Burn Pit Exposure Is Associated With Increased Sinonasal Disease

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Objective: The aim of this study was to determine whether self-reported burn pit exposure is associated with increased subjective and objective sinus disease. **Design:** A cross-sectional study was performed evaluating consecutive adult patients presenting to a US Military rhinology clinic. Demographics, medical histories, sinonasal quality-of-life scores, and nasal endoscopy examinations were obtained. Participants were divided into three cohorts based on self-reported exposure histories and outcomes compared. **Results:** One hundred eighty-six patients met the inclusion criteria, the majority of whom were male. Patients with burn pit exposure had worse Sinonasal Outcome Test-22 scores (49.9) compared with those deployed without burn pit exposure (31.8) or never deployed (31.5). Endoscopic findings demonstrated worse disease within those exposed (Lund-Kennedy score, 3.3) compared with the other cohorts (1.8 and 1.7, respectively). **Conclusions:** These novel findings suggest that deployment-related burn pit exposure is associated with increased subjective and objective sinus disease.

Keywords: burn pit, chronic rhinosinusitis, deployment, fine particulate matter, Middle East, NOSE, SNOT-22

The lining of the respiratory tract is constantly subjected to airborne toxins and particulate matter within the ambient environment. Before making its way to the capillary-rich alveoli of the lungs, inspired air is first warmed and filtered by the lining of the sinonasal cavity. Thus, the nose acts as a gatekeeper for airborne hazards entering the lower respiratory tract and serves as the initial site of particulate deposition and mucosal absorption. It is well described that exposure to environmental pollution increases the incidence of asthma.[1–3] However, the effects of environmental exposure on the development of sinus disease are less certain.

A retrospective cohort study of first responders involved in rescue efforts at the World Trade Center collapse on September 11, 2001, found that firefighters had significantly higher rates of chronic rhinosinusitis (CRS) than did emergency medical technicians, which was attributed to dust exposure from excavation efforts.[4] Population-based studies suggest that air pollution may worsen CRS symptoms.[5,6] As wildfires and environmental pollution increase globally, there is an increasing need to understand the specific mechanism by which these airborne hazards alter the respiratory tract and in particular the sinonasal cavity given its role as a first line of defense against such insults.

An extreme example of one such environmental exposure occurs with our service members. During post-9/11 military operations in the Middle East, US service members were exposed to high levels of sand, industrial emissions, fumes from ammunition discharges, and smoke from open-air burn pits (Fig. 1).[7,8] These open-air burn pits were utilized to help dispose of solid waste, wood, plastics, rubber, paints, solvents, human waste, other organic matter, munitions, lubricants, metal, and various combustible products such as jet fuel in forward operating bases.[9] Burn pit smoke contains multiple chemical and volatile organic compounds that cause cellular injury in both tissue and animal models.[10–12] In addition, burn pit smoke contains respirable particulate matter that is 10 μm in diameter or less (PM_{10}) and fine particulate matter that is 2.5 μm in diameter or less ($PM_{2.5}$), both of which have been linked to a variety of conditions, including asthma, pulmonary fibrosis, cognitive losses, hypertension, stroke, and cardiac arrest.[11]

A newly published systematic review has highlighted an association between burn pit exposure and subjective pulmonary symptoms but was unable to link exposure with objective pulmonary findings.[13] To date, most burn pit–related research has focused on pulmonary diseases, specifically asthma, bronchitis, and deployment-related distal lung disease.[14–17] With the Unified Airway Theory positing similar pathophysiologies between the upper and lower respiratory tracts in response to pathogens and allergens, as well as the central role of the sinonasal cavity as a gatekeeper to the lower respiratory tract, we hypothesized that service members with self-reported burn pit exposure would suffer worse subjective and objective sinus disease compared with those without exposure. This cross-sectional study uses quality-of-life measures and in-office nasal endoscopy findings to test this hypothesis and assess the impact of burn pit exposure on sinonasal disease.

METHODS

A cross-sectional study was performed for consecutive new patients presenting to a US Military treatment facility rhinology clinic from September 1, 2019, to March 31, 2020. The study was approved by the Naval Medical Center Portsmouth Investigational Review Board in compliance with all applicable federal regulations governing the protection of human subjects under protocol no. NMCP.2020.0070. The study population comprised active-duty service members, retired veterans, and civilian beneficiaries 18 years and older.

New patients received an intake packet consisting of the Sinonasal Outcome Test (SNOT-22) and Nasal Obstruction Symptom Evaluation (NOSE) questionnaires.[18,19] In recent years, a four-question deployment questionnaire has been included to ask about the number and location of previous deployments, previous deployment-related burn pit exposure (yes/no), and knowledge of the Veterans Affairs burn pit registry (yes/no). Four authors (C.J.H., C.D.M., D.C.A., and G.G.C.) retrospectively reviewed

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FIGURE 1. Burn pit at Camp Taji, Iraq, 2010.

medical records and obtained comprehensive medical, surgical, and social histories including, but not limited to, histories of upper and lower respiratory tract diseases, current or previous treatments for chronic sinusitis, previous sinus surgery, and tobacco use as provided by patient history. As indicated by chief complaint, patients were examined with nasal endoscopy at the time of their initial visit. These examinations were recorded and retrospectively scored in a blinded fashion according to the Lund-Kennedy endoscopic scoring system by the four investigators previously mentioned, who were randomly assigned.[20]

Patients were retrospectively divided into three cohorts based on self-reported deployment history and burn pit exposure: (1) patients who had never deployed (never deployed); (2) those who had deployed

TABLE 1. Demographics and Pertinent Medical and Surgical Histories for Each Cohort, Adjusted for Age, Gender, and Duty Status

	Never Deployed (1)	Deployed Without Exposure (2)	Deployed With Exposure (3)	Overall	Adjusted *P*	Tukey Test
Previous diagnoses						
Asthma					0.21	
Count (%)	60 (32.4%)	71 (38.4%)	54 (29.2%)	185		
Yes	7 (11.7%)	9 (12.7%)	12 (22.2%)	28 (15.1%)		
No	53 (88.3%)	62 (87.3%)	42 (77.8%)	157 (84.9%)		
Missing	0	1	0	1		
Allergic rhinitis					**<0.001**	**1–3, 2–3**
Yes	16 (26.7%)	17 (23.9%)	33 (61.1%)	66 (35.7%)		
No	44 (73.3%)	54 (76.1%)	21 (38.9%)	119 (64.3%)		
Missing	0	1	0	1		
CRSwNP					**0.001**	**1–3, 2–3**
Count (%)	60 (32.4%)	71 (38.4%)	54 (29.2%)	185		
Yes	4 (6.7%)	6 (8.5%)	15 (27.8%)	25 (13.5%)		
No	56 (93.3%)	65 (91.5%)	39 (72.2%)	160 (86.5%)		
Missing	0	1	0	1		
CRS without nasal polyposis					0.09	
Count (%)	60 (32.4%)	71 (38.4%)	54 (29.2%)	185		
Yes	2 (3.3%)	1 (1.4%)	5 (9.3%)	8 (4.3%)		
No	58 (96.7%)	70 (98.6%)	49 (90.7%)	177 (95.7%)		
Missing	0	1	0	1		
Past or present tobacco use					0.71	
Count (%)	58 (33.7%)	63 (36.6%)	51 (29.7%)	172		
Yes	13 (22.4%)	16 (25.4%)	15 (29.4%)	44 (25.6%)		
No	45 (77.6%)	47 (74.6%)	36 (70.6%)	128 (74.4%)		
Missing	2	9	3	14		
Prior FESS					**0.003**	**1–3, 2–3**
Count (%)	60 (32.4%)	72 (38.9%)	53 (28.6%)	185		
Yes	7 (11.7%)	8 (11.1%)	17 (32.1%)	32 (17.3%)		
No	53 (88.3%)	64 (88.9%)	36 (67.9%)	153 (82.7%)		
Missing	0	0	1	1		
Prior septoplasty					0.4	
Count (%)	60 (32.4%)	72 (38.9%)	53 (28.6%)	185		
Yes	8 (13.3%)	9 (12.5%)	11 (20.8%)	28 (15.1%)		
No	52 (86.7%)	63 (87.5%)	42 (79.2%)	114 (80.3%)		
Missing	0	0	1	1		

(1) Never deployed, (2) deployed without exposure, (3) deployed with exposure. Bold type signifies a significant difference. 1–3 or 2–3 signifies there is a significant difference between group 1 and group 3, or group 2 and group 3, respectively.

but denied any exposure to open-air burn pits (deployed without exposure); and (3) those who had both deployed and reported exposure to open-air burn pits (deployed with exposure). Primary outcomes, which included quality-of-life scores (NOSE and SNOT-22) and nasal endoscopy, were then compared across the cohorts as described below. Secondary outcomes, including medical and surgical histories, were initially compared using descriptive statistics, followed by post hoc statistical comparisons when notable differences among cohorts were observed.

Scores on the NOSE and SNOT-22 are presented as mean ± SD. These, as well as other continuous variables, were compared among the three cohorts and assessed for statistical differences using a one-way analysis of variance, with a Tukey honest significant difference test for multiple comparisons to determine significant differences between individual cohorts. Gender and medical history components were compared using a Fisher exact test with a Tukey post hoc multiple-comparisons test used to determine significant differences between individual cohorts. The SNOT-22 scores were analyzed according to the symptom subdomains of sleep, nasal, otologic, and emotional, as published by Feng et al.[21] Individual nasal endoscopy scores were compartmentalized and compared by domain as follows: polyps, edema, discharge, scarring, and crusting. Data analysis was performed by all authors, whereas statistical analysis was specifically performed by Y.H. and F.C.-L. Significance was represented by $P < 0.05$, which were adjusted for age, gender, and duty status (active duty vs beneficiary vs retired) with 95% confidence intervals used to demonstrate the differences in means between compared outcomes. Subjects with missing deployment histories and burn pit exposures were excluded.

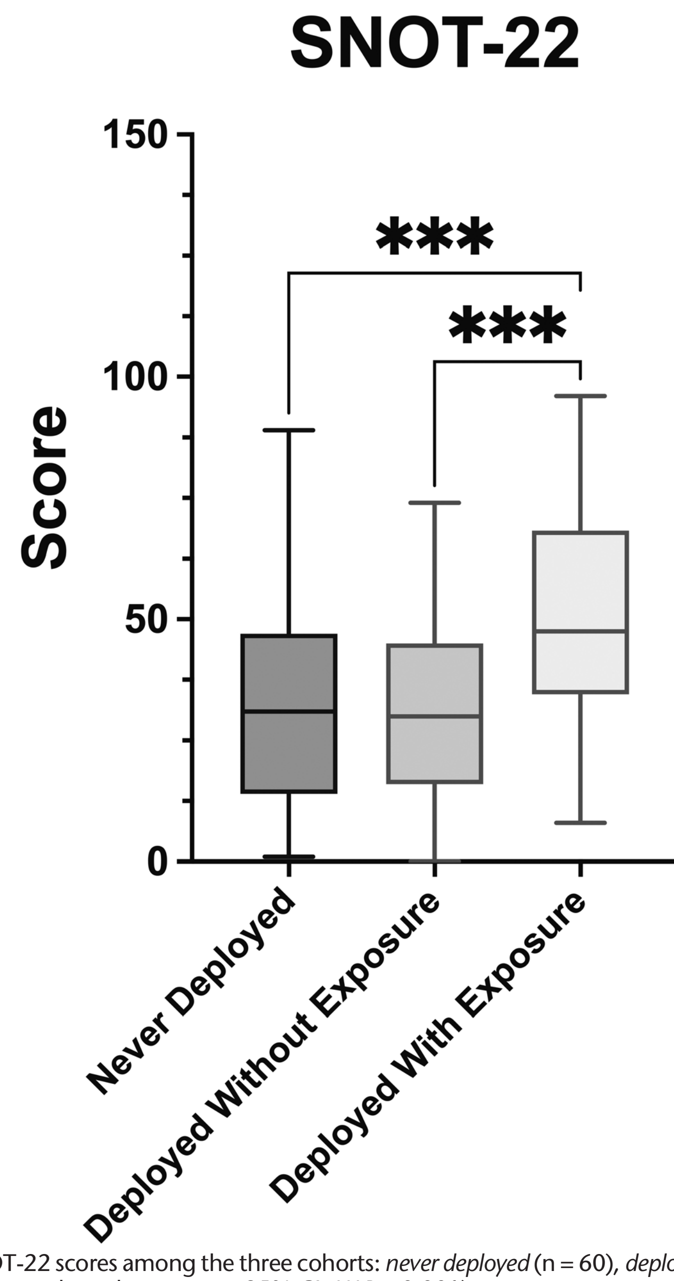

FIGURE 2. Comparison of SNOT-22 scores among the three cohorts: *never deployed* (n = 60), *deployed without exposure* (n = 72), and *deployed with exposure* (n = 54; error bars demonstrate 95% CI; ***$P < 0.001$).

RESULTS

In total, 214 records were reviewed, with 28 excluded because of incomplete data, leaving 186 patients included in the study. Most patients presented with sinonasal complaints, although some presented with other ENT-related complaints (eg, hearing loss, tonsillar hypertrophy, enlarged lymph node). The average age of patients at presentation was 36.3 ± 12.5 years, and 71% of patients were male. Regarding duty status, 153 patients (82.6%) were active duty at the time of presentation, whereas 18 (9%) were beneficiaries, and 15 (8%) were retired.

Fifty-four patients (29%) were deployed with exposure, 72 patients (39%) were *deployed without exposure* group, and 60 patients (32%) were never deployed. Patients within the *deployed with exposure* cohort were older than those in both the *deployed without exposure* cohorts or *never deployed* (42.1 ± 13.5 years vs 35.6 ± 10.2 years and 31.8 ± 12.1 years, respectively; $P < 0.001$) and were predominantly male (91% vs 79% and 43% respectively; $P < 0.001$). Additional characteristics of each cohort are summarized in Supplemental Table 1, http://links.lww.com/JOM/B82.

Patients with burn pit exposure exhibited significantly higher rates of sinonasal disease at presentation compared with either of the other two cohorts (Table 1). The rate of CRS with nasal polyposis (CRSwNP) in the *deployed with exposure* cohort was 27.8%, which was significantly higher than either the *deployed without exposure* cohort (8.5%; mean difference 95% CI, 5.2%–33.4%; $P = 0.004$) or the *never deployed* cohort (6.7%; mean difference 95% CI, 6.5%–35.8%; $P = 0.002$), respectively (Table 1).

Similarly, those in the *deployed with exposure* cohort also had higher rates of allergic rhinitis (61.1%) than either of the other two cohorts (*never deployed* 26.7%; mean difference 95% CI, 14.5%–54.4%; $P < 0.001$; and *deployed without exposure* 23.9%; mean difference

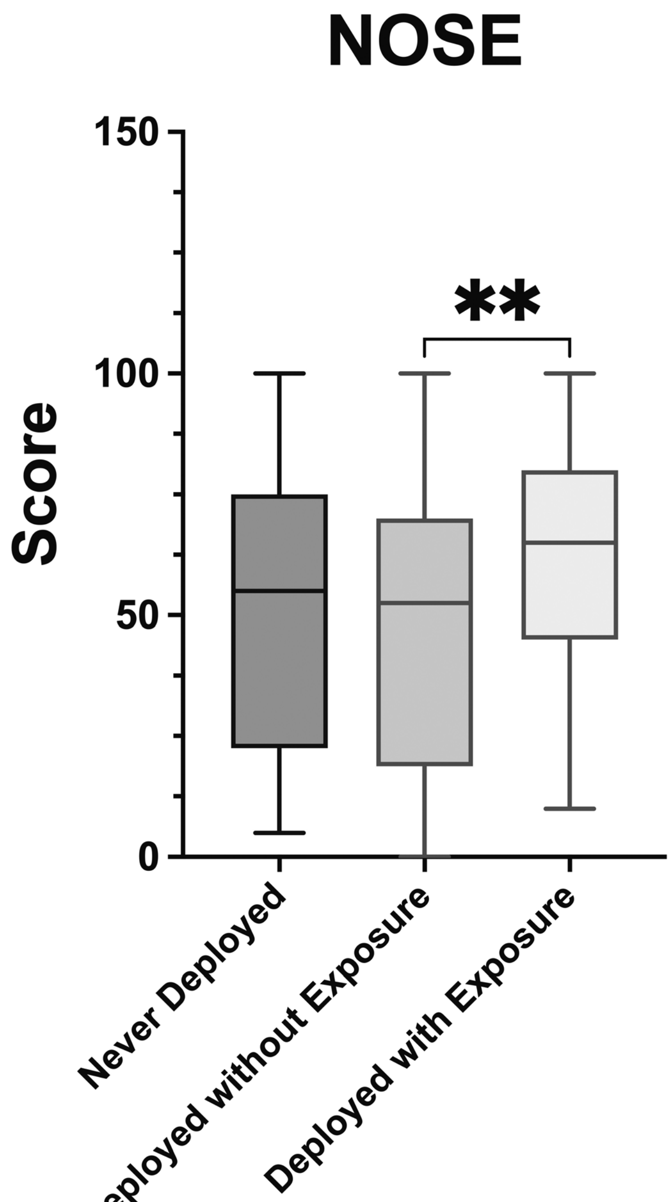

FIGURE 3. Comparison of NOSE score among the three cohorts: *never deployed* (n = 60), *deployed without exposure* (n = 72), and *deployed with exposure* (n = 54; error bars demonstrate 95% CI; $^{**}P < 0.01$).

95% CI, 17.9%–56.4%; $P < 0.001$). In addition, the *deployed with exposure* cohort demonstrated a higher incidence of previous sinus surgery (32.1%) than either the *never deployed* (11.7%; mean difference 95% CI, 4.3%–36.5%; $P = 0.009$) or *deployed without exposure* cohort (11.1%; mean difference 95% CI, 5.4%–36.4%; $P = 0.005$; Table 1).

Average SNOT-22 scores were significantly higher in participants within the *deployed with exposure* cohort (49.9 ± 23.0) compared with those in both the *never deployed* cohort (31.8 ± 20.5; mean difference 95% CI, 9.0–27.2; $P < 0.001$) and the *deployed without exposure* cohort (31.5 ± 18.8; mean difference 95% CI, 9.6–27.1; $P < 0.001$; Fig. 2). Subdomain analysis of the SNOT-22 scores demonstrated this same relationship and was statistically significant across all domains (sleep, nasal, otologic, and emotional; Supplemental Fig. 1, http://links.lww.com/JOM/B83). The NOSE scores were also significantly higher within the *deployed with exposure* cohort (63.6 ± 23.9) compared with the *deployed without exposure* cohort (45.7 ± 37.0; mean difference 95% CI, 5.3–30.6; $P = 0.003$) but were not significantly higher than the *never deployed* cohort (51.4 ± 26.9; mean difference 95% CI, −0.9–25.3; $P = 0.07$; Fig. 3).

Endoscopic examination findings, as represented by Lund-Kennedy scores, demonstrated significantly increased disease within the *deployed with exposure* cohort (3.3) compared with both the *never deployed* (1.8; mean difference 95% CI, 0.3–2.7; $P = 0.009$) and *deployed without exposure* cohorts (1.7; mean difference 95% CI, 0.5–2.7; $P = 0.003$). Subdomain analysis demonstrated that those with burn pit exposure exhibited worsened edema (1.8 vs 1.1 vs 1.1; 95% CI, 0.06–1.3; $P = 0.03$; 95% CI, 0.16–1.3; $P = 0.008$) and discharge (0.7 vs 0.2 vs 0.3; 95% CI, 0.1–1.0; $P = 0.005$; 95% CI, 0.01–0.8; $P = 0.04$) than either the *never deployed* or *deployed without exposure* cohort, respectively (Fig. 4).

DISCUSSION

More than 3 million service men and women have been deployed to the Middle East in the course of Operations Iraqi Freedom, Enduring Freedom, and New Dawn and were potentially exposed to open air burn pits. In a 2020 study, 15% of individuals who were treated at a military occupational lung disease clinic following their deployment to the Middle East self-reported a history of deployment-related rhinosinusitis.[15] Using this incidence, it is estimated that upward of 450,000 service members currently experience deployment-related sinus disease. Most of these service members are no longer active duty and likely receive their health care in the civilian sector.

Several government agencies and working groups have investigated the health-related effects of burn pits, and each has concluded that there were concerning levels of particulate and emission exposure; however, there was not enough evidence to link these exposures to pulmonary disease.[22–24] Altogether, these studies suggest that there has been a lack of objective, quantifiable pathology to validate subjective complaints.[7,15,16,22,23,25–32]

In contrast to these reports, our investigation demonstrates that burn pit exposure is associated with significantly more objective disease as observed on in-office nasal endoscopy compared with control cohorts with a high disease burden. Because our control cohorts were also presenting to a rhinology subspecialty clinic, our controls (*never deployed* and *deployed without exposure*) have higher rates of previously diagnosed CRSwNP than the general population. A recent systematic review found that the incidence of CRSwNP within the United States is estimated at 1.1%, well below our two control cohorts (6.7% and 8.5%; Table 1).[33] Consequently, it is likely that the effects of burn pit exposure are underestimated in our study.

One limitation of our study is the heterogeneity of deployment history among the participants. We were unable to quantify the duration or proximity of burn pit exposure in this study or to provide a characterization of the inspired burn pit smoke. Moreover, repeated and extended deployments, including those to the Middle East, are accompanied with several environmental and combat-related exposures that are independent of burn pits, but that could potentially cause long-term harm to a patient's sinonasal health. The difficulty in correlating health outcomes with specific exposures is one of the most significant challenges facing epidemiologic studies of these recent conflicts. Although our study is limited in its ability to clearly associate the duration and degree of burn pit exposure to severity of rhinosinusitis or other sinonasal complications, it provides clear evidence of objective change in the respiratory system in a cohort of service members exposed to burn pits.

CONCLUSION

Burn pits are a unique deployment-related airborne hazard that highlights the need for further research into the respiratory effects of environmental airborne toxins. Our study provides clear evidence of an association between self-reported burn pit exposure and objective measures indicative of more severe sinus disease. This finding is supported by population and observational data that suggest a link between airborne hazards and sinus disease. The long history of burn pit use and the millions of military and civilian personnel potentially

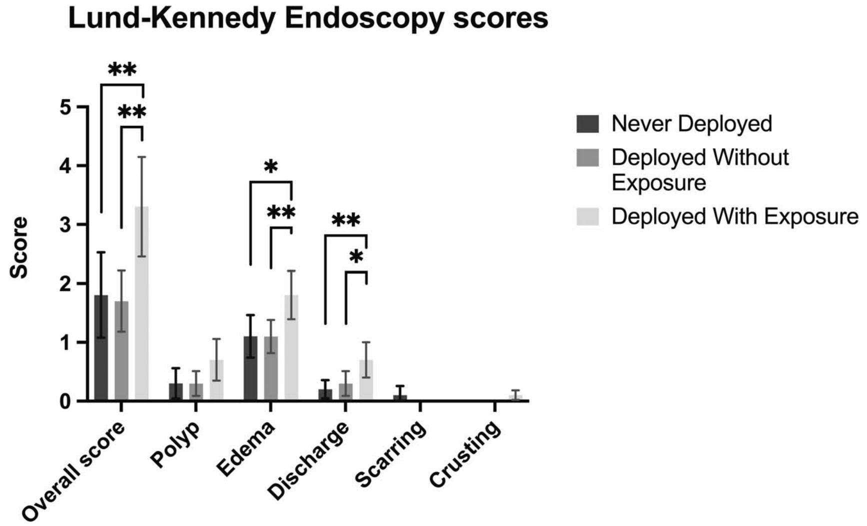

FIGURE 4. Lund-Kennedy endoscopy scores comparing the three cohorts: *never deployed* (n = 60), *deployed without exposure* (n = 72), and *deployed with exposure* (n = 54; error bars demonstrate 95% CI; *$P < 0.05$, **$P < 0.01$).

exposed and affected highlight the need for providers to consider the potential impact of deployment-related exposures on a patient's sinonasal health. As the veterans of these Middle East conflicts age and enter the civilian health care system, this newly discovered risk factor for CRS warrants further study and broader attention from military and civilian physicians alike. Moreover, findings from these studies are likely to be directly applicable to those in the general public who are exposed to airborne hazards as a consequence of industrial fumes, demolition-associated particulate matter, and wildfires.

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