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Effect of nasal dilators on nasal structures, sniffing strategies, and olfactory ability*

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SUMMARY *This paper describes the effects that nasal dilators have on olfactory ability. Experimental results demonstrate that nasal dilators increase odorant identification, lower odorant threshold, and increase perceptual odorant intensity. In other experiments, magnetic resonance imaging (MRI) data demonstrates that the size of the nasal cavity especially around the region of the nasal valve is increased when nasal dilators are worn Additionally, pneumotachograph data demonstrates that during a sniff, the peak flow, maximum flow rate, volume, and duration are all increased when nasal dilators are worn. Taken together, the increase in olfactory ability can most easily be explained by an increase in both the amount and the proportion of inspired odorant molecules that are directed to the olfactory mucosa and are, therefore, available for odorant perception.*

Key words: nasal dilators, olfaction, nasal airflow, sniffing behavior

INTRODUCTION

This paper describes a number of experiments designed to investigate the effect that nasal dilators have on olfactory ability. Psychophysical techniques described the effect that nasal dilators have on odorant perceptual intensity and on measures of odorant detection threshold and identification. Imaging techniques evaluated the changes in nasal anatomy that resulted from wearing nasal dilators whereas pneumotachographic techniques quantified the effect of nasal dilators on sniff parameters measured during the performance of olfactory tasks.

MATERIALS AND METHODS

Psychophysics

All subjects in the following experiments provided written informed consent under protocols approved by the Institutional Review Boards of St. Lawrence University or the SUNY Health Science Center at Syracuse. Most subjects were paid for their participation. For the olfactory tests, 12 subjects (6 males and 6 females ranging in age from 18–50) were tested with and without the nasal dilator. Testing order was counter balanced across subjects. Approximately 5 minutes separated each of the olfactory tests.

Odorant Identification

Odorant identification was evaluated with a standard clinical test of olfactory function, the Odorant Confusion Matrix or OCM (Wright, 1987; Kurtz et al., 2000). Odorant concentration was reduced from that presented in the standard test by 15 fold to allow for the possibility that nasal dilators may increase odorant identification. This modification in the OCM resulted in the correct identification being lowered from 100% to about 40% for normosmic subjects.

Threshold Measurements

Olfactory threshold was evaluated with a 2-interval forced-choice phenethyl alcohol (PEA) ascending testing procedure (Cain et al., 1983). Twenty successive binary dilutions were prepared from a 10.0% v/v stock PEA solution in propanediol. The lowest concentration at which the subject chose the bottle containing the odorant 5 times correctly was taken to be threshold.

Nasal Imaging Studies

Nasal dilators are designed to move the lateral walls of the nasal vestibule laterally. The influence of this movement on the volume of the nasal vestibule was evaluated with Magnetic Resonance Imaging (MRI). Although acoustic rhinometry can give information on the interior of the nasal cavity, it would not be

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accurate in defining regions of interest therefore the nasal cavities of two subjects were imaged with a clinical 1.5T General Electric Signa MRI (T1-weighted coronal images) with and without nasal dilators. The first scan was performed after the dilator had been on the nose for 30 minutes. The subject's head was stabilized with a special pillow that form-fit the head, and could be made rigid. After the first scan, the dilator was removed with minimal movement of the head or body of the subject, keeping the head in the fixed position. Before the second scan, 10 minutes was allowed for the nasal soft tissues to return to their natural position. The second scan was then performed using the same MRI scanner registration settings as the first.

Sniff Measurements

The delivery of odorant molecules is dependent on airflow from the external naris to the olfactory cleft located posteriorly and superiorly. Any change in the volume of the nasal cavity will alter the aerodynamics of nasal airflow and the delivery of odorant molecules to the olfactory cleft (Hornung et al., 1997). Because of this, it was expected that nasal dilators would alter both nasal airflow and olfactory ability. To record nasal airflow, the subject placed his/her face in a standard anesthetic gas mask connected to a still-air odorant delivery system and a No. 2 Fleisch pneumotachograph (Youngentob et al., 1986). Airflow was recorded digitally and analyzed with a MacLab system.

Ten college-age normosmic nonsmoking subjects without nasal pathology or complaint served as subjects. The odorant set included licorice (trans-anethole), orange (D-limonene), rose (phenethyl alcohol) and vinegar (acetic acid). Each odorant was presented at a concentration close to its identification threshold. Each subject was instructed to place his/her face in the mask and make a tight seal. Subjects were instructed to smell long enough to identify the odor and, using absolute magnitude estimation (Zwislocki and Goodman, 1980), rate its intensity. The four odorants were presented in random order within a block. Two such blocks were presented during each test condition (with and without nasal dilators). The inter-stimulus interval was approximately 90 seconds.

RESULTS

Odorant identification increased significantly from 42 percent correct without nasal dilators to 54 percent correct with the nasal dilator ($p<0.01$, $t = 3.27$, two tailed paired test, 11 d.f). This change in odorant identification was mimicked by a similar change in PEA threshold. Average PEA threshold for subjects wearing nasal dilators was 15.21 whereas an average dilution step of 13.42 was observed for subjects not wearing dilators (note: a higher dilution step means a lower concentration). For all 12 subjects, threshold was lower wearing a dilator than without ($p<0.001$, two tailed $t = 4.27$, 11 d.f.).

Nasal Imaging Studies

The cross-sectional area of the nasal airways ("soft region") was analyzed first from the tip of the nasal vestibule posteriorly to the nasal valve and second ("bony region") from the nasal valve posteriorly to the anterior extent of the olfactory cleft. The second area is notable in that its walls are formed by bony structures rather than the cartilaginous tissue of the nasal vestibule. The angle of the coronal images obtained in these studies was parallel to the caudal edge of the nasal bones, thus it was easy to divide the anterior nasal cavity into a "soft" region between this edge and the nasal tip, and a "bony" region between the edge and the anterior olfactory cleft.

These cross-sectional areas were converted to volumes separately for the left and right nasal passages. For the "soft" anterior region, there was a 28% (right) and 22% (left) increase in the summed airspace areas. The summed areas from the "bony" posterior region had an increase of 8% on the right and 14% on the left in the presence of nasal dilators.

Not surprisingly, these data show that the volume of the soft anterior region increased with the use of the nasal dilator. This is the region of the nasal valve (Kern, 1978; Haight and Cole, 1983). Also noted was an increase in the volume of the anterior "bony" nasal cavity located posteriorly to the nasal vestibule. While an increase in the "soft" part of the nasal cavity can be easily understood as a direct action of the nasal dilator, the increase in the volume of the bony part of the nose is not immediately intuitive. We hypothesize that one explanation for this increase in volume is that trigeminal and/or autonomic receptors alter the level of engorgement in the nasal mucosa in response to changes in the anterior nasal airflow pattern. However, because the sample size is small, any changes in the volume of these area require further investigation.

Sniff Measurements

A summary of the olfactory test results and sniff parameters with and without nasal dilators is shown in Table 1. Subjects wearing nasal dilators rated the odorants as being more intense

Table 1. Effect of a nasal dilator on odorant identification, intensity rating and sniff characteristic.

Parameter	Without Dilator	With Dilator	p value
% Correct Identification	78%	99%*	0.04
Intensity Rating	7.9	12.0*	0.008
Sniff Mean Flow Rate	45.3 l/min	54.9 l/min*	0.03
Sniff Max Flow Rate	80.0 l/min	92.8 l/min*	0.030
Sniff Volume	1.09 l	1.54 l*	0.001
Sniff Duration	1.4 sec	1.7 sec*	0.008

* Significantly different than without dilator, paired t test

and were more likely to correctly identify the odorants when compared to the intensity ratings and number of correct identifications made without the dilators.

The presence of a nasal dilator increased the maximum sniff flow rate, the average sniff flow rate, the sniff volume and the time of the sniff. These effects were consistent across subjects and, as can be seen in Table 1, were highly significant (p values ranging from 0.03 to 0.001). These results are consistent with neurophysiological data in which the magnitude of the olfactory response was related to the sniff volume and duration and to the sniff flow rate and odorant delivery rate (Mozell et al., 1984).

DISCUSSION

The importance of an increased nasal vestibule size in regards to olfactory ability is related to the path that gas molecules take on their trip through the nasal cavity. Masing (1967) has demonstrated in models that there is a distribution of nasal fluid flow from the floor to the olfactory area depending on the location in the nostril of entry. For example, central and medial flow rises vertically into upper nasal areas whereas dorsal, ventral and lateral flows are refracted spirally and travel mainly through the lower part of the nasal cavity. From our data, we would predict that a greater percentage of flow would rise vertically in the nasal cavity if Masing's experiments were repeated with a nasal dilator in place. This increase in flow could deliver more odorant molecules to the olfactory receptors and so influence olfactory function.

As shown in the above MRI analysis of nasal volumes, nasal dilators increased the cross-sectional area at the level of the nasal valve. Because the nasal valve is the point of maximum resistance, dilation of the nasal valve would naturally significantly reduce the overall nasal resistance. To reconcile the observations that the sniff parameters of flow rate and volume increased while the nasal resistance decreased, it is hypothesized that the sniff pressure (the negative pressure developed at the nasopharynx by the lungs) remained relatively constant. That is, if a subject applied the same negative pressure to a reduced nasal resistance, flow rate and volume must increase.

The increase in nasal flow rate and volume seen when subjects have a lower nasal resistance is somewhat in opposition to the observations of Youngentob et al. (1986), who had subjects rate the intensity of odorants as they sniffed against an increased nasal resistance. Youngentob observed that, in the face of increasing nasal resistance, subjects proportionally increased sniff vigor causing nasal flow rate to remain unchanged.

An obvious difference between the Youngentob experiment and the current work is that Youngentob increased nasal resistance whereas in the current study nasal dilators decreased nasal resistance. One hypothesis to explain these seemingly incongruous results is that the odor sampling system is regulated to maintain a minimum sniff flow rate (as would be encountered in the case of increasing nasal resistance). This minimum flow rate might be maintained because, as suggested by Laing (1982), this condition is "close to that providing optimum odor perception." However, when nasal resistance is decreased, as happens with the nasal dilators (but likely does not happen often in nature), flow rate and volume increase beyond the minimum necessary to maintain olfaction. Since this increase does not detract from olfactory perception, a system may not have evolved for this high-end nasal flow regulation.

The increase in the time of the sniff seen with nasal dilator is perhaps less clear but may be related to the increase in inspired volume. That is, the sniff time is increased to accommodate, in part, the larger sniff volume.

Nevertheless, these data show that, at least over the short term, nasal dilators have a dramatic effect on sniff characteristics. These changes in sniff characteristics must then be considered in evaluation of the effect that nasal dilators have on odorant threshold, identification and intensity ratings.

As shown above, nasal dilators increase odorant identification and lower odorant threshold and increase perceived odorant intensity (Hornung et al., 1997). While perceptual size constancy (where perceptual strength is judged in relation to sniff vigor) has been evoked to explain the changes in intensity ratings with changes in nasal airflow (Youngentob et al., 1986; Hornung et al., 1997), the current results can most easily be explained by changes in the delivery of odorant molecules to the olfactory receptors. Recall that the nasal dilator increased the size of the nasal valve. Increasing the size of the nasal valve changes the resistance characteristics of the nose which, in turn could influence the distribution of nasal airflow between pathways that lead toward and away from the olfactory mucosa (Keyhani et al., 1995). That is, nasal dilation may increase the proportion of inspired odorant molecules that are directed to the olfactory mucosa and which would be, therefore, available for odorant perception.

In addition, the results reported above clearly demonstrate that each of the parameters of the sniff increased with the application of nasal dilators, e.g., sniff volume, sniff flow rate, sniff duration. An increase in these parameters would then increase the number of odorant molecules available for detection, identification and perceptual intensity. These two mechanisms (increase in nasal airflow and redirection of nasal airflow) are not mutually exclusive. That is, they could be acting in concert to increase the delivery of odorant molecules to the olfactory receptors.

The present results may provide the basic science background for a simple clinical test to diagnose olfactory disorders that are conductive in nature.

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