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Radical or partial maxillary sinus surgery: A dilemma today? An experimental study*

Pablo J. Melgarejo-Moreno, Inmaculada Ribera-Cortada, Esteve Sarroca-Capell

Department of Otorhinolaryngology, School of Medicine, Hospital Arnau de Vilanova, Lleida, Spain

SUMMARY

To evaluate partial or radical surgical removal of the maxillary sinus mucosa, 20 New-Zealand albino rabbits were used. After three months, specimens were taken for examination. Bacteriological cultures, light- and electron microscopy were performed, and mucociliary transport was studied. These experimental findings add further support to the concept of performing a conservative sinus procedure rather than a radical removal as a first procedure.

Key words: maxillary sinus surgery, antrostomy, maxillary sinus mucosa

INTRODUCTION

Certain surgical procedures carried out on the nasal chambers and paranasal sinuses include partial or total removal of the mucosal lining. In cases of chronic sinusitis, the Caldwell-Luc (CL) operation (Caldwell, 1893; Luc, 1897), with various modifications, has traditionally been the preferred treatment.

The importance of ethmoidal sinus disease and ostiomeatal obstruction in the pathogenesis of sinus disease is well recognized. Persistence of disease in the infundibulum or anterior ethmoidal area appears to be a significant cause of failure after both inferior meatal antrostomy and CL surgery (Kennedy et al., 1987).

Functional endoscopic sinus surgery (FESS) failures often have polypoid, scarred mucosa, despite a widely patent middle meatal antrostomy and ethmoidal cavity. Failure is not a result of poor ventilation or residual ethmoidal disease, but of irreversible mucosal changes, as reported by Hyams (1989).

Radical or partial surgical removal of maxillary sinus mucosa for such disorders raises questions concerning mucosal regeneration and subsequent sinus function.

MATERIAL AND METHODS

Twenty adult albino rabbits (strain: New-Zealand) were anaesthetized with intramuscular injections of 60-70 mg/kg ketamine. The anterior wall of the right sinuses was entered with a small hammer and drill and the mucosa was identified. The procedure was performed with an operating microscope and with middle ear microsurgical instruments.

The animals were divided into 4 groups: Group A consisted of 5 rabbits in which the maxillary sinus mucosa of the anterior part was completely removed without interfering with the ostium, and an inferior nasoantral window 5 mm in diameter was created. Group B consisted of 5 rabbits in which the mucosa of the anterior part of the right maxillary sinus was removed, but the mucosa around the ostium was not disturbed. Group C consisted of 5 rabbits in which only a strip of maxillary right sinus mucosa of 5×2 mm between the ostium and the floor of the sinus was removed. Group D consisted of 5 rabbits in which the sinus was exposed in the same manner as in the surgical groups, but no procedure was performed on the sinus mucosa.

After three months, the animals were again anaesthetized and the sinuses were opened and inspected. Note was made of the patency of the nasoantral windows, absence or presence of pus, and mucosal appearance.

In two rabbits from each group, fixation was performed by intra-arterial perfusion of 4% phosphate-buffered formalin followed by immersion fixation in the same fixative, decalcification in formic acid, paraffin embedding, and whole-mount sectioning of the nose complex (section thickness: 5 μm). The sections were stained with either haematoxylin-and-eosin or Alcian blue-PAS (pH 1.0 and 2.5).

In three rabbits from each group, fixation was done by perfusion with 2.5% phosphate-buffered glutaraldehyde, followed by processing for scanning- and transmission electron microscopy.

In all animals, specimens of the mucosa were removed from the same sites. These sites were the mucosa (*in toto*) of the medial and lateral walls of the maxillary sinus, with the exception of the ostium zone. Special care was taken to prevent removal of the mucosa beneath the drill hole when evaluating the regenerated mucosa.

The scanning electron microscopical study was used to compare the density of cilia and globet cells in each maxillary sinus

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mucosa. The number of cilia in an area of 5×5 μm was used as reference, and the area of 50×50 μm for goblet cells. Special care was taken to avoid a change in the orientation of the mucosa during all processing steps. We studied 10 specimens from each animal (5 from the lateral wall and 5 from the middle wall), and six specimens from the contralateral sinus (3 from the lateral and 3 from the middle wall).

Bacteriological cultures from the right maxillary sinus cavities were taken with cotton swabs. The media used for cultivation were blood agar, McConkey agar, and haematin agar. The plates were incubated for 24 h aerobically and also for 48 h in anaerobic jars.

In one animal from each group, mucociliary transport of India ink was observed in the right maxillary sinus, as has been described by Kennedy and Shaalan (1989). The animals were not treated prophylactically with antibiotics.

RESULTS

At the initial operation all of the sinuses appeared free of infection. However, the initial bacteriological cultures from the right maxillary sinus showed in 19 animals *Pasteurella multocida*, and one animal from group D showed no microbial growth.

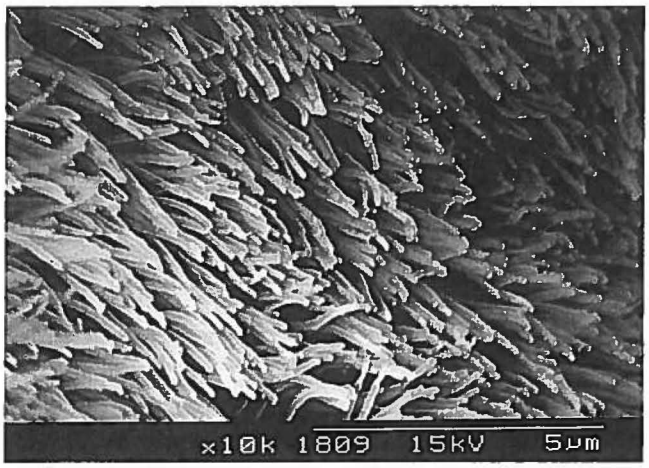

Figure 1. Normal ciliary epithelium of the rabbit maxillary sinus mucosa.

The normal maxillary sinus consists of a pseudostratified ciliated epithelium (Figure 1) with ciliated cells, goblet cells, basal cells and some intermediate cells on a basal membrane. Beneath the basal membrane is the lamina propria, which contains numerous serous glands and vessels.

The mean value of cilia in an area of 5×5 μm was 100.93±11.4, with a maximum of 115 and a minimum of 93. We obtained this result from a study of 100 specimens from groups A and B, at the beginning of the study.

After three months, in all of the maxillary sinuses from groups A and B (with radical removal of the mucosa) there was evidence of mucus stasis, and the medial walls frequently were retracted laterally. Moreover, all of the nasoantral windows in group A were closed. However, in groups C and D there was no evidence of mucus stasis, and the medial walls of the sinuses were normal.

The light- and electron microscopical findings were similar in groups A and B after three months. In all rabbits from groups A and B, the maxillary sinus mucosa was a hypertrophic pseudostratified epithelium with localized loss of the ciliary lining and an increased number of goblet cells. In these groups, round-cell infiltration (mainly lymphocytes and plasma cells) and local fibrosis were particularly characteristic.

The representative samples of regenerative maxillary sinus mucosa from both groups A and B were examined by transmission electron microscopy. In these groups the total number of cilia present was decreased, and the central microtubules of the cilia were oriented in an angle of 30°, parallel to the neighbouring cilia and perpendicular to the cell border. Also, electron microscopical examination revealed scattered, short microvilli, and bleb-like epithelial surface structures. Oedematous cilia were relatively frequent in specimens from groups A and B, but compound cilia were not identified. Deviation from the normal "9+2" microtubular arrangement was identified only in one specimen of the maxillary sinus mucosa from one rabbit of group A, and this deviation was a "9+2+2" microtubular arrangement. However, in groups C and D the maxillary sinus mucosa did not show any changes at the light- and electron microscopical level after three months.

Scanning electron microscopical findings in the sinus after radical mucosa removal showed a decrease in cilia density, and the cilia were embedded in mucus (Figure 2). In the mucosa of the right maxillary sinus of group A, the mean value of cilia in an area of 5×5 μm was 50.06. In group B, it was 47.83 cilia in the same area. However, in groups C and D the number of cilia did not change after three months; the mean value of cilia was 100.56 in group C, and 100.80 in group D. In the contralateral maxillary sinus, the mean number of cilia was 103.62 for the same area. The mean values after 3 months are shown in Table 1.

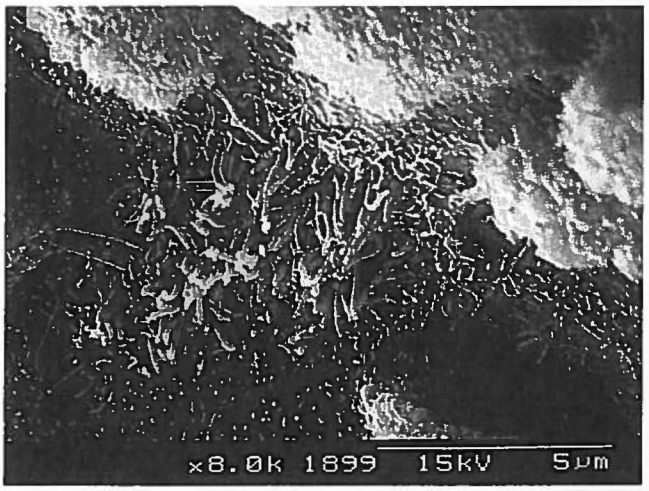

Figure 2. Decreased cilia density. In the radical antrostomy specimens, the cilia are embedded in mucus.

Also, an increase in the number of goblet cells was observed in the regenerated mucosa after three months (Figure 3). In group A, the mean value for goblet cells in an area of 50×50 μm was 23.2±4.4, and in group B it was 21.9±4.1. However, in group C the mean value of goblet cells in an area of 50×50 μm was

2.1±1.2, and in group D it was 1.9±1.1. In the contralateral sinus, the mean value of goblet cells in the same area was 2.4±1.8.

Table 1. Mean values (±SD) of cilia in an area of 5 × 5 μm after three months.

	group A	group B	group C	group D
rabbit 1	46.3±5.2	52.3±6.1	97.6±3.1	105.1±2.2
rabbit 2	54.1±3.3	43.1±7.1	102.9±4.5	99.2±3.1
rabbit 3	49.8±6.2	48.1±5.2	101.2±2.8	98.1±2.9
contralateral sinus	104.6±2.1	100.9±3.2	105.3±2.6	103.7±3.7

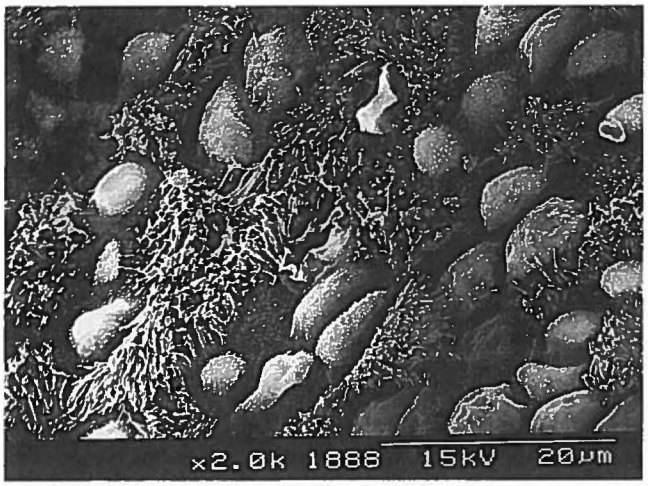

Figure 3. Increase of goblet cells in the regenerated mucosa of the groups with radical removal.

Also, in 10 animals with radical removal, the maxillary sinus mucosa showed a decrease in number of serous glands, and there was a dense infiltration in the lamina propria by plasma cells, lymphocytes and granulocytes.

In the contralateral sinus of all animals after three months, there were no signs of infection, nor of mucus stasis. The light- and electron microscopical studies were similar to the right sinus of groups C and D.

After three months bacteriological cultures showed *P. multocida* in all animals. However, in group A, *Moraxella sp.* was found as well as *P. multocida* in one animal, and in one other animal *Pseudomonas sp.* In the remaining animals, only *P. multocida* was found. Also, in group B, *P. multocida* together with *Bordetella sp.* (n=1) or *Flavobacterium sp.* (n=1) were found; in the remaining animals only *P. multocida* was found.

Initial mucociliary transport was normal in four animals studied, with a star-shaped pattern from the floor of the sinus, up the walls, and toward the natural ostium. After three months, mucociliary transport was absent in groups A and B, and the India ink tended to collect in the floor of the sinus. However, mucociliary clearance in group C was similar to that in the control group (group D).

DISCUSSION

Recent technological advances have led to the development of FESS, which has changed many standard indications for the CL procedure (Stankiewicz, 1991). It is no longer necessary to violate the anterior wall of the antrum to remove a polyp or cyst, obtain a biopsy, or establish adequate drainage of the sinus as described by others (Messerklinger, 1968; Wigand, 1978).

The sinus mucociliary transport mechanism is dependent on a complex interaction of ciliary motility: the characteristics of the mucus, glandular secretion and absorption, and the sinus environment. Chronic inflammatory diseases of the nose and paranasal sinuses can inhibit mucociliary transport, resulting in mucus stasis and secondary sinusitis (Stammberger, 1986). Surgical removal of the sinus mucosa for such disorders raises questions concerning mucosal regeneration and subsequent sinus function (Hilding 1933; Benninger et al., 1989).

In our study, the maxillary mucosa was regenerated in the 10 right sinuses three months after radical removal. However, a decrease in the total number of cilia, acute and chronic inflammation, a decreased number of serous glands and increased numbers of globets cells were found in all of the regenerated sinuses after surgical removal.

The total number of cilia decreased in the sinuses with radical surgery in comparison to the other groups. As reported by Benninger et al. (1989), by evaluating the number of cilia per area of specimen and comparing those undergoing radical surgery and control specimens at the same level of magnification, a mean of 54 cilia were present in the specimens operated with radical surgery on, compared with a mean of 100 cilia in the controls. Radical removal of maxillary sinus mucosa resulted in contracted sinuses and fibrous tissue proliferation, with poor mucociliary clearance, and similar changes were also observed in some patients after CL procedures (Gorham et al., 1930; Hilding et al., 1963). Forsgren et al. (1995) studied histopathological changes in the mucosa occurring in patients with chronic maxillary sinusitis, both before and after FESS or CL operation, and they reported that a greater reduction of inflammatory parameters in the sinus mucosa is obtained with the CL operation than with FESS after one year. Thus, in the clinical situation, a more radical treatment should be considered for asthmatic patients and especially for patients with sinonasal polyposis.

Normal human maxillary sinus mucosa exhibits scattered subepithelial tubulo-acinar glands, but no true glandular layer, whereas goblet cells are fairly evenly distributed throughout the epithelial lining. An increase in goblet cell frquency is often found during airway infections (Tos, 1982). In human chronic maxillary sinusitis, it has been reported that hyperplasia occurs in the tubular subepithelial glands, whereas the number of goblet cells decreases (Tos and Mogensen, 1984).

The healthy rabbit mucosa lacks mucous goblet cells, but its lamina propria has a fairly evenly distributed layer of serous glands (Forsgren et al., 1993). However, in our study we have observed that there is an increase of goblet cells and a decrease of serous glands in the regenerated mucosa. In the maxillary sinus mucosa, pluripotent basal cells and "resting" dark cells may transform into goblet cells. In experimental sinusitis in rabbits, the presence of goblet cells indicates a state of relative recovery, whereas the most severly damaged mucosa lacks goblet cells (Westrin et al., 1993).

In group C (partial mucosal removal), there are no changes in the sinus mucosa. Selective removal of the mucosa may allow mucosal regeneration, resulting in improved mucociliary transport and a reduction of sinus infection (Benninger et al., 1991).

In our study, the absence of infection in the control group (group C) as well as the contralateral sinuses is surprising, since in rabbits a certain incidence of spontaneous sinusitis has to be expected. It is possible that some infections occurred during the time of observation, but have resolved spontaneously and are not present at re-examination.

P. multocida has been reported as a major airway pathogen, and is carried by more than 90% of individuals in rabbit populations in the USA as a subclinical infection (Friedman et al., 1989; Perko et al., 1992). Interferences with the mucociliary transport can induce sinus infections with *P. multocida* in rabbits. This may explain why in groups C and D the cultures show *P. multocida*, while there is no evidence of infection (as judged by purulent sinus secretions), because mucociliary transport is not disturbed.

In conclusion, radical surgical removal of the rabbit maxillary sinus mucosa results in regeneration of sinus mucosa with abnormal cilia as well as chronic inflammatory changes and an increase in the number of goblet cells. In these sinuses, the absence of mucociliary clearance may result in chronic mucus stasis and subsequent recurrent infection.

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Dr. Pablo J. Melgarejo-Moreno
Avda. Juan José Marco Banegas, 2
E-30600 Archena-Murcia
Spain