Follow-up of patients with inverted papilloma of the nasal cavities: Computer tomography, video-endoscopy, acoustic rhinometry?*

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SUMMARY *Seventeen patients were operated suffering from unilateral inverted papilloma of the nasal cavities, in one male associated with malignancy. We investigated these patients pre- and post-operatively by clinical examination, video-endoscopy, acoustic rhinometly, and computed tomography (CT). The aim was to find out which technique delivers reliable information about tumour recurrence in follow-up. By these controls three recurrences could be detected in a period of two-years' follow-up. Our results showed that the combination of CT, video-endoscopy and histological examination of biopsies is reliable to detect recurrence of inverted papil/oma. To study the possibilities of detecting tumour recurrence by means of acoustic rhinomet,y, investigations on models of nasal cavities with various shape, size and location of tumour masses were undertaken. A comparison between the results of the model study and the acoustic rhinometric measurements in patients showed that growth of tumour masses can be detected by this method in an early phase under constant conditions such as nasal models. In patients, however, it is not easy to evaluate the absolute size and site of the growing tumour masses, because there are several factors which lead to false-positive inte lpretations, such as localized inflammations of the mucosa, crusting and nasal secretion and especially the movements of the soft palate. We conclude f 'om our results that acoustic rhinometly does not deliver more information than obtained by video-endoscopy and CT to detect tumour recurrence in the nasal cavity.*

Key words: acoustic rhinomefly, computed tomography, video-endoscopy, inverted papi!loma, tumour recurrence

INTRODUCTION

Inverted papilloma, first described by Ward in 1854 (cf., Hyams, 1971; Majumdar et al., 1984), is a tumour of unknown aetiology, which arises from the lining membranes of the nasal cavities and paranasal sinuses. The tumour emanates from the Schneiderian respiratory membrane, an epithelium which is of ectodermal origin (Stammberger, 1983; Majumdar et al., 1984). Inverted papilloma has a capacity to destroy the adjacent structures and a tendency to recur if incompletely excised. Although a benign tumour, its association with malignancy in the manifestation of an invasive squamous cell carcinoma has been known since the end of the 19th century (Hyams, 1971; Majumdar et al., 1984).

The literature presents excellent articles about the history (Kramer et al., 1935; Lambertico et al., 1963; Myers et al., 1990), histopathology (Hyams, 1971), epidemiology (Eavey, 1985; Segal et al., 1986; Buchwald et al., 1989), and clinical significance of inverted papilloma (Vrabec, 1975).

However, there are only few reports on the follow-up of patients after surgical treatment. Since recurrence of the tumour is not rare - ranging from 22% to 78% (Segal et al., 1986) - we were interested in an early diagnosis of the relapse.

To this end we have applied computed tomography (CT), video-endoscopy and acoustic rhinornetry in 17 patients with inverted papilloma, to compare the diagnostic value of these methods for recognition of tumour recurrence.

Furthermore, we compare our clinical observations to findings of acoustic rbinometry obtained in nasal models prepared to imitate intranasal tumours of different size, shape and location.

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METHODS

Subjects

Between 1989 and 1990 we operated 17 patients (10 males, 7 females) suffering from unilateral inverted papilloma of the nasal cavity (Table 1). In one male this papilloma was associated with malignancy.

In addition to the examination by nasal endoscopy and CT, we have used acoustic rhinometry to study the changes in the geometry of the nasal cavities after surgical treatment. Four to five weeks after surgery, when epithelization of the operated nasal cavity was completed, coronal paranasal CT, video-endoscopy and acoustic rhinometry of the decongested nasal cavity were performed. The nasal cavity was decongested by spraying a solution of 0.05% xylometazoline. The same examinations were repeated every four to six months in order to detect recurrences. By these follow-ups over a period of two years three recurrences could be found and treated, two in females, and one in a male.

Computer tomography

CT examinations were performed mainly with a General Electric 9800 Quick apparatus. We used a slice thickness of 2 mm at 4-mm intervals.

Video-endoscopy

We used Hopkin's endoscopes from 0° to 120° and flexible nasopharyngoscopes (Storz®, Germany), a chip camera (NC 4500), a S-VHS recorder (Panasonic NV-FSlOO) and a videoprinter (Sony FS 5000).

Acoustic rhinometry

Acoustic rhinometry calculates airway geometry by analysis of acoustic pulse-response measurements. The acoustic pulse is introduced into one nasal cavity via a perspex nose piece. The response is measured between 100 Hz and 10 kHz and the area distance function of the acoustically equivalent structures is calculated. We used the Stimotron® acoustic rhinometer RK1000® (Stimotron Medizintechnik, Germany). Details of the equipment are described in recent papers (Jackson et al., 1977; Hilberg et al., 1989; Lenders et al., 1990a-c; Lenders et al., 1991; Lenders et al., 1992a-c). The distance of measurement is software adjustable between Oto 33 cm. Six curves in each different condition (before and after decongestion, right and left side separately) are automatically recorded. Superposition of different curves is used for evaluation and documentation, and the mean values with standard deviations of technically satisfying traces can be calculated automatically. The total time of registration (12 measurements) is usually less than 30 s.

To receive reliable and reproducible data by acoustic rhinometry it is very important that the connection between the rhinometer and the nose does not distort the valve area. We could show (Lenders et al., 1992b, c) that using two different nose pieces (outer diameter: 1.2 and 1.5 cm, respectively) only 28% of the patients could be measured in a correct way concerning the cross-sectional areas in the anterior one-third of the nose. The use of 12 different nose pieces (outer diameter: 0.4 to 1.5 cm, respectively) improves the result of correct measurements to 73%. The nose piece was modified to allow a correct measurement of 99% in all patients. This was achieved by designing the nose pieces in such a way, that-they do not distort the entrance of the nose (Lenders et al., 1992b, c).

Nasal model

To study the recognition of tumour recurrence by means of acoustic rhinometry, investigations on models of nasal cavities with various shape, size and location of tumour masses were undertaken. Nasal casts were taken from human cadavers to get models of the nasal cavities and nasopharynx. The walls of the models were built up by wax and outlined by sticky wax. The nasal septum was imitated by a removable layer of glass.

The acoustic rhinometer was tested concerning the reproducibility and accuracy of measurements.

In a first phase we determined the layers within the nasal cavity, where the acoustic pulse is present at the same time. We ter-

Table 1. Data on 17 patients with inverted papilloma (m: male; f: female; np: nasal polyposis; ip: inverted papilloma; X-ray: plain paranasal radiographs and/or pluridirectional tomography; CT: computed tomography before treatment; arrow: initial sinus surgery or polypectomy with consecutive lateral rhinotomy; e: ethmoidal cells; f: frontal sinus; s: sphenoidal sinus; m: maxillary sinus; it: inferior turbinate; mt: middle turbinate).

no.	sex	age	diagnosis	X-ray	CT	initial surgery: sinus surgery, polypectomy	lateral rbinotomy	localization	recurrence
1	m	58	ip	+	+	-	+	m,e,it,mt	+
2	m	23	np	+	+	+	-	**m,e,s**	-
3	m	60	op	-	+	+ - - - - • -	+	m,e,it,mt	-
4	f	64	np	+	+	biopsy	+	e,it,mt	-
5	m	59	op	+	+	biopsy	+	m, e, s, it, mt	-
6	f	68	np	+	+	-	+	**m,e,s, it,mt**	+
7	f	66	np	-	+	+ - - - - • -	+	m, e, it, mt	-
8	m	51	op	+	+	+ - - - - • -	+	m, e, s, f, it, mt	+ malignant
9	f	54	op	-	+	+ - - - - - - - 1 1 -	+	m, e, s, f, it, mt	-
10	m	44	ip	+	+	biopsy	+	m, e, f, it, mt	-
11	m	57	op	+	+	+ ——— . . -	+	e, s, f, it, mt	-
12	f	21	np	-	+	+ - - - - - - - 1 1-	+	m,e,mt	-
13	f	33	np	-	+	+ - - - - . -	+	**m, e, s, it**	-
14	m	41	ip	-	+	-	+	m, e, s, f, it, mt	-
15	m	63	ip	+	+	-	+	m, e, s, f, it, mt	-
16	m	70	ip	+	+	-	+	m, e, s, f, it, mt	-
17	f	54	ip	+	+	-	+	e, s, f, it, mt	+

med these layers "isotemporals," which are roughly oriented parallel to the nasal valve.

In a second step all possible planes within the nasal cavities and nasopharynx of the models were correlated to the cross-sectional areas measured by acoustic rhinometry. These planes of the nasal models were calculated by computer reconstruction of the nasal model from 2-mm cuts. The difference between the measured (by acoustic rhinometry) and calculated cross-sectional areas is up to 3% in the nasal cavity, and up to 17% in the nasopharynx. The hypothesis concerning the "isotemporals," that the measured cross-sectional areas are located parallel to the isthmus nasi, could be confirmed (for details, see Lenders et al., 1992b).

RESULTS

Computer tomography

CT was performed in all our patients (Table 1), pre- and post-operatively. Although there was no specific radiographic criterium in CT for the presence of inverted papilloma, the coronal CT scans were an excellent help to define pre-operative borders of resection and gave reliable informations concerning anatomical details of the orbits and of the anterior cranial fossa.

Post-operatively, it was sometimes difficult to recognize early recurrences of inverted papilloma in the mucosa! scars of the nasal walls by CT. Small bony destructions, however, could be detected early on, even when they had been developed in the depth of the nasal sinuses.

In the three cases of recurrence, the CT established the localization of the inverted papilloma, which was also suspected by video-endoscopy.

During follow-up 12 CT scans in eight patients showed radiologic alterations (bony destructions and polypoid mucosa! thickening), which were suspicious for a relapse of inverted papilloma. But histological examination after biopsy excluded a tumour recurrence.

Video-endoscopy

Video-endoscopy with rigid and/or flexible endoscopes was performed in all patients pre- and post-operatively. Pre-operatively in eight patients only nasal polyps were seen, and inverted papilloma was diagnosed just after histological examination of all the material removed during endonasal surgery (Table 1). Six patients were sent to the hospital with histologically confirmed diagnosis of inverted papilloma. In three patients suspected areas of the nasal lining were taken for histological investigation, which confirmed the diagnosis of inverted papilloma. Thus, nine patients (53%) were correctly diagnosed by endoscopic findings.

In the other eight patients (47%) inverted papilloma was diagnosed after initial treatment (sinus surgery and polypectomy) and histological processing of the removed tissue.

Following these 17 patients we were able to detect recurrence of inverted papilloma in all three cases by video-endoscopy. In eight patients, 21 suspected areas of tumour recurrence were biopsied, but histological examination discarded the tumour recurrence.

Acoustic rhinometry in patients

In the following part we present some typical acoustic rhinometry curves, to discuss the diagnostic value of this new method for detecting nasal tumour recurrence.

In Figure 1 the pre-operative acoustic rhinometry curves of patient No. 17 are depicted. There are two curves separating at 2-cm distance from the nostril. The upper curve shows cross-sectional areas of the healthy decongested right nasal cavity. The lower curve represents the cross-sectional areas of left decongested nasal cavity filled with inverted papilloma.

The first centimeters (straight line) of the curves reflect the dimension of the nosepiece and allow the self-test of the system.

The following part of the curves is a notch (I-notch: "isthmus nasi" notch), which represents the minimal cross-sectional area of 0.61 cm^2, corresponding to the functional isthmus nasi.

The second notch (C-notch: "concha" notch) of the upper curve after a small peak with cross-sectional area of 1.2 cm^2 corresponds to the head of the inferior concha and the septal body. This pattern of curve in Figure 1 - we term it "climbing W" - with the minimal cross-sectional area at the isthmus nasi and a second minimum at the region of the anterior inferior turbinate and septa! body, is typical for normal controls (Lenders et al., 1990a-c).

The second notch of the lower curve with minimal cross-sectional area of 0.2 cm^2 corresponds to the obstructing tumour masses 3.5 cm behind the nostril.

In Figure 2 we compare the acoustic rhinometry curves of the healthy nasal cavity (lower curve) to the state three months after lateral rhinotomy (upper curve) of patient No. 17. This comparison clearly demonstrates that the cross-sectional areas of the operated nasal cavity are markedly enlarged as a consequence of the surgical procedure. The minimal cross-sectional area, which pre-operatively was in the second notch, is now located in the unchanged isthmus nasi (I-notch).

Figure 3 presents the acoustic rhinometry curves measured during three follow-ups within six months in intervals of eight

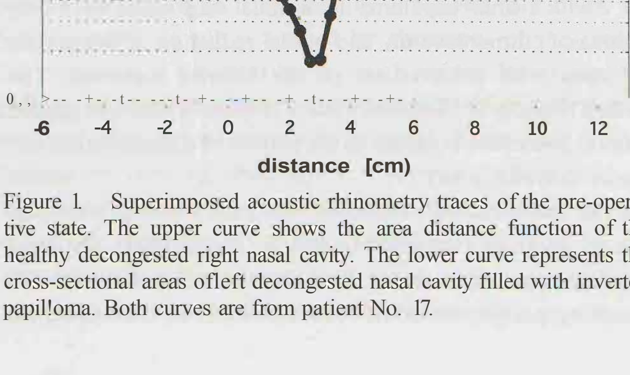

Figure 1. Superimposed acoustic rhinometry traces of the pre-operative state. The upper curve shows the area distance function of the healthy decongested right nasal cavity. The lower curve represents the cross-sectional areas of left decongested nasal cavity filled with inverted papil!oma. Both curves are from patient No. 17.

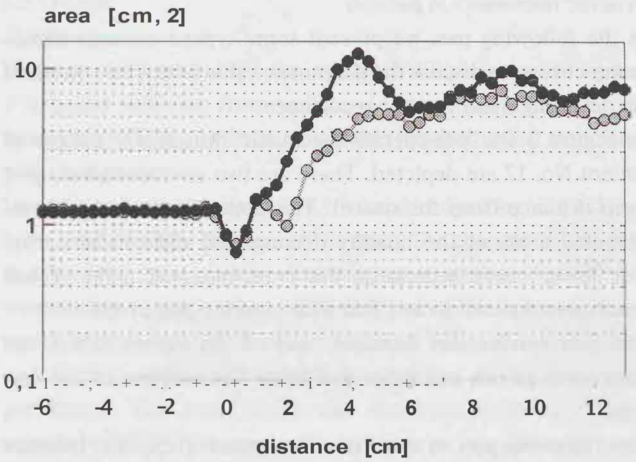

Figure 2. Superimposed acoustic rhinometry traces of the healthy nasal cavity (lower curve) and three months after lateral rhinotomy (upper curve) of patient No. 17. The operated nasal cavity is markedly wider than the healthy one.

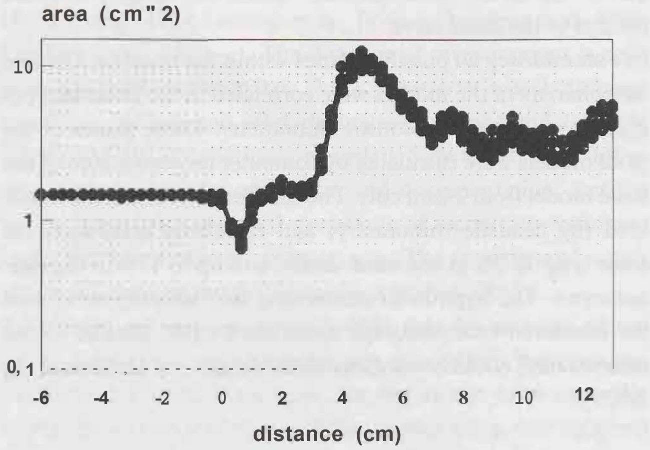

Figure 3. Four assessments during follow up of patient No. 5: All 12 curves are nearly identical within the period of six months.

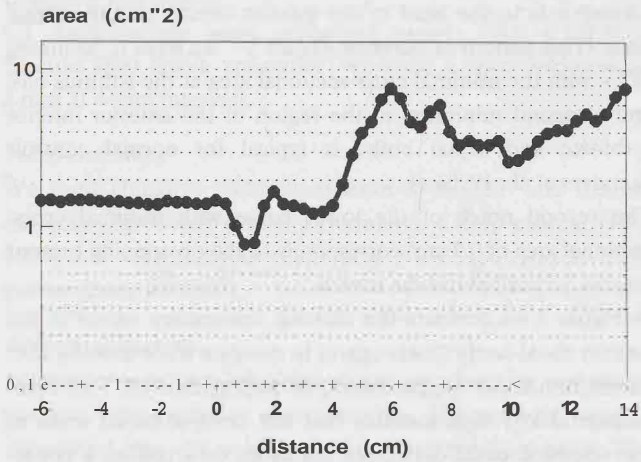

Figure 4. The pattern of acoustic rhinometry curve after endonasal ethmoidectomy and partial reduction of the middle turbinate (limited surgical procedure) in patient No. 2 is more similar to that of a healthy nasal cavity (compare to Figure 2, lower curve) than to the state after radical surgery.

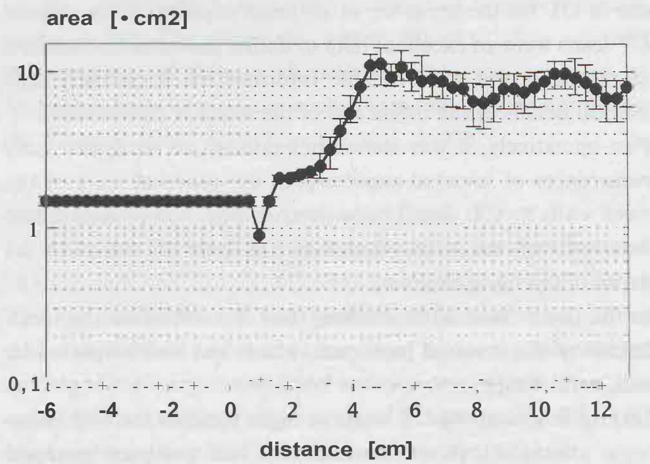

Figure 5. Mean curve and standard deviations of 10 subsequently measured traces from patient No. 7 during normal breathing: The increase of standard deviations 5 cm distant from the nostril to the nasopharynx represents the changes of cross-sectional areas due to movements of the soft palate.

weeks in patient No. 5 without tumour recurrence. On each follow-up three measurements were recorded, therefore this bundle of acoustic rhinometric curves is composed of 12 single curves. From Figure 3 we can recognize, that all these curves are nearly identical within the period of six months.

Acoustic rhinometry allows to distinguish whether only the ethmoidal cells had been removed or the whole lateral nasal wall including the inferior turbinate had been resected. Patient No. 2 with a small papilloma in an initial stage underwent only endonasal ethmoidectomy and partial reduction of the middle turbinate with preservation of the inferior turbinate. The pattern of acoustic rhinometry curve (Figure 4) after this limited surgical procedure is similar to the pattern of a healthy nose (cf., Figure 2, lower curve).

For the interpretation of acoustic rhinometry curves, we would like to point to two observations in our patients. In serial measurements (for instance 10 shots within 3 s) in a normally breathing patient, we could record changes in cross-sectional areas (Figure 5) as a result of movements of the soft palate. Figure 5 shows the mean curve and standard deviations of 10 subsequently measured curves. The increase of standard deviations 5 cm distant from the nostril onwards to the nasopharynx represents the changes of cross-sectional areas caused by movements of the soft palate. When the same patient was asked to stop his breathing during the measurements, we got 10 nearly identical curves like those in Figure 3.

Presentation of acoustic rhinometry measurements in a logarithmic scale eliminates small changes of cross-sectional areas in the nasopharynx, and small changes of cross-sectional areas are normal and in most cases without clinical significance. In follow-up examinations such small changes of cross-sectional areas are very interesting, because they can be a sign of beginning tumour growth. The logarithmic scale presentation, however, makes these small alterations invisible. To imitate such small alterations, we inserted defined small pieces (0.1-0.6 ml) of wax in different locations of operated nasal cavities. In

Figure 6 the acoustic rhinometry curves with and without the piece of wax (0.3 ml) of patient No. 11 are depicted. There is no striking difference between both curves.

When we calculate the volumes of the corresponding regions, where the piece of wax was inserted, we received a difference of volume of 0.3 ml. This favourably corresponds to the volume of the piece of wax.

Acoustic rhinometry in nasal models

The following experiments show, how exactly acoustic rhinometry can discover even very small changes of cross-sectional areas, provided the conditions are constant. In Figure 7, for instance, a defined volume of sticky wax (0.3 ml) is added to the middle meatus of the nasal model. The two curves in Figure 7 clearly demonstrate that this tiny volume is visible in the acoustic rhinometry curves for the condition of normal nasal anatomy. If we insert the same pieces of wax in the same plane of a nasal model with larger cross-sectional areas in this region (like after ethmoidectomy including resection of the turbinates), these changes are invisible in the acoustic rhinometric curves, too. These curves of the model are nearly identical to the curves from our experiments in operated patients as shown in Figure 6.

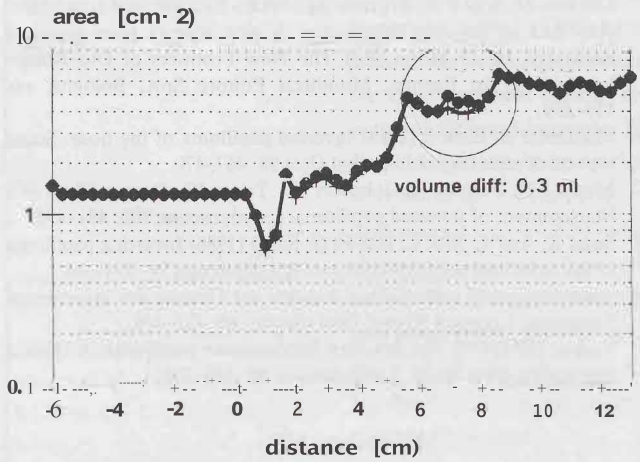

Figure 6. To imitate a tumour recurrence, a small piece of wax was inserted in the posterior nasal cavity of patient No. 11 (circle): There is no striking difference of the superimposed acoustic rhinometry curves with and without the piece of wax.

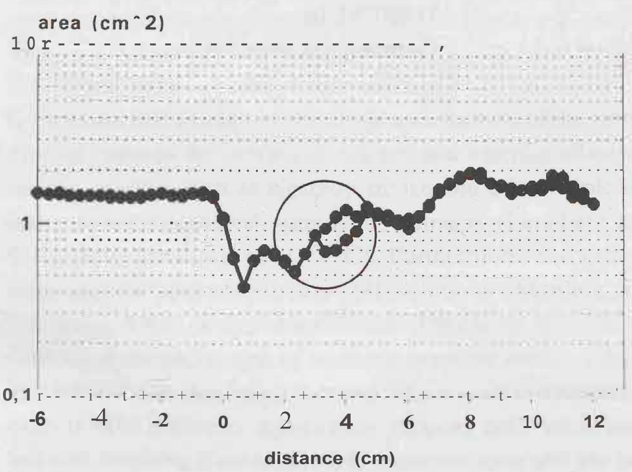

Figure 7. In a nasal model, imitating normal anatomy, the same experiment was performed as in Figure 6. The superimposed acoustic rhinometry curves with and without the piece of wax clearly demonstrate that this tiny volume is visible (circle).

DISCUSSION

Radiographic methods

According to the results of the literature and our findings, plain paranasal sinus radiographs are not sufficient for the treatment and follow-up of patients with inverted papilloma of the nasal cavities. Most of our patients attended our hospital with this type of radiographs. These plain radiographs are not adequate in determining the extent of tumour involvement and to visualize bone destruction. Therefore, we recommend coronal CT in order to determine the extent of the tumour and to plan the surgical treatment. For the rhinosurgeon coronal CT scans present better information concerning the anterior skull base and orbits than axial CT scans.

Although inverted papilloma has no specific radiographic features, CT is a great help in detecting tumour recurrence especially when the tumour masses are localized laterally from the sinuses. This was also found by Buchwald et al. (1990).

Video-endoscopy

As a second diagnostic method we used video-endoscopy to visualize alterations in the lining of the nasal cavities and to document them for comparison with later follow-ups. The main advantage of this kind of documentation is that the findings of earlier examinations can be evaluated by another examiner in the video tape.

Another advantage of video-endoscopy is a more complete and three-dimensional documentation of the surfaces of the nasal cavities compared to a series of photographs of the same anatomical structure. Buchwald et al. (1990) pointed to the essential help of fibre endoscopy for detecting inverted papillomas on the septum. In our 17 cases there was no case with this tumour localization.

It is a disadvantage that small submucosal recurrences, especially those which destroy the bony walls, cannot be discovered by video-endoscopy.

Acoustic rhinometry

Acoustic rhinometry was used as a third method to look for recurrence of inverted papillomas in the nasal cavities. Principally, this new method is able to measure crosssectional areas and their alterations by tumour growth in interesting nasal regions. This has been established by measurements in nasal models and in patients. The reliability of acoustic rhinometry to detect tumour growth is limited by alterations of the cross-sectional areas of the nasal cavity, which are not due to tumour growth. In the nasal cavity these alterations of the cross-sectional areas can be caused by mucosa! changes due to inflammation, crusting, small layers of secretion, which can not be completely removed from each area of an operated cavity and which vary from day to day. Therefore, small changes of cross-sectional areas, caused by a small tumour recurrence, cannot reliably be detected by acoustic rhinometry.

The cross-sectional areas are further influenced by the movements of the soft palate. The reason for that is, that the acoustically measured cross-sectional areas are parallel to the functional isthmus nasi in the whole nasal cavity. Therefore, the soft palate may act as the opposite wall of the surgically changed region. In normal controls we could show that the variability of cross-sectional areas is up to 17% of absolute value from mean in this segment of nasopharynx. In patients with chronic rhonchopathies and obstructive sleep apnoea syndrome (Lenders et al., 1991; Lenders et al., 1992l:t) this variability has been measured up to 50% of absolute value. Some of these patients are able to stabilize their soft palate during voluntary apnoea, thus the standard deviations of repeated measurements are in the range of less than 1% of absolute value from mean. From these observations we can conclude that it can be very difficult to detect small changes of cross-sectional areas in the surgically treated segments of the nasal cavity by acoustic rhinometry.

CONCLUSION

These findings show that the combination of video-endoscopy and CT is a reliable way to detect tumour recurrences following patients with inverted papilloma.

This does not hold true for acoustic rhinometry that is not adequate in determining the extent of tumour involvement under clinical conditions. Because of the high recurrence rate and risk of malignancy we recommend a follow-up of patients with inverted papilloma every three months comprising clinical examination and video-endoscopy. CT should be performed every six months in the first two years after surgery. Thereafter, patients are regular controlled every six months.

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