J. Soc. Cosmetic Chemists, **15,** 541-547 (1964)

AN EVALUATION OF THE CONTRIBUTION OF LUNG AIR TO TOTAL ORAL ODOR

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ABSTRACT

This study is concerned with the contribution to oral odor of the air which had been in contact with bronchii and alveolar processes of the lung of subjects whose mouth odor was being observed. A Fair and Wells osmoscope was modified to allow air from the test subject to be exhaled directly into it either *via* the nose or the mouth. Tests performed on nine subjects and duplicated by two trained observers showed that the lungs normally contributed no odor to that generated in the oral cavity. However, heavy smokers were found to have a tobacco odor in their lung air, and the odor of garlic in an individual whose diet normally included foods flavored with garlic was found in the lung air sample.

Introduction

A study was undertaken to determine the extent of involvement of the air which has been in contact with the bronchii and alveolar processes of the lungs of subjects whose mouth odor was being observed by trained odor evaluators using the Fair and Wells osmoscope (1). A preliminary study had shown that the method of evaluation of mouth odors by having the subject breathe deeply twice and then exhale into an osmoscope at the end of the second inspiration was inadequate.

A technique was then devised and tested experimentally which does give a valid separation of the observed odor attributable to the oral cavity and odor attributable to lung air. This method was based upon the following analyses. Breathing deeply twice through the nose or mouth has the effect of diluting the lung air total capacity (Fig. 1). The release of the complemental air (Fig. 1) of the lungs into the osmoscope moves the standing column of air out through the osmoscope in the following order: air in the osmoscope, air in the mouth, air from the velopharyngeal area, air from the

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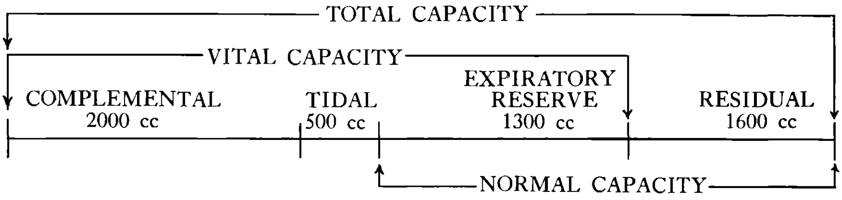

Figure 1.—A breakdown of the volumes of air in the lung. The *tidal* volume is that amount of air that enters and leaves the lung during the natural breathing cycle. The amount of air which can be inhaled through a maximum effort over and above tidal volume makes up the *complemental* volume (also referred to as the *inspiratory reserve*). The amount of air which can be exhaled after the tidal air has escaped naturally is the *expiratory reserve* (also referred to as the *supplemental* volume). The sum of the tidal air volume and the expiratory reserve is the *vital capacity*. The *normal capacity* is the volume of air remaining in the lung after a natural effortless expiration of air. A volume of air remains in the lung even after the most vigorous possible expiration efforts. This volume of air is the *residual* air. The sum of the vital capacity and the residual air volume make up the *total capacity* of the lung. Although the actual amounts may vary widely with individuals, the ratios between the volumes remain more or less constant (cf. Wiggers (2)).

laryngeal areas, air from the bronchial areas, air from the alveolar environs. Since any detected odor considered objectionable is final for a given osmoscope setting (settings from 0 to 6 show the relative intensity of the odor, with 6 denoting an odor of high intensity), any objectionable odor in any part of the air column is totally included in the test. As expected, readings obtained by use of this method were found to agree exactly with, or to parallel closely at a lower value, the readings obtained by the use of the standard mouth odor testing procedures. Such factors as the length of time the air is in contact with a given interface, the amount of air dilution by prebreathing, and the partial pressure generated by the exertion of holding the breath while the osmoscope is inserted in the subject's mouth all contribute to the results obtained in the standard mouth odor testing procedures.

In order to isolate air which had been in contact with the alveolar and bronchial processes, a new technique based upon the following rationale was devised.

In obtaining air from the alveolar and bronchial regions, it is necessary to expel the complemental and tidal volumes as well as a portion of the expiratory reserve air, if any dilution procedure is to be employed. The admixture of odor-bearing air within the oral environs will follow either solution or vapor diffusion laws. Two phenomena must be considered in the transfer of odors from the surface of the oral cavity. The first is dependent upon the difference in concentration of the odor substance between the surface of the oral tissues and the air immediately above. This is important when lung air is flowing across the surface. The odors can be shown to transfer into the surrounding air at an interfacial rate porportional to the magnitude of the gradient of any particular odor in the two gaseous environments meeting at an interface in accordance with Fick's Law. Therefore, in any experimental design measuring odor in the lungs *via* the mouth route, it is necessary to ensure that there is no stoppage of air rushing from the lungs into the osmoscope.

Consideration of equation 1(where c is the concentration of the diffusing substances at the interface and where dc is the difference in amount of substance with reference to each side of the interface) indicates that the transfer rate $d\mathcal{Q}/dt$ increases proportionately as the concentration difference (dc) becomes large; thus the amount of odor transferred ($d\mathcal{Q}$) will still be a number of important magnitude at a given point x above the surface as (dt) becomes very small.

$$\frac{d\mathcal{Q}}{dt} = -\Delta \left(\frac{dc}{dx}\right), dy, dz \qquad (1)$$

where

Δ = the diffusion constant of the odor vapor and
$\mathcal{Q}$ = the amount of odor passing in the direction x through the interfacial area dy, dz in the interval dt.

Any stoppage of air in the oral cavity will increase the transfer interval and allow more odor to transfer from the oral tissues. It is also known that at least some of the odor-contributing components are not at the oral tissue interface but are generated through the continuing breakdown of oral tissue and debris components directly into the air above the interface surface in the oral cavity. These gases are free to diffuse from pockets in the oral cavity into the air stream flowing from the lungs. It can be shown that several of the malodorous components encountered are low density gases (densities calculated from molecular weights of less than 200). It may then be demonstrated by Graham's Law that the rate of transfer of such gases will be inversely proportional to the square roots of the densities of those gases. The time necessary to transfer detectable quantities of low density gases and classes of substances highly sensitive to the human nose (some mercaptans are detectable in concentrations of less than one part in 10^9) across an interface becomes extremely small, in the order of milliseconds.

A further advantage obtained from the rushing column of lung air is a reduction of the net diffusion into the column at the oral interfaces, since the velocity pressure to overcome resistance placed on the air column by the osmoscope increases the gas pressure at these interfaces.

Other stipulations for the success of a method analyzing lung odor are that the subjects be healthy, free of sinus conditions, and that they have been given sufficient time to release from the lungs and mouth any dissolved substances, such as ethanol and oxidation products prior to detoxification in the liver.

METHODS

The experiment designed to determine the relative contribution of lung air to the detectable odor of the mouth was divided into three parts.

Equipment used in the study consisted of an osmoscope modified by the addition of a bypass valve which would allow a subject's expired air to be channeled either into the room air in the bypass position or through the osmoscope in the pass-through setting. In this way, the last $^1/_3$ or $^1/_2$ of his expired volume (reserve lung air) could be directed through the osmoscope. Thus, an uninterrupted flow of air, a necessity in carrying out measurements 1a. and 1b. below, could be obtained.

For the measurement of nose-expired air in Part II a double tube adjustable endpiece, fitting tightly into the nostril of the subject, replaced the mouthpiece used in tests which evaluate mouth-expired air.

Part I, 1a. Measurements of *residual lung air* (Fig. 1). External air was inhaled through nose into lungs, with the vital lung capacity changed twice. Inspiration of a third volume equal to the lung's vital capacity was allowed to equilibrate with its environment for ten seconds. Total exhalation was then passed through the mouth at a rapid velocity.

Part I, 1b. Measurement of odor in nose-*inspired tidal lung air* exhaled by mouth and pushing mouth, velopharyngeal, and pharyngeal air ahead of it.

Instructions Given to Subjects (Procedure 1a. *vs.* 1b.)

1. "Lung" Odor: (Exhaled through mouth)
Take two deep breaths through the nose. Take a third deep breath, hold for ten seconds, then exhale slowly. When approximately one-half of the breath has been released, turn the bypass valve from the bypass position to the pass-through position.

Instructions Given to the Odor Observers

1. The osmoscope will be inserted at the beginning of the procedure, and the odor observer will make the analysis after the bypass valve has been placed in the pass-through position.
2. Place the osmoscope fitted with the bypass valve and mouthpiece into the subject's mouth.
3. In order not to saturate the odor observer's sense of smell, lung odors are to be run first.

Part II, 2a. Measurement of odor in *residual lung air* inspired through the nose, as described in 1a. of this section, but exhaled totally through the nose.

Part II, 2b. Measurement of odor in nose-inspired air as described in 1b. of this section.

Instructions Given to Subjects (Procedure 2a *vs.* 2b)

1. Mouth Odor:

Method as described for Part I, 1b. of this section.

2. "Lung" Odor: (Nostril exhaled air)

Take two deep breaths through the nose. Take a third deep breath, hold for ten seconds and exhale slowly. When approximately one-half of the breath has been released, turn the bypass valve to the pass-through position.

Instructions Given to the Odor Observers

The osmoscope will be fitted with the nostril endpieces inserted into the subject's nose at the beginning of the procedure. The odor observer will make the analysis after the bypass valve has been placed in the pass-through position.

Part III, 3. A bolus of cinnamon flavored gum was placed in subject's mouth, with instructions to the subject to chew bolus slightly but to swallow no saliva. Odor measurement analysis of gum odor followed the procedures described in Parts I, 1a. and I, 1b. of this section.

Instructions Given to Subjects (On subjects having osmoscope reading of 0).

Place the piece of gum in your mouth and chew one minute. Do not swallow any saliva. Follow instructions in Parts I and II of this study.

Instructions Given to the Odor Observers

Follow the instruction in Parts I and II of this study.

Results

The results of this study are given in tabular form. Table I shows data

Table I—Lung Odor *vs.* Mouth Odor Study
(Readings Before Breakfast)

	Osmoscope Readings	
Subjects	Reserve Lung Air Exhaled *via* Mouth (1a.)	Mouth Odor (1b.)
Ca	6.0*	6.0*
Fe	6.0‡	6.0
Hu	6.0	6.0
Jo	6.0	6.0
Mo	6.0	6.0
Ne	5.0	6.0
Sc	5.0	6.0
Tu	6.0	6.0
Wi	6.0†	6.0

* Odor of garlic.
† Odor of cigarette smoke. No cigarette smoke odor observed in mouth odor.
‡ Had trouble following directions.

obtained when the individuals tested inhaled through their noses and exhaled through their mouths (the second column in the table). These data are compared with data obtained when these same individuals inhaled and exhaled through their mouths. Osmoscope readings of 6.0 denote odors of the highest intensity whereas a zero reading on the osmoscope indicates that no odor was discernible. A slight lessening of the odor is indicated in two cases when the nose-inhaled air was exhaled through the mouth. Table II summarizes the data obtained from the same test group. All measurements made in this study were repeated independently by two trained odor observers. The readings given in the tables are the averages of the reading obtained by each observer. Only a few variations in readings obtained by the two observers appear in the third and fourth columns of Table II where osmoscope readings of 1.5, 0.5, and 3.5 are shown. Because of its design, the osmoscope is much more sensitive to small amounts of odor and thus subject to greater variations in readings at the low odor intensity end of the scale (readings on the osmoscope from 1.0 to 4.0). Preliminary testing had indicated that lower odor values could be expected when expiratory reserve air was exhaled through the nose. After mouth odors were tested in the manner described in Part I, 1b. of the Methods section (column 2, Table II), the odor observers waited ten minutes to allow their noses to become clear for the evaluation of slight odors. So that the odor observers would have maximum sensitivity to odor, the subjects were examined in the order shown by the columns in Table II. The order of testing of individuals was also held as shown. No effect of saturation was noted even in the case of the individual following the subject having a heavy tobacco odor in his lung air. To be certain that odors in

Table II—Lung Odor *vs.* Mouth Odor Study
(Readings after Lunch)

	Osmoscope Readings (In the Order Taken)		
Subjects	Mouth Odor (1b.)	Reserve Lung Air Exhaled *via* Nostrils (2a)	Reserve Lung Air Exhaled *via* Mouth (1a.)
Tu*ǁ	6.0	1.5	5.0
Jo*	6.0	0.0	3.0
Cu*ǁ	6.0	0.0	5.0
Wi†ǁ	6.0‡	6.0‡	4.0‡
Hu*	6.0	0.0	1.0
Mo*	6.0	0.0	0.5
Sc*	6.0	0.0	0.5
Fe§	6.0	0.0§	3.5§

* Nonsmoker.
† Heavy smoker.
‡ Odor of tobacco only.
§ Had trouble following directions.
ǁ Did not brush teeth for 18 hr before test.

the oral cavity did not mix with the air column moving from the lungs out through the nose, an analysis was made on three individuals who showed no odor when tested by the method described in 1b. earlier in the paper. Table III shows the results of tests made on these individuals when the

TABLE III—ADMIXTURE OF PLANTED ODOR IN THE MOUTH*
(On Subjects Having Osmoscope Readings of 0)

	Average Osmoscope Readings (In the Order Taken)		
	Reserve Lung Air (1a.) Exhaled *via* Mouth	Reserve Lung Air (2a.) Exhaled *via* Nostrils	Mouth Odor (1b.)
Immediately prior to planted odor	0.0	0.0	0.0
Immediately following planted odor	4.0†	0.0	6.0†

* Cinnamon Gum Bolus.
† Odor of Cinnamon.

odor of cinnamon was planted in their mouths. These data show that lung air directed through the oral cavity does pick up the odor in a short time (column 1, Table III). No transfer of a planted odor from the oral cavity into the air inhaled and exhaled through the nose was observed, (column 2, Table III) while the odor was immediately observed when the subjects inhaled and exhaled through their mouths (column 3, Table III).

CONCLUSIONS

1. It is possible to isolate the air which has been in contact with the alveolar and bronchial processes and to subject this air to osmoscopic evaluation.
2. The transfer of odor components from the mouth surface into air passing over the oral interfaces is extremely rapid, probably in the order of fractions of a second.
3. The contribution to osmoscopically measurable odor by air which has equilibrated with alveolar and bronchial interfaces to the odor measured from the mouth of normal healthy individuals being tested using mouth odor analysis osmoscopic techniques is negligible.

(Received January 2, 1964)

REFERENCES

(1) G. M. Fair and W. F. Wells, *U. S. Patent* No. 2,136,844 (1938).
(2) C. J. Wiggers, *Physiology in Health and Disease*, 4th ed., Lea and Febiger, Philadelphia, 1944, pp. 384–389.