Original Investigation

Risk Factors for Hazardous Events in Olfactory-Impaired Patients

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IMPORTANCE Normal olfaction provides essential cues to allow early detection and avoidance of potentially hazardous situations. Thus, patients with impaired olfaction may be at increased risk of experiencing certain hazardous events such as cooking or house fires, delayed detection of gas leaks, and exposure to or ingestion of toxic substances.

OBJECTIVE To identify risk factors and potential trends over time in olfactory-related hazardous events in patients with impaired olfactory function.

DESIGN, SETTING, AND PARTICIPANTS Retrospective cohort study of 1047 patients presenting to a university smell and taste clinic between 1983 and 2013. A total of 704 patients had both clinical olfactory testing and a hazard interview and were studied. On the basis of olfactory function testing results, patients were categorized as normosmic (n = 161), mildly hyposmic (n = 99), moderately hyposmic (n = 93), severely hyposmic (n = 142), and anosmic (n = 209).

INTERVENTIONS Patient evaluation including interview, examination, and olfactory testing.

MAIN OUTCOMES AND MEASURES Incidence of specific olfaction-related hazardous events (ie, burning pots and/or pans, starting a fire while cooking, inability to detect gas leaks, inability to detect smoke, and ingestion of toxic substances or spoiled foods) by degree of olfactory impairment.

RESULTS The incidence of having experienced any hazardous event progressively increased with degree of impairment: normosmic (18.0%), mildly hyposmic (22.2%), moderately hyposmic (31.2%), severely hyposmic (32.4%), and anosmic (39.2%). Over 3 decades there was no significant change in the overall incidence of hazardous events. Analysis of demographic data (age, sex, race, smoking status, and etiology) revealed significant differences in the incidence of hazardous events based on age (among 397 patients <65 years, 148 [37.3%] with hazardous event, vs 31 of 146 patients ≥65 years [21.3%]; $P < .001$), sex (among 278 women, 106 [38.1%] with hazardous event, vs 73 of 265 men [27.6%]; $P = .009$), and race (among 98 African Americans, 41 [41.8%] with hazardous event, vs 134 of 434 whites [30.9%]; $P = .04$).

CONCLUSIONS AND RELEVANCE Increased level of olfactory impairment portends an increased risk of experiencing a hazardous event. Risk is further impacted by individuals' age, sex, and race. These results may assist health care practitioners in counseling patients on the risks associated with olfactory impairment.

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Olfactory impairment may occur from a variety of causes, including aging and neurodegenerative disorders, head trauma, nasal obstruction, or viral upper respiratory tract infections, and has been estimated to affect up to 25% of the population.[1-5] Given the population's advancing age, olfactory dysfunction will become even more common in the United States, as 60% to 70% of patients 80 years or older have impairment.[2] Olfactory function plays a key role in our appreciation of the flavor of foods as well as the perception of odors both pleasant and unpleasant, and its impairment has been shown to decrease quality of life (QOL).[6] In a previous study, we demonstrated a link between olfactory impairment and risk of experiencing select olfaction-associated hazardous events.[7] However, further insight regarding such risks and factors that might modify them may allow health care practitioners to better counsel patients with olfactory impairment. For example, smoking has been shown to have a dose-dependent effect on olfactory function and thus may also have an impact on risk of hazardous events.[8,9] In addition, even with similar levels of dysfunction, olfactory deficits resulting from different causes could lead to different risks of hazardous events. For example, despite indications of intact olfactory nerves, patients with a head injury can exhibit significant impairment in olfaction.[4] This conundrum of head injuries in addition to the other associated neurologic sequelae make this pathologic condition particularly interesting. As such, the primary objective of this study was to determine which factors may affect the risk of olfactory-impaired patients experiencing specific hazardous events related to their impairment. Lastly, given potential changes occurring over time, such as improved home or workplace safety monitoring or even increased lay public or physician awareness of olfactory dysfunction, we also sought to determine if risk of such hazardous events was changing over time.

Methods

This study was approved by the institutional review board of Virginia Commonwealth University (VCU). The patient database of the Smell and Taste Disorders Center of VCU Health System (VCUHS), including data from 1047 patient evaluations, was reviewed. Database entries for each patient consisted of data obtained from a single clinical evaluation in the center, including patient history, physical examination findings, and olfactory test results. Historical data collected included demographics, smoking status, medical history, and etiology of olfactory or gustatory loss if known. As a routine part of this evaluation, patients were asked to complete an olfactory hazard questionnaire, asking whether they had experienced specific hazardous situations that are commonly associated with olfactory cues. This questionnaire included 5 questions: "Have you had any incidents while cooking which were caused by your smell disturbance? Specifically, (1) have you burnt pots and/or pans or (2) have you started a fire while cooking?" (3) "Were you ever unable to smell smoke from a fire?" (4) "Have you had any incidents in which natural gas was leaking and you were unable to smell it?" (5) "Have you ingested any spoiled foods or swallowed any toxic substances?" Each patient's responses to these questions were recorded as a yes or no response along with their demographic and medical data and the results of their olfactory function testing.

Prior to olfactory testing, nasal airflow was assessed for each nasal passage independently by occlusion of 1 nares while inhaling through the other. Nasal airway obstruction for either the right or left side was recorded if the patient reported difficulty or was unable to inhale through that nostril. Olfactory testing was performed using a standardized method developed at the University of Connecticut Chemosensory Clinical Research Center.[5] Olfactory detection threshold was assessed through a 2-bottle forced-choice paradigm. The patient was presented with 2 bottles, one containing an odorant (butanol) in deionized water and the other containing water alone (blank), and was asked to indicate which bottle had the odorant. The concentration of butanol in the odorant bottles was increased by one-third log steps beginning at 0.00061% and continuing up to 4% butanol if needed. The bottle containing the lowest concentration of butanol at which the patient was able to correctly select in 4 consecutive trials defined their odor detection threshold. Odor identification was assessed using common household products with well-known odors such as coffee, baby powder, and peanut butter presented in jars. Patients are asked to identify the odorant presented. Scores from both threshold detection (range, 0-50) and odor identification tests (range, 0-50) are combined to determine a composite score for each nostril (range, 0-100).[5] Right and left nostril scores were averaged to yield a global olfactory function score (range, 0-100). Olfactory function scores were used to place the patients in 1 of the 5 diagnostic categories: normosmic (range, 100-85), mildly hyposmic (range, 84-65), moderately hyposmic (range, 64-45), severely hyposmic (range, 44-15), or anosmic (range, 14-0).

Patients with obstructed nasal airways, younger than 18 years, with incomplete olfactory testing or with incomplete olfactory hazard questionnaires, were excluded from the study population. Data were extracted from the patient database and analyzed with SPSS (version 21; IBM Corp). Frequencies were computed to assess study population demographic factors. Binary logistic regression analysis was used to compare frequencies of occurrence of hazardous events between diagnostic categories based on level of olfactory function. Odds ratios were calculated to assess the relative risk of experiencing any olfactory related hazardous event for each diagnostic category compared with those with normal olfactory function. To test for changes in the impaired population over 3 decades, a binary logistic regression analysis was used. Cross-tabulations and the Pearson χ^2 test were used to test the effect of demographic metrics on the incidence of hazardous events. For all analyses, $P < .05$ was considered statistically significant.

Results

The VCUHS Smell and Taste Disorders Center database included data from 1047 patients evaluated between 1983 and 2013. A review of these records yielded 704 patients 18 years or older, with intact nasal airflow for which demographic data,

Table 1. Study Population Demographics and Level of Olfactory Function

Variable	Patients, No. (%)
Sex	
Male	340 (48.3)
Female	364 (51.7)
Race/ethnicity	
White	561 (79.5)
African American	127 (18.0)
Other	16 (2.1)
Age, y	
<65	539 (76.6)
≥65	165 (23.4)
Smoking status	
Nonsmoker	589 (83.0)
Smoker	115 (16.3)
Associated head injury	
No	531 (75.4)
Yes	173 (24.6)
Olfactory function	
Anosmic	209 (29.7)
Hyposmic	
Severely	142 (20.2)
Moderately	93 (13.2)
Mildly	99 (14.1)
Normosmic	161 (22.9)

medical history, olfactory hazards questionnaire, and olfactory function testing results were available, who comprised the study population. Demographic data and olfactory testing results for the study population are given in **Table 1**.

The impact of level of olfactory dysfunction on risk of experiencing any hazardous event was analyzed by binary logistic regression. As determined by odds ratios, the risk of experiencing hazardous events increased progressively with degree of impairment; with anosmic patients being almost 3 times more likely to experience an olfactory related hazardous event than individuals with normal smell function (**Table 2**). Viewed alternately, **Figure**, A, depicts the percent of patients at each level of olfactory function who had experienced 1 or more hazardous events. We also sought to determine if any changes in incidence of hazardous events had occurred over the past 3 decades. Figure, B, shows the percentage of all olfactory-impaired patients experiencing each type of hazardous event as revealed by testing over 3 decades. Events are ranked in order of prevalence in the impaired population, as averaged over the entire 30-year study period. By comparing the decades a relatively consistent rank order of the specific hazards was seen, although any apparent trends were not significant by a binary logistic regression.

We then sought to determine if any demographic metrics might have an impact on an individual's risk of experiencing a hazardous event. Analysis of risk by demographic factors using Pearson χ^2 test revealed a significantly higher incidence of hazardous events among female patients, those younger than 65 years, and African Americans, but not for smokers or those with associated head injuries (**Table 3**).

Table 2. Odds of Experiencing a Hazardous Event for Patients With Impaired Olfactory Function

Level of Olfactory Function	Odds of an Event[a]	*P* Value
Anosmic	2.94	<.001
Hyposmic		
Severely	2.18	.004
Moderately	2.06	.02
Mildly	1.30	.41

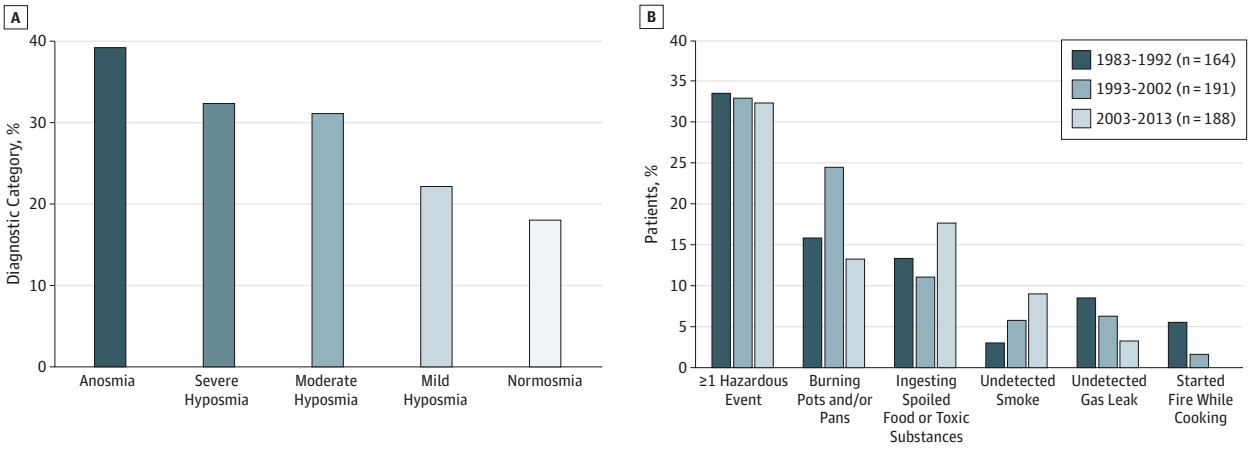
[a] Odds of experiencing a hazardous event for normosmic patient, 1.00.

Discussion

A National Health Interview Survey (NHIS) in 1994 determined that 1.4% of the US adult population self-report that they have some disorder of the sense of smell.[10] Application of the 2013 population estimate by the US Census Bureau would suggest that there are approximately 4.4 million adults in the United States with impaired olfactory function.[11] However, a 2002 epidemiological study using objective olfactory testing of individuals aged from 53 to 97 years revealed that 24.5% had impaired smell function, despite only 9.5% self-reporting a deficit.[1] The incidence increased to 62.5% for those older than 80 years. These data illustrate that self-reporting is a far less accurate indicator of olfactory dysfunction than objective testing in this age group. Thus, the number of people in the United States with olfactory dysfunction may be far more than 4.4 million at present, and with the anticipated aging of the population, this number may climb even higher.

Previous studies have shown that olfactory impairment can have substantial negative effects on patients' QOL by affecting enjoyment of foods and fragrances and even overall satisfaction with life.[6] In addition, 15% to 20% of olfactory-impaired patients older than 60 years have depressive symptoms.[12] Cognitive impairment has also been associated with impaired olfactory function.[13] These changes can have drastic effects on a patient's level of function and have been linked with loss of employment.[14] In a previous report, we demonstrated that the effects of olfactory impairment are not limited to QOL but can also increase patients' risk of experiencing hazardous situations.[7] The present study confirms this relationship, indicating an increasing incidence of hazardous events with increased level of olfactory impairment. Analysis of demographic factors showed that patients' age, sex, and race may modify their risk, with those younger than 65 years, women, and African Americans having higher risk. The cause of these associations is unclear. We may speculate that the higher incidence seen in those younger than 65 years may be due to an increased potential for exposure to hazardous situations. This may be due to a higher proportion of working patients with additional opportunities for exposure in the workplace. Also, patients in this age group may more frequently assume caregiver roles where they would be responsible for cooking in the home. Managing multiple responsibilities such as child care, professional commitments, and social obligations among this group may lead to distractions, potentially increasing the number of hazardous events. Conversely,

Figure. Incidence of Events and Hazardous Events



A, Percentage of patients at each level of olfactory function who experienced at least 1 hazardous event. The blue bars represent different degrees of olfactory impairment, from complete loss of smell (anosmic [darkest blue]) to normosmia (lightest blue). B, The incidence of hazardous events in olfactory-impaired patients (n = 543).

those older than 65 years may include a higher proportion of patients with age-related olfactory dysfunction. Typically, this occurs as a gradual decline in olfaction; thus, these patients may adapt to their diminished function over time and compensate for their impairment through increased vigilance, reducing their risk. Similarly, the effect of race on risk may reflect differences in home or work environments for the patients in our cohort. Further investigation is needed to better understand the observed differences in risk based on age, sex, and race, as innumerable confounding issues likely exist.

Surprisingly, we found no significant trend in the overall incidence of hazardous events over the 3 successive decades of our sampling. Regarding specific hazards, the number of fires caused while cooking and undetected gas leaks decreased, but these trends were not significant. Undetected smoke showed an increase over the 3 decades but was also not significant. We had postulated that improvements in building and safety standards would have led to an overall reduction in hazardous events, although this was not shown by the data.

Analysis of the potential impact of patient demographics surprisingly revealed no significant effect on occurrence of hazardous events based on smoking status or presence of an associated head injury. Given that olfactory impairment is among the many systemic changes associated with smoking and that the practice of smoking poses increased risk of causing fires, we had suspected a higher incidence of hazardous events among smokers. Potentially, the lack of increased risk seen may be attributed to the gradual nature of onset of impairment through the dose-dependent relationship of smoking and olfactory impairment. A gradual onset of impairment may allow better long-term compensation for the deficit. We had also suspected an increased risk in patients with head injuries; however, in this population the difference was not significant (P = .07). It is possible that a larger sample size would have made this difference significant. This lack of a significantly increased risk in patients with an associated head injury could be due to these patients' increased vigilance caused by heightened concern surrounding their head injury. It is likely that patients receive more extensive evaluation and possibly treatment for head injuries than for other common causes such as normal aging. This increased medical care could cause patients to be more aware of their environment and risks owing to fears of decreased perceptual ability.

There are several limitations of this study that are associated with both the manner and nature of data collected and the retrospective nature of the study. At the time of evaluation, patients were asked to indicate whether they had experienced any hazardous events during the entire period over which they had impaired olfaction, which for some had been years. Thus, between the time of onset of olfactory disturbance and evaluation, patients may have had fluctuation in level of olfaction or further change due to other factors such as normal aging that could affect their olfactory test results or their risk of hazardous events. For example, a patient who temporarily had complete anosmia that recovered to mild hyposmia or normosmia by time of testing may have experienced the same number of hazardous events as a patient who had long-standing and stable moderate or severe hyposmia. Recall bias may have contributed to an underestimation of hazardous events. Further, our database recorded whether patients had experienced each type of event but not the number of times each event was experienced, again leading to underestimation of events reported. Lastly, other factors not recorded in the database may have had an impact on the occurrence of events, including type of heating system or number of gas appliances in the home, safety measures such as smoke or carbon monoxide detectors in the home or workplace, presence of cohabitants in the home, and patients' occupations.

Further work is required to more definitively indicate the nature and degree of the effect of various factors on risk of occurrence of hazardous events. For example, inclusion of an in-depth interview detailing patients' living and working condi-

Table 3. Olfactory-Impaired Patients in Each Demographic Group Experiencing Hazardous Events

Risk Factor by Group	No. With Hazardous Event/Group Total, No. (%)	*P* Value
Age, y		
<65	148/397 (37.3)	<.001
≥65	31/146 (21.3)	
Sex		
Female	106/278 (38.1)	.009
Male	73/265 (27.6)	
Race		
African American	41/98 (41.8)	.04
White	134/434 (30.9)	
Head injury		
Associated head injury	55/140 (39.3)	.07
No associated head injury	124/403 (30.8)	
Smoker		
Nonsmoker	153/458 (33.4)	.61
Smoker	26/85 (30.6)	

tions, such as information about appliances and safety features in the home and workplace, could allow better determination of patients' potential exposure to hazardous situations, compared with their reported frequency of actually experiencing such events. Further longitudinal studies of olfactory impaired cohorts could be used to assess the impact of specific risk counseling on reducing occurrence of hazardous events. Also, a longitudinal study of patients including repeated testing of olfaction over time could assess the impact of changing olfactory function on risk. Some ongoing work that will complement this work is the inclusion of an olfactory assessment in the National Health and Nutrition Examination Survey (NHANES).[14] NHANES collects data through an extensive questionnaire and physical examination on an estimated 5000 patients each year who are a representation of the US population. This survey will give valuable data on the prevalence of olfactory impairment that can be compared with the many other data points collected in this study.

Conclusions

Our study demonstrates the substantial risks of experiencing hazardous events associated with impaired olfactory function and shows that these risks do not appear to be diminishing with time. However, patients are frequently unaware of these dangers, and recent reports have also indicated that patients are seldom educated by their primary care providers,[15,16] with as many as 95% not receiving any counseling prior to referral to specialized smell and taste centers. Results of this study can be used to guide health care practitioners and public health agencies to increase awareness and increase safety measures or help patients institute compensatory strategies. By providing focused risk counseling to olfactory-impaired patients, health care practitioners may help reduce individuals' personal risk of olfactory-related hazardous events.

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