ORIGINAL ARTICLE

Quantifying the ice test in halitosis patients

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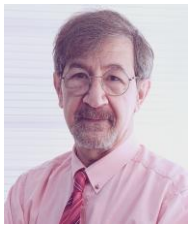

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Title: Quantifying the ice test in halitosis patients

Abstract

Objectives:

Odor is in the oral air when halitosis occurs orally. Since oral gases shrink when cooled, oral halitosis disappears when a piece of ice is placed in the patient's mouth. This physical phenomenon provides a basis for distinguishing oral from non-oral halitosis, but has yet to be quantified.

Material and Methods:

The records of twenty-nine halitosis patients were retrospectively analysed. Gas concentrations were measured with a portable gas detector (IBRID-MX6) before and after cooling the mouth with 1x1x2 cm ice for 30 seconds. Patients were asked to rate their halitosis. Tongue temperature and oral gas concentrations were compared with paired t-tests and one-way ANOVA.

Results:

The tongue cooled by an average of 13.09 °C with ice (from 36.0 to 22.4 °C). The mean values of the concentrations of VOC, NH_3, H_2S, and H_2 decreased proportionally with cooling: 74.10, 77.51, 81.26, and 96.12%, respectively. The self-reported halitosis score decreased from 4 to 0 ($n=29$, $p<0001$)

Conclusions:

It can be concluded that the ice test suppresses oral gases in sufficient quantity to detect oral halitosis.

Keywords: ammonia, bad breath, diagnosis, halitosis, hydrogen sulfide.

Introduction

The odor originates from the mouth air in patients with oral halitosis by putrefaction of protein artifacts by oral bacteria whereas it originates from the nasal or alveolar air in patients with non-oral halitosis with some systemic pathologies.[1]

It has differential diagnostic value for oral or non-oral halitosis. Comparison of the odours of gases emanating from the nose and mouth was used to distinguish the source of the odour. [1,2] The organoleptic method (sniffing the patient's mouth or breath) is not reproducible.[3]

A previously described technique can partially separate oral, nasal, or alveolar gases, with contamination of nasal air (2.8%) and alveolar air (5.0%) by oral hydrogen sulfide (H_2S); alveolar air (2.06%) and oral air (4%) by nasal organic gas; and nasal air (18.43%) and oral air (9.42%) by alveolar H_2.[4]

Nevertheless, there is a need for a new, practical, easy-to-use, and objective method to distinguish the origin of halitosis. Cooling of the mouth may be an alternative technique. It is known that cooling the oral mucosa to as low as 20 °C with ice chips in conjunction with chemotherapy reduces the severity of oral mucositis. [5] Cooling devices for patients receiving myeloablative therapy prior to stem cell transplantation. [6]

Gases shrink when cooled. According to Charles's law, the volume of a given gas at constant pressure is directly proportional to its absolute temperature.

$V_1 / T_1 = V_2 / T_2$

(where "V" is the volume of a gas and "T" is the absolute temperature)

The volume of the oral cavity is 2.7 x10-5 m^3 on average. [7] When the volume of oral gases is reduced by cooling, halitotic gases also shrink and lose volume according to Amagat's law. Amagat's law explains that the volume of a gas mixture is simply the sum of the partial volumes of the individual components. The volume of each halitotic gases decreases.

$V_t = V_1 + V_2 + V_3$ …...

(where V_t is the total volume of the gas mixture and V_x is the partial volume of the individual halitotic gases)

Therefore, it can be hypothesized that when the oral cavity of halitosis patients is cooled with a piece of ice, the odorous gases in the mouth condense and become non-volatile, so halitosis suddenly disappears for a while. Disappearing halitosis indicates that it is oral halitosis, otherwise it is non-oral halitosis. This simple test can be performed by doctors as well as by patients themselves. It can be used to assess whether oral or non-oral halitosis is present.

In the literature, this test has been successfully used to distinguish between subjective and objective halitosis,[8] but it has not been quantified. The aim of this study was

not check the validity of the ice test but to quantify the change in oral gas concentration when the mouth is cooled with a piece of ice.

Material methods

Patient selection

Twenty-nine patient records (16 male, ranging from 19 to 61, mean age 24 years) who had attended the halitosis clinic were retrospectively reviewed. Patients with periodontal unhealthy (pocket depth >5mm) or having tongue coating (Winkel index 3/6) were enrolled. It was confirmed that their oral H2S concentrations were above 1.2 ppm. None of the subjects were pregnant or expecting menstruation, and none were consuming medications or odor-intensive foods. All subjects were fasting for at least 4 hours. This project was reviewed and approved by the Municipal Hospital Ethics Committee (2021/2566). Participants gave written informed consent.

Gas measurement protocol:

To individualize control data, each patient's baseline oral gas levels VOC, NH_3, SO_2, H_2S, and H_2 were measured using a portable multigas detector (IBRID MX6 C526R311, IndSci), following to a previously described method.[4] While breathing through the nose, the subject places his left index finger between the upper and lower left molars, and gently bites leaving a space between the anterior teeth. The aspirating tube is connected to the gas detector and the tip placed on the dorsal tongue. [4]

Patients were then asked to rate their own halitosis from none (0) to very strong (5). The baseline values of each participant VOC, NH_3, SO_2, H_2S, H_2 in the oral air were used as individual control data.

Cooling procedure:

Tongue temperature was measured using an infrared thermometer (Voltcraft IR 500-12S, resolution 0.1 °C) at two different locations (apex and near the terminal sulcus).

A 1x1x2 cm^3 piece of ice from the freezer compartment of a refrigerator was placed in the patient's mouth. The ice piece was held on the tongue surface for 30 seconds. Then the temperature of the tongue was measured at the same locations and recorded. Immediately afterward, oral halitosis was measured again using the same gas measurement protocol. Patients were asked to rate their own halitosis again.

Statistical Methods:

statistical analysis was performed using the MedCalc v19.8 software program (MedCalc Belgium). The data were tested for comparability using the paired t test. For comparison of significant differences between means, the one-way test ANOVA was performed. Multiple

comparisons were conducted using Tukey's post hoc test. A p value of less than 0.05 was considered statistically significant. Graphs were created using SigmaPlot v12.5 software and fitted to the curve.

Results

Cooling the mouth decreased the tongue surface temperature from an average of 36.0 to 23.3 °C. The mean temperature change was 13.09 °C (between 9.5 °C and 15.9 °C, median 13.1 °C) (Table 1).

At baseline, the mean self-reported halitosis score was 4.0 (median, 4; n=29) which decreased to 1 (median, 0; n=29, p=0.001) immediately after the ice test.

The concentrations of the oral gases VOC, NH_3, H_2S, and H_2 decreased proportionally with temperature: 74.10, 77.51, 81.26, and 96.12%, respectively. Since SO_2 did not change, it was not evaluated. (Table 2 and Figure 1)

Gas concentrations decreased proportionally with temperature. (Figure 2)

It was found that the concentration difference for VOC and NH_3 was much larger at colder temperatures than at warmer temperatures. (Figure 3)

Table 1 Temperature changes on tongue surface with ice piece (n=29)

Tongue area	Average temperature (^oC)	
	Initial	After cooling
Apex	35.6 ±2.1	20.3 ±1.9
Terminal sulcus	36.4±1.3	24.5 ± 2.0

Table 2 Average values of oral gas concentration changes with cooling (n=29)

	Initial concentrations (ppm)		After cooling (dT=13.09 ^oC)	
Gases	Min-Max	Mean (±SD)	Min-Max	Mean (±SD)
VOC	0.6-6.0	2.78 (±1.23)	0.62-0.72	0.72 (±0.62)
NH_3	1.0-6.0	2.89 (±1.78)	0.81-0.65	0.65 (±0.81)
SO2	0.0-0.0	0.0 (±0.0)	0.0-0.0	0.0 (±0.0)
H_2S	1.2-7.8	3.26 (±1.61)	0.0-2.0	0.61 (±0.58)
H_2	4.0-103.0	33.69 (±30.3)	0.0-9.0	1.31 (±2.88)

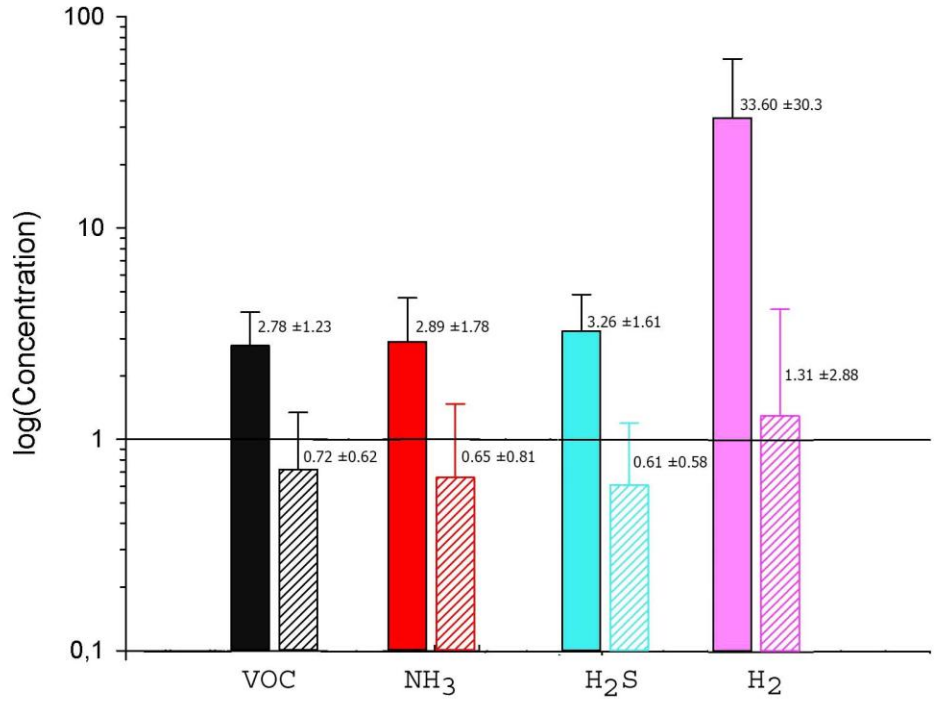

Figure 1 Oral gas concentrations before and after cooling the mouth. SO_2 was not shown.

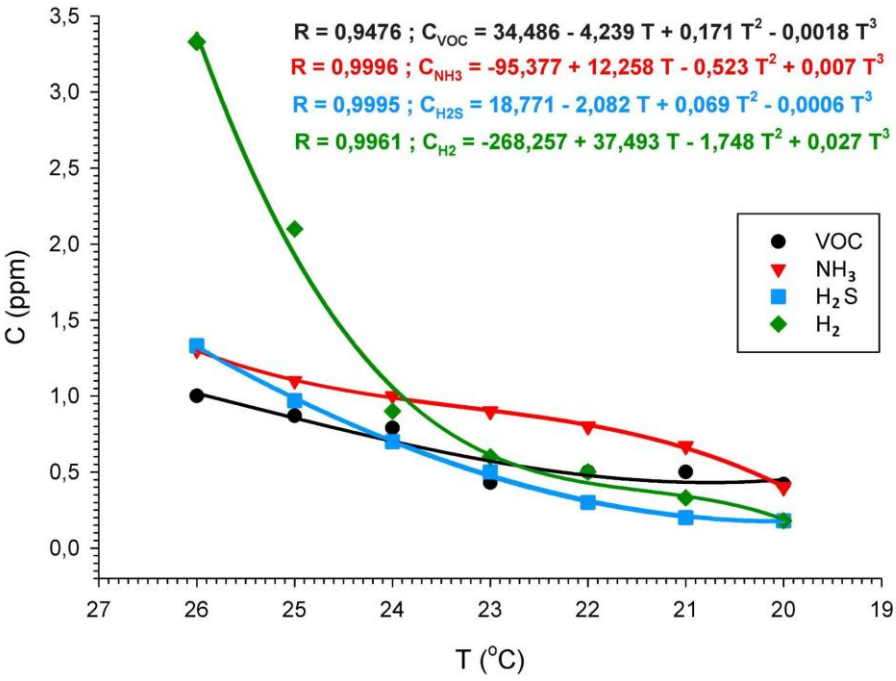

Figure 2 Change in the concentrations of oral gases in proportion to decreasing temperature. SO_2 was not shown

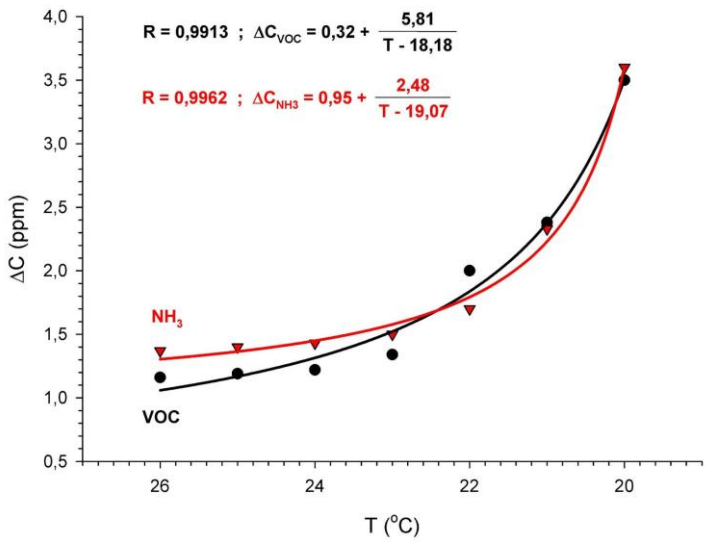

Figure 3 Concentration difference was found correlated with temperature for VOC and NH_3 but not for H_2S and H_2.

Discussion

Changes in gas concentration:

Oral gases collapse, lose energy, and become less volatile when the mouth is cooled with a piece of ice. Although sulfur family gases are the main cause of most halitosis cases, ammonia or organic gases also contribute to halitosis.[3] In this study, not only H_2S but also other halitotic gases were reduced by cooling. The ice test affected all gases, albeit to varying degrees.

The change in gas ratios was greater than expected. The tongue dorsum temperature decreased from 36.4 °C (T1=309.4 K) to a minimum of 20.3 °C (T2=293.3 K). According to Charles's law, initial gas concentrations are expected to decrease by only 1.05 times (T1/T2). However, in this study, the gas concentrations were found to decrease by 3.8 to 25.7 times (VOC and H_2, respectively). It is possible that some of the oral gases are dissolved in the chilled saliva or in the cold water of the melting ice. The melting of ice in the oral cavity increases the amount of liquid in the oral cavity, which also decreases the halitosis. According to Henry's law, the solubility of gases in water, increases when the temperature decreases. [9] The solubility of NH_3 in water is 340 g/L (at 36 °C) and 500 g/L (at 22.4 °C). The solubility of H_2S is 2.5 g/L (at 36 °C) and 3.9 g/L (at 22.4 °C), and that of H_2 is 0.0014 (at 36 °C) and 0.0016 g/L (at 22.4 °C). [10] In this experiment, the tongue surface cooled to 22.4 °C, but the oral cavity was probably colder than the tongue, so more gas dissolved than the amount calculated here. The water solubilities are consistent with the ratios of change in gas concentrations found in this study (Table 2).

The sharp decrease in oral gas concentrations with cooling can be explained by the "kinetic theory" of real gases. Gas molecules get closer to each other at low temperatures. Attractive forces between the molecules increase and tend to pull the molecules closer together, resulting in a smaller volume than expected from the volume calculated using the ideal gas law. Eventually, these forces lead to liquefaction;[11] which reduces the vapour concentration of halitotic gases in the mouth cavity.

Another possible mechanism for reducing gas concentration may be related to bacterial cells in the tongue biofilm. Microbial metabolism is rapidly slowed when the temperature is lowered. Oral bacteria are adapted to a body temperature of 35-37ºC. The metabolic rate (and growth rate) can be rapidly reduced (within seconds) when the temperature is lowered by 10ºC, and this may be another mechanism for reducing oral halitotic gas concentrations.

Similar studies in the literature have attempted to reduce oral H_2S concentrations with using different concentrations of $ZnCl_2$ rinse. Initially, 1.7 ppm of oral H_2S was reduced to approximately 0.5 ppm by rinsing with 3 mM $ZnCl_2$ and to around 0.1 ppm by rinsing with 12 mM $ZnCl_2$.[12] Another study showed that oral gases VOC, NH_3, SO_2, H_2S, and H_2 decreased by 93.65%, 72.45%, 0%, 89.27%, and 93.06%, respectively, after rinsing with 20 mM $ZnCl_2$. [13] However, no publications dealing with oral gases by cooling the mouth cavity were found to compare the results of this study.

The tendency of cooled halitotic gases to decrease:

The derivatives of the concentration curves exhibit a tendency to decrease. Below 23.0 °C, the decreasing trend of the gas concentrations becomes more stable. (Fig. 2) In order from the smallest to the largest value, the derivatives (at 22 °C) of NH_3, VOC, H_2 and H_2S were found to be -7.4, -3.4, -3.2, and -0.3 ppm/^{o}C, respectively. (data not shown) It was calculated that the fastest decrease was for NH_3 (7.4 ppm/°C) and the slowest for H_2S (0.3 ppm/°C). The negative derivatives indicate that the decreasing trend continues at lower temperatures. This means that more cooling would result in more reduction of the mouth gases.

Limitations:

There are some limitations to this study. A total of 3481,[14] thousands,[15] 1840, [16] 400–700,[17] or 694[18] compounds can be detected in the human breath of individuals with or without halitosis. Any of these gases can be assumed to be a possible cause of halitosis at any time.[3] However, the gas detector (MX6) used in this study has one photoionization detector and four electrochemical gas sensors. According to the MX6 user manual, the photoionization and hydrogen sensors are sensitive to more than 72 volatile compounds and

116 organic gases, including the major halitotic gases such as H2S, methylsulfide, dimethyl sulfide, alcohols, aldehydes, ketones, ammonia.

The solubility of VOCs depends on additional factors such as the polarity of the particular organic compound and the salinity of the solvent.[19] These factors were not considered in this study.

In addition, this study does not cover alterations in nasal or alveolar gases of non-oral halitosis patients. Only 3 patients with non-oral halitosis were admitted to the clinic over a period of approximately 1.5 months. One of them was pregnant, another was under 18 years of age, and the third did not want to participate in the study. Therefore, the opportunity to perform the ice test in the mouth of patients with non-oral halitosis could not be obtained.

A second group of patients with non-oral halitosis is not required because the aim of the study is not to compare oral and non-oral halitosis, but only to quantify the gas changes on cooling. The baseline oral concentrations VOC, NH_3, SO_2, H_2S, and H_2 for each participant were used as individualized controls.

SO_2 was expected to contribute to halitosis as it is one of the sulfur family gases. However, it was not found in the oral cavity in the literature[4,13] or in this study. Therefore, SO_2 was not evaluated.

Goals of the study:

It is clear that the ice test simplifies the management of halitosis cases. It may prevent the loss of time, money, or effort if halitosis disappears after cooling (positive test result). Otherwise, a negative test result indicates that further testing for extraoral conditions is needed. Furthermore, any halitosis patient can use the ice test at home. This way, patients with halitosis can decide which specialist not to visit. While a piece of ice is in the mouth cavity, the taste and olfactory receptors dispersed in the mouth or throat are cooled by the ice, the chemical stimuli on these receptors decrease, or less information is transmitted to the brain. Not only the taste receptors, but also the vibrotactile sensitivity of the tongue alters with cooling. The tongue's vibratory perception thresholds varied significantly ($P < 0.01$) when tongue surface temperature decreased from 33°C to 20°C. [20] Therefore, cooling the mouth with a piece of ice is a useful tool for distinguishing oral from non-oral clinical forms and for detecting the neurological clinical forms of subjective halitosis (chemosensory dysfunctions, dorsolingual olfaction, taste-odor confusion, etc.). This is an untargeted goal of this study but needs to be studied in more detail.

Conclusion:

It can be concluded that the ice test sufficiently suppresses gases in the oral cavity to distinguish between oral and non-oral halitosis.

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