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Gross Hematuria and Lower Urinary Tract Symptoms Associated With Military Burn Pits Exposures in US Veterans Deployed to Iraq and Afghanistan

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Objective: The aim of the study is to describe rates of hematuria and other lower urinary tract symptoms, including self-reported cancer rates, among veterans post-burn pits emissions exposure during deployment to Iraq and Afghanistan. **Methods:** US post-9/11 veterans with burn pits emissions exposure confirmed via DD214 forms in the Burn Pits360.org Registry were sent a modified survey. Data were deidentified and anonymously coded. **Results:** Twenty-nine percent of the 155 respondents exposed to burn pits self-reported seeing blood in their urine. The average index score of our modified American Urological Association Symptom Index Survey was 12.25 (SD, 7.48). High rates of urinary frequency (84%) and urgency (76%) were self-reported. Bladder, kidney, or lung cancers were self-reported in 3.87%. **Conclusions:** US veterans exposed to burn pits are self-reporting hematuria and other lower urinary tract symptoms.

Keywords: burn pits, JP-8, Iraq, Afghanistan, benzene, hematuria, urological symptoms

LEARNING OBJECTIVES

1. Since 2001, more than 2 million US soldiers were exposed to burning trash in burn pits containing multiple carcinogens, including benzene and naphthalene, during deployments to Iraq and Afghanistan.
2. The 2022 promise to address comprehensive toxics act provides medical care for 33 presumptive medical conditions, including lung, lymphatic, and reproductive cancers, but not lower urinary tract symptoms or bladder cancer.
3. We now describe high rates of self-reported lower urinary tract symptoms, including gross hematuria, in this cohort of young veterans.

Since 2001, more than 2 million US soldiers were exposed to burn pits in Afghanistan and Iraq in support of Operation Enduring Freedom and Operation Iraqi Freedom, respectively.[1] In early 2022, the Senate Veteran's Affairs Committee informed the public that approximately 3.5 million post-9/11 combat veterans may have experienced some level of exposure to burn pits worldwide.[2] Burn pits entail burning trash in open air without incinerators, which generates airborne particulate matter.[3,4] The largest burn pit, a 10-acre garbage disposal area in Balad, Iraq, is shown in Figure 1. Particulate matter air pollution

From the SUNY Downstate Health Sciences University, Brooklyn, New York (M.M.P.); Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, New York, New York (H.E.M.-M.); Icahn School of Medicine at Mount Sinai, New York, New York (M.F.L.-W.); Maimonides Medical Center, Brooklyn, New York (M.F.L.-W.); Burn Pits 360 Veterans Organization, Robstown, Texas (J.M.T.); Henry Mayo Newhall Hospital, Valencia, California (E.F); Hematology and Oncology Section, Minneapolis VA Health Care System, Minneapolis, Minnesota (M.A.K.); Department of Medicine, University of Minnesota, Minneapolis, Minnesota (M.A.K.); Masonic Cancer Center, University of Minnesota, Minneapolis, Minnesota (M.A.K., J.H.T.); Minneapolis VA Health Care System, Minneapolis, Minnesota (J.H.T., T.A.B.); Department of Laboratory Medicine and Pathology, University of Minnesota, Minneapolis, Minnesota (J.H.T.); Department of Food Science and Nutrition, University of Minnesota, St Paul, Minnesota (T.A.B.); Department of Neuroscience, University of Minnesota, Minneapolis, Minnesota (T.A.B.); Center for Veterans Research and Education, Minneapolis, Minnesota (T.A.B., A.G.); Drexel University College of Medicine, Philadelphia, Pennsylvania (R.A.P.); Stony Brook University School of Nursing and Stony Brook University Cancer Center, Stony Brook, New York (P.K.G.); Thomas Jefferson University School of Medicine, Philadelphia, Pennsylvania (P.B.); Division of Pulmonary and Critical Care, Division of Allergy/Immunology, Department of Medicine, Department of Occupational Medicine, Epidemiology and Prevention, Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Hempstead, New York, Northwell Health, New Hyde Park, New York (A.M.S.); Department of Occupational Medicine, Epidemiology and Prevention, International Center of Excellence in Deployment Health and Medical Geosciences, Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Hempstead, New York (A.M.S.); Stony Brook University, Department of Technology and Society, College of Engineering and Applied Sciences, Stony Brook, New York (A.M.S.); Three Village Allergy and Asthma, PLLC, South Setauket, New York (A.M.S.); and RDS2 Solutions, Inc, Stony Brook, New York (A.M.S.).

Ethical Considerations and Disclosures: The Stony Brook University IRB number is IRB-2022-00015 "AUA and "Burn Pits Survey" Anthony Szema, principal investigator. This is a survey study, which used the Burn Pits360.org registry, which currently has more than 8000 self-reporting US Veterans who have been exposed to burn pits emissions. Prerequisite enrollment in our study required valid DD214 records (Certificate of Release or Discharge from Active Duty). Our survey, standardized by the AUA, clinically modified with one question omitted and two questions added, was emailed using the software TypeForm. Data were anonymously coded and deidentified.

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Conflict of interest: None declared.

M.M.P. and H.E.M.-M. contributed equally to the manuscript.

Authors' contribution: M.A.P. and A.M.S. did the IRB protocol. M.A.P., H.E.M., M.L.W., E.F., R.A.P., M.L.W., and A.M.S. did the writing of manuscript. M.A.P., E.F., A.M.S., R.A.P., M.L.W. J.H.T., M.A.K., T.A.B., and J.M.T. did the conceptualization. A.A.G. contributed to statistical analysis. M.A.P., H.E.M., M.L.W., R.A.P., M.L.W., A.M.S., A.P., P.G., J.H.T., M.A.K., T.A.B., A.A.G., P.A.B., and P.K.G. did the data analysis and interpretation. M.A.P., H.E.M., M.L.W., E.F., R.A.P., M.L.W., A.M.S., J.H.T., M.A.K., T.A.B., A.A.G., J.M.T., P.A.B., and P.K.G. did the reviewing of the original draft. M.A.P., H.E.M., M.L.W., E.F., R.A.P., A.M.S., M.A.K., J.H.T., T.A.B., A.A.G., J.M.T., P.A.B., and P.K.G. did the editing of the final version. M.A.P., A.M.S., T.A.B., and J.M.T. did the visualization. A.M.S., M.A.K., T.A.B., and J.H.T. did the funding acquisition.

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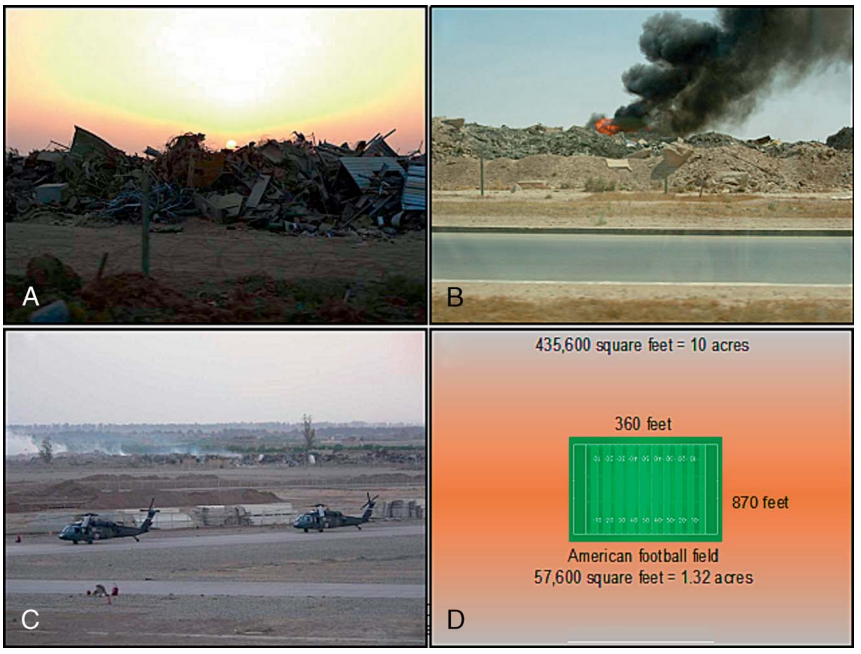

FIGURE 1. Burn pit at Balad Air Base, Iraq. Photos of the Balad Burn Pit by Julie Tomaska, PhD (Ret. Air National Guard) in 2005, with permission. A, Smoke obscures horizon. B, Black plume rising from burn pit. C, Smoldering white smoke near airfield. D, The Balad Air Base burn pit was equivalent to 7.6 football fields.

is associated with risk of asthma and chronic obstructive pulmonary disease.[3] These burn pits were the primary means of solid waste disposal for both Operation Enduring Freedom and Operation Iraqi Freedom. The US military began scaling back the use of burn pits, commencing with the largest 10-acre burn pit at Balad Air Base, Iraq, in December 2009.[5] However, as of March 2022, according to United States Senate Armed Services Committee testimony by the Department of Defense, there are still nine active burn pits under the aegis of United States Central Command in areas such as Egypt and Syria.

Burn pits are ignited mainly by a military version of Jet Propellant-8 fuel (JP-8).[6] Burn pit smoke has been shown to contain heavy metals and harmful substances such as polycyclic aromatic hydrocarbons, furans, lead, volatile organic compounds, mercury, dioxins, as well as carcinogens benzene and naphthalene.[4,6] Exposure to burn pits raises concerns about increased risk of multiple diseases.[5–7] While the major emphasis in research on the potential long-term effects of burn pits smoke relates to respiratory system effects, the Department of Veterans Affairs has released a list of 33 presumptive conditions involving multiple organ systems that may result from burn pits exposure, including kidney cancer, lymphoma, and reproductive cancer.[8] These conditions are incompletely studied with reference to burn pits. However, lower urinary tract symptoms (LUTS) and bladder cancer have not yet been included in this list.[9] Lower urinary tract symptoms are included in the American Urological Association (AUA) Symptom Index Survey, but screening has not yet been adopted by the Department of Defense or the Department of Veterans Affairs.[10] We hypothesized that soldiers with burn pits exposure will have increased irritative, voiding symptoms, and blood in the urine compared with nonexposed individuals.

METHODS

Study Design

This study comprised a self-reported survey approved by the Stony Brook University Institutional Review Board (IRB Study 2022-00015). The study was classified as minimal risk, which required no informed consent from the research subjects. Participants were confirmed to have DD214 forms from the Department of Defense. A DD214 form validates the name of the subject, honorable discharge from a branch of the military, along with dates and locations of deployment. The survey was delivered through email and the data collected through TypeForm software (Barcelona, Spain, 2012) were deidentified and anonymously coded. Both exposure and outcome were self-reported in the study, so the DD214 forms served to confirm deployment dates and locations with known burn-pit operations but do not quantitate degree of exposure.

Study Population

The study population includes members of the Burn Pits 360 Veterans Organization Burn Pits Registry. Burn Pits 360 is a 501(c)(3) nonprofit organization, which hosts an independent burn pits exposure registry (burnpits360.org) and has more than 8000 veterans registered with their Web site. The 155 veterans who responded were confirmed to have DD214 forms by Burn Pits 360.

Measurements

The survey tool was a modified version of the American Urological Association Symptom Index Survey (AUASIS). The AUASIS is a validated, standardized survey instrument, which is designed to quantify LUTS.[11] Our survey was based on the AUASIS survey but was modified for clinical relevance.

All members of the Burn Pits 360 registry were contacted via their listed email address and asked to participate in the survey as part of an active social media recruitment strategy. Additional active recruitment included platforms such as Facebook. This was conducted anonymously with deidentified data via TypeForm. Respondents were asked to supply a Department of Defense Form 214 (DD214), indicating honorable discharge, as well as dates and locations of deployment in Iraq and Afghanistan. Deployments were in areas where burn pits were active. Once this information was provided, all respondents were asked to fill out the modified AUASIS questionnaire. All completed surveys were deidentified, and the results were entered into a secure database for subsequent analysis. The survey instrument is shown in Figure 2.

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Thank you for participating in this survey. Please answer the following questions below by checking the appropriate boxes.

	Not at all	Less than 1 time	Less than half the time	About half the time	More than half the time	Almost always	Score
Incomplete emptying- It does not feel like I empty my bladder all the way.	0	1	2	3	4	5	
Frequency- I have to go again less than two hours after I finish urinating.	0	1	2	3	4	5	
Intermittency- I stop and start again several times when I urinate.	0	1	2	3	4	5	
Urgency- It is hard to wait when I have to urinate.	0	1	2	3	4	5	
Weak stream- I have a weak urinary system.	0	1	2	3	4	5	
	None	1 time	2 times	3 times	4 times	>5 times	Score
Nocturia- I get up to urinate after I go to bed until the time I get up in the morning.	0	1	2	3	4	5	

	Not at all	Less than 1 time	Less than half the time	About half the time	More than half the time	Almost always	Your Score
Pain- I feel pain when urinating.	0	1	2	3	4	5	
Blood- I see or have seen blood in my urine.	0	1	2	3	4	5	

	Yes	No
Have you ever been diagnosed with bladder, kidney, or lung cancer?		
Have you ever smoked cigarettes? If yes, how many packs a day and how many years?		
If no, do you have a history of other types of cancers?		
Have you noticed significant weight loss recently?		
Do you have a family history of urological problems?		
Have you been exposed to burn pits during your deployment?		

If yes, please state where you were exposed and for how long you were exposed for.	
How old were you when you were exposed to burn pits? How old are you now?	

TOTAL SCORE: _____

0-7 mild symptoms; 8-19 moderate symptoms; 20-35 severe symptoms

FIGURE 2. Modified AUASIS Survey. AUASIS, American Urological Association Symptom Index Survey.

Statistics

A total score was calculated for the modified AUASIS scale by adding up the individual items. For all other variables, descriptive measures are shown. For categorical variables, frequency and percentages are shown. For continuous variables, mean, standard deviation, median, minimum, and maximum are shown. Statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc, Cary, NC)

RESULTS

A total of 8000 veterans were invited to participate in the study. One hundred fifty-five subjects submitted the survey and a copy of their DD214 form. Of the 155 subjects, 127 were male and 28 female. All subjects had served in areas where burn pits were in use at the time of their deployment. The mean age at time of burn pits exposure was 29 years, and the mean age of survey respondents was 45 years

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(Table 1). The most common country for burn pits exposure was Iraq (119/155). Joint Base Balad, located in Iraq, was the most common location for burn pits exposure (38/155).

The average index score of our modified AUASIS survey was 12.25 (SD, 7.48). The results of the survey are listed in Table 2. A score of 1 or more in any category indicates a symptom. There are eight categories of symptoms. One hundred forty-three of respondents (92.9%) had no family history of urological problems. One hundred thirty-six of respondents (88.9%) had no significant recent weight loss. Eighty-nine of respondents (59.2%) had never smoked cigarettes. Of survey respondents, 6 (3.87%) had been diagnosed with bladder, kidney, or lung cancer. Among respondents, LUTS were self-reported at rates of urinary frequency (84%), urgency (76%), and hematuria (29%).

DISCUSSION

We have surveyed 155 post-9/11 veterans who were deployed to Iraq and Afghanistan and received their responses in a descriptive manner by self-reported responses to the survey. These data contribute novel information for both healthcare providers and the medical literature because urological symptoms and bladder cancer have not yet been recognized as presumptive conditions related to burn pits exposure.

TABLE 1. Demographics

Variable	Total $N = 155$
Burn pit exposure? (BURNPITEXP)	
Yes	155 (100)
N missing	0
Family history of urological problem (FAMHX_FX)	
No	143 (92.86)
Yes	11 (7.14)
N missing	1
Have you noticed significant weight loss recently? (SIGWEIGHTLOSS)	
No	136 (88.89)
Yes	17 (11.11)
N missing	2
Have you ever smoked cigarettes? (SMOKED_EVER)	
No	89 (58.94)
Yes	62 (41.06)
n missing	4
Have you ever been diagnosed with bladder, kidney or lung cancer? (CANCER_BKL)	
No	148 (96.1)
Yes	6 (3.9)
N missing	1
If no, do you have an hx of other types of cancers? (NO_HXOTHERCANC2)	
No	105 (71.92)
Yes	41 (28.08)
N missing	9
agewhenexp (AGEWHENEXP)	
Mean	29.35
SD	9.07
Median	27.00
Minimum	19.00
Maximum	58.00
N missing	0
agenow (AGENOW)	
Mean	44.74
SD	9.12
Median	43.00
Minimum	21.00
Maximum	73.00
N missing	0

hx, history.

TABLE 2. Summary of Means of Numeric Variables ($N = 155$)

Variables	Mean	SD
Age during exposure	29.35	9.07
Current age	44.74	9.12
Incomplete emptying	2.30	1.62
Frequency	2.65	1.64
Intermittency	1.93	1.64
Urgency	2.29	1.77
Weak stream	1.63	1.70
Nocturia	1.65	1.21
AUASIS modified total survey score	12.25	7.48
Pain when urinating	0.86	1.6
I see or have seen blood in my urine	0.52	0.97

AUASIS, American Urological Association Symptom Index Survey.

In contrast, asthma has been well studied in the setting of burn pits exposure and is a presumptive condition. To further test an association and determine whether there is an increased risk of urological cancer in US veterans due to burn pits exposure, we intend to survey an age-matched control military population that was not burn pits exposed.

The results of this survey-based study indicate that this cohort of burn pits exposed veterans' self-reported high rates of LUTS. Bladder cancer is the sixth most common type of cancer in the United States.[12] Urothelial carcinoma is the most common histological subtype of bladder cancer.[13] In Western countries, bladder cancer is predominately seen in men.[14,15] Bladder cancer is diagnosed more often in older patients domestically, with an average age at diagnosis 73 years, according to the American Cancer Society.

Gross painless hematuria is the most common presenting symptom of bladder cancer.[16]

The AUA microscopic hematuria guidelines list the prevalence of microscopic hematuria between 2.4% and 31.1%, and the rate of malignancy in the population with gross hematuria is reported at 10%.[17,18] In our cohort, 29% of veterans reported gross hematuria—visible blood in the urine. Gross hematuria carries a genitourinary malignancy rate as high as 10%.[19] It is difficult to report a prevalence of gross hematuria in the general population as it is a self-reported and subjective measure. Wallner et al[20] reported approximately 41% of civilian cohort men, ages 45 to 69 years, who were not on medication for LUTS and had no diagnosis of benign prostatic hyperplasia, had self-reported moderate to severe LUTS using the AUASIS survey. Although we cannot compare our rate of gross hematuria to a control group, we do find our results to be an alarming finding. Given our concern that burn pits exposures are carcinogenic, we feel that this rate of gross hematuria in our relatively young cohort (average age 45 years) should not be overlooked. In addition, Zhou et al[21] showed that the presence of LUTS is associated with development of bladder cancer in men. Zhou et al[21] also showed that a subset of bladder cancer patients will present only with LUTS. Of note, Dobbs et al[22] showed that a greater percentage of veterans (4.4%) with bladder cancer presented solely with LUTS when compared with the general population (1%–2%). These symptoms could portend an increased risk of undiagnosed bladder cancer among veterans exposed to burn pits.

The average age of respondents in our survey was 45 years, which is considerably lower than the age range of the cohort of Wallner et al.[20] The age range for our cohort was 19 to 58 years. The mode was 20 years. We assert the presence of LUTS in a younger population of veterans exposed to burn pits should alert physicians to screen for bladder cancer. The most definitive risk factor for bladder cancer is tobacco smoking.[23] Forty-one percent of our survey respondents answered yes when asked whether they ever smoked cigarettes. This is higher than the previously reported rates of cigarette smoking (21.6%) among veterans.[24]

In addition to cigarette smoking, 5% to 25% of all bladder cancer cases have been associated with workplace exposures.[25,26] The

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relationship between chemical exposure and urinary tract tumors has been well established. In 1895, Rehn reported an association between the exposure of the industrial dye aniline and bladder cancer.[27] Occupational smoke exposure by firefighters has been linked to increased risk of bladder cancer.[28] Our findings support the concept that occupational burn pits exposure may be a potential risk factor for LUTS and bladder cancer.

Military JP-8 jet fuel was routinely used to maintain combustion in burn pits.[4,6,29] Use of JP-8 results in environmental exposures to carcinogens, including benzene and naphthalene.[4,6,29] Serdar et al[30] demonstrated that heavy exposure to JP-8 contributed roughly the same amount of benzene and more than three times the amount of naphthalene compared with cigarette smoking. This was done by measuring benzene, naphthalene, and 1- and 2-naphthol levels in urine samples obtained from 322 US Air Force personnel with exposure to JP-8.[30] Benzene is a group 1 carcinogen in humans and naphthylamines have been shown to induce bladder cancer in animal models.[31–33]

To further test an association and determine whether there is an increased risk of urological cancer in US veterans due to burn pits exposure, we intend to survey an age-matched control military population that was not burn pits exposed. For a proposed future study, we will potentially consider validation of self-reported hematuria with a urinalysis and subsequently indicated evaluation.

Limitations

Limitations of this study include a response rate of 2.5%, which may not be a representative sampling of the Burnpits360.org population. The survey tool relies on patient self-reporting of burn pits exposure. However, we confirmed deployment dates and locations with DD214 forms from the Department of Defense. The survey used was based on a standardized, validated, and published questionnaire from the AUA that relied on self-reported symptoms. The questionnaire was clinically tailored to address the at-risk burn pits exposed veterans populations. We acknowledge that veterans deployed to these areas had varying levels of exposure to burn pits emissions. A veteran's exposure to burn pits emissions may vary greatly depending on the individual's job, specific location of their living spaces, and climatic conditions.

CONCLUSIONS

Our veteran cohort reported gross hematuria at a rate of 29%. The population was exposed to carcinogens. Development of LUTS after exposure to carcinogens in burn pits necessitates vigilance and early screening for bladder cancer in our veteran population. Appropriate workup of LUTS and hematuria is always warranted and individual evaluations should consider potential occupational exposure to carcinogens, particularly in veterans who may have been exposed to burn pits.

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