the atmospheric pressure.

Macbeth (1968) reported that the Caldwell-Luc procedure with removal of the sinus mucosal lining is a safe operation and the patient will have lost nothing. Benninger et al. (1991) concluded that partial or selective removal of mucosa may allow regeneration of more normal mucosa. But what happens if the direction of mucosal lining is changed? The second part of the experiment shows that if one changes the direction of the mucosa by creating flaps, it impairs the drainage of the sinus. This is also in accordance with the first part of the experiment. Ciliary beating is direction-fixed, in other words they do not always beat towards the natural ostium, but they do always beat in the direction they are conditioned to during development. If the only determinant were the natural ostium, the rotation of flaps would end up with the same amount of clearance as the control side. However, that is not the case and if one changes the location of the flaps the direction of mucociliary flow would also change. A normal ostium is no insurance for a normal mucociliary flow. This finding also brings up the question whether the nasal mucosal flaps turned down into the maxillary sinus as performed during sinus surgery function or not. The mucosal lining which regenerates from normal sinus mucosa, will also beat towards the ostium. But if the mucosa regenerates from nasal mucosa this is another situation. If the cilia continue to

beat in the same direction as they have before in the posterior direction, it does not help the clearance mechanism. For that reason nasal mucosal flaps ought to be developed in a fashion which helps the clearance mechanism most.

However, long-term studies are necessary to evaluate the effect of transposed flaps in maxillary sinuses on mucociliary flow.

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Metin Önerci, MD
Billur sokak
14/14 Kavaklidere
06700 Ankara
Turkey