

Semiquantitative Chest Computed Tomography Assessment Identifies Expiratory Central Airway Collapse in Symptomatic Military Personnel Deployed to Iraq and Afghanistan

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Purpose: We noted incidental findings on chest computed tomography (CT) imaging of expiratory central airway collapse (ECAC) in dyspneic patients after military deployment to southwest Asia (mainly Iraq and Afghanistan). We developed a standardized chest CT protocol with dynamic expiration to enhance diagnostic reliability and investigated demographic, clinical, and deployment characteristics possibly associated with ECAC.

Materials and Methods: We calculated ECAC in 62 consecutive post-9/11 deployers with dyspnea who underwent multi-detector chest CT acquisition. ECAC was defined as $\geq 70\%$ reduction in the cross-sectional tracheal area at dynamic expiration. We compared demographics (age, smoking, body mass index), comorbid conditions (gastroesophageal reflux, obstructive sleep apnea [OSA]), and clinical findings (air trapping, forced expiratory volume in 1 second percent predicted) in deployers with and without ECAC. We examined associations between ECAC and forced expiratory volume in 1 second percent predicted, air trapping, OSA, deployment duration, and blast exposure.

Results: Among 62 consecutive deployers with persistent dyspnea, 37% had ECAC. Three had severe ($>85\%$) collapse. Those with ECAC were older (mean age 46 vs. 40 y, $P=0.02$), but no other demographic or clinical characteristics were statistically different among the groups. Although not statistically significant, ECAC odds were 1.5 times higher (95% confidence interval: 0.9, 2.5) for each additional year of southwest Asia deployment. Deployers with ECAC had 1.6 times greater odds (95% confidence interval: 0.5, 4.8) of OSA.

Conclusions: Findings suggest that ECAC is common in symptomatic southwest Asia deployers. Chest high-resolution CT with dynamic expiration may provide an insight into the causes of dyspnea in this population, although risk factors for ECAC remain to be determined. A standardized semiquantitative approach to CT-based assessment of ECAC should improve reliable diagnosis in dyspneic patients.

Key Words: tracheobronchomalacia, excessive dynamic airway collapse, expiratory central airway collapse, military deployment

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Since September 11, 2001, the United States has sent nearly 3 million military and civilian “deployers” to zones of conflict in Iraq and Afghanistan. These deployers are often exposed to poor air quality and inhalational hazards.¹ New-onset respiratory symptoms after deployment have been linked to chronic rhinitis/rhinosinusitis, laryngeal dysfunction, asthma, bronchiolitis, and pulmonary eosinophilic syndromes.^{2–4} Although exposure to high concentrations of irritant and allergen-containing particulates and to explosive blasts has been linked to most of these adverse respiratory health outcomes, the causal role of such exposures in cartilaginous tracheal disorders such as tracheobronchomalacia (TBM) and excessive dynamic airway collapse (EDAC) is not well understood.

TBM and EDAC are often subsumed under the more general category of expiratory central airway collapse (ECAC), as risk factors are overlapping and poorly understood.^{5,6} Congenital causes of TBM include inherited polychondritis associated with diffuse inflammation and multi-system destruction of cartilage, and other genetic conditions that cause tracheobronchomegaly such as idiopathic giant trachea, Ehlers-Danlos, Mounier-Kuhn syndrome, and trisomies 9 and 21.^{7–9} Known causes of acquired TBM include tracheal injury after intubation or tracheotomy or as a sequela of prolonged external compression (eg, from thyroid goiter, malignancy, or cyst).¹⁰ Chronic airway inflammation from cystic fibrosis, smoking-related

bronchitis, or chronic obstructive pulmonary disease (COPD) (especially combined with obesity), severe asthma, gastroesophageal reflux disease (GERD), and oral corticosteroid use may contribute to risk for both TBM and EDAC.^{6,11–15} Although some studies have suggested an association between obstructive sleep apnea and ECAC, it is unclear whether ECAC is a risk factor for OSA or whether OSA itself confers risk for ECAC.^{16,17} A few reports implicate environmental and occupational exposures causing TBM and EDAC including a case series of TBM in 13 sulfur mustard-exposed civilians during the Iran-Iraq war, TBM in an e-cigarette user with vaping-related lung injury, and EDAC in 6 post-9/11 military deployers.^{4,18,19}

Limited understanding of cartilaginous tracheal disorders is likely due in part to challenges with diagnosis. The 2 major diagnostic tools for identifying central airway disorders are direct visualization of the large airway via fiberoptic bronchoscopy and chest CT imaging. Although chest imaging is less expensive and less invasive, protocols to assure reliable and reproducible CT image acquisition and standardized measurements of tracheal collapse are poorly defined.^{5,20}

Although tracheal abnormalities may be asymptomatic, cough, shortness of breath, and wheezing are commonly reported.¹³ Given variable and nonspecific clinical presentations and inconsistent diagnostic criteria, ECAC is often unrecognized clinically. Prevalence estimates range from 4% to 23% in populations with underlying respiratory diseases including cystic fibrosis, COPD, and asthma.^{13,15,21} Most studies do not distinguish between TBM and EDAC, further contributing to uncertainty in reported prevalence rates.

During diagnostic evaluation of military personnel with persistent respiratory symptoms after southwest Asia deployment, we noted incidental chest imaging findings of TBM and EDAC. These recurring findings prompted us to develop an optimized approach to chest CT image acquisition and a novel quantitative scoring system to measure the presence and extent of ECAC. Using this image acquisition protocol and scoring system, we carried out a cross-sectional study analyzing 62 consecutive diagnostic chest CT scans from symptomatic deployers for the presence and severity of both TBM and EDAC. Our main study objective was to determine whether southwest Asia deployment exposures, in combination with other clinical factors, increase the risk of ECAC. We hypothesized that ECAC would be more likely in those with more frequent and longer total deployment duration or with reported exposure to explosive blasts during military deployments to Iraq, Afghanistan, and neighboring southwest Asia locations. Further, we investigated whether odds of ECAC would increase in association with other potential risk factors including steroid use, obesity, smoking status, GERD, OSA, or lung abnormalities including obstructive lung disease and air trapping.

MATERIALS AND METHODS

Study Population

With IRB approval (HS-2689 BRANY IRB), we designed a cross-sectional study assessing risk factors for ECAC in 62 symptomatic post-9/11 deployers referred for the evaluation of persistent dyspnea and/or cough. Study participants underwent high-resolution computed tomography (HRCT) of the thorax with dynamic airway imaging as part of their clinical evaluation between December 2017 and January 2020. They completed detailed deployment exposure questionnaires, medical/social histories, physical

examinations, body plethysmographic lung function testing, and, in some cases, methacholine challenge to evaluate for asthma. Smoking histories were obtained using standardized questions for smoking status and total pack-years. For 3 participants who did not complete questionnaires, information was obtained from their clinical records.

Study participants were characterized by demographic variables and smoking status and by comorbidities including obesity (defined as a body mass index [BMI] > 30),²² physician-diagnosed GERD, and obstructive sleep apnea. We also examined use of inhaled or oral corticosteroids; full pulmonary function test findings that were available in 61/62 study participants; and air trapping or deployment-related asthma based on new-onset asthma during or after deployment to Iraq, Afghanistan, or southwest Asia.² Air trapping was defined as an elevated residual volume (> 120% predicted) on lung function testing or imaging findings of mosaic attenuation.^{23–25} Asthma was defined by the presence of either a postbronchodilator increase in forced expiratory volume in 1 second (FEV1) of ≥ 200 mL and an FEV1 increase of $\geq 12\%$ or by an abnormal methacholine challenge with a 20% decrease in FEV1 at a dose of ≤ 8 mg/mL methacholine.^{26,27}

High-resolution Chest CT Image Acquisition Protocol

CT scans were obtained using a 64-dual-energy multi-detector row CT (Definition; Siemens, Germany) or a 128-row-detector MDCT (Definition AS Plus; Siemens) scanner. Contiguous 3 mm images were reconstructed from the volumetric data set, and 1.0 or 1.5 mm images, at 1 cm intervals, and additional coronal and sagittal reformats. All patients underwent a standard central airway protocol, which included imaging during 3 phases of respiration: end-inspiration, end-expiration, and dynamic expiration.

Image Analysis and Central Airway Collapse Measurement

Chest CT scan images were deidentified, and a cardiothoracic radiologist blinded to clinical findings analyzed each scan using the “closed polygon ROI” tool in Horos, a widely used open-source Digital Imaging and Communications in Medicine (DICOM) viewer (The Horos Project v3.0, Annapolis, MD). The cross-sectional area of the tracheal inner lumen was traced on end-inspiration (EI) and dynamic end-expiration (EE) at the level of maximal collapse, at 1 cm above the carina, and at the level of the aortic arch.²⁸ Measurements of the left and right mainstem bronchi 1 cm distal to the carina at EI and EE were recorded. As noted on the chest CT scoring form in Figures S1–S3 (Supplemental Digital Contents 1–3, <http://links.lww.com/JTI/A196>, <http://links.lww.com/JTI/A197>, <http://links.lww.com/JTI/A198>), the percentage change in the cross-sectional luminal area, also referred to as luminal collapse (LC), was calculated by luminal area (LA) measurements: $LC = 100 \times [1 - (LA_{EE}/LA_{EI})]$. Using previously published imaging criteria, we also assessed for air trapping, defined as the presence of mosaic attenuation in more than one bronchopulmonary segment on expiratory imaging.²⁹

ECAC Case Definitions

We defined ECAC cases as those deployers with evidence of central airway collapsibility based on 70% or greater reduction in the cross-sectional area of the trachea at dynamic expiration. Those with > 85% collapse were defined as having severe ECAC. ECAC cases were further

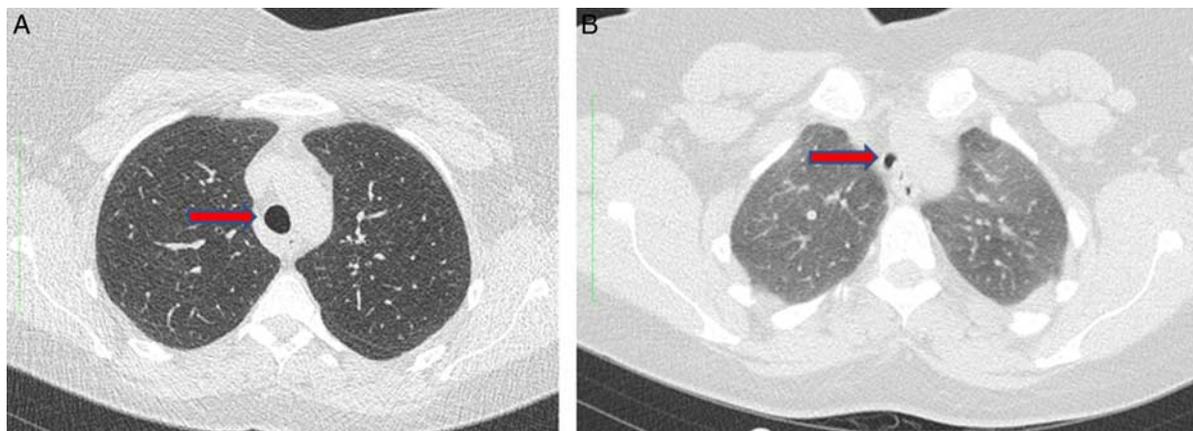


FIGURE 1. Axial CT images in a 40-year-old woman with TBM who currently smokes, spent 20 months in Iraq, and reported new-onset dyspnea after exposure in close proximity to explosive blast and fire. She also burned human waste mixed with jet-propellant (JP-8) fuel and reported exposure to diesel particulates, desert dust particulate matter, and burn pit emissions. A, Inspiratory CT image. B, Severe tracheal collapse on dynamic expiratory CT imaging showing decreased overall cross-sectional area of the trachea on expiration compared with tracheal morphology noted during inspiration from image in (A) (denoted by red arrows). [full color online](#)

categorized as having TBM, EDAC, or both. TBM was defined as airway collapse of $\geq 70\%$ with morphologic findings of circumferential, crescentic, saber-sheath, or other tracheal collapse patterns not involving the posterior tracheal membrane. EDAC was defined as $\geq 70\%$ airway collapse from invagination of the posterior tracheal membrane. Combined TBM and EDAC required tracheal collapse involving both the anterior and lateral walls of the trachea and the posterior membrane.

Deployment Exposures

We used a deployment exposure questionnaire to elicit details about the number and duration of each military deployment. The questionnaire collected information on reported frequency of exposure to explosive blasts (improvised explosive device detonations, explosions, or impact from launched rocket-propelled grenades or mortars) during each deployment to southwest Asia.

Data Analysis

Descriptive statistics were calculated separately for individuals without ECAC, individuals with TBM, those

with EDAC, and those with any ECAC. To compare the demographic, clinical, and deployment characteristics in those with and without ECAC, *t* tests were used for continuous characteristics using the Satterthwaite result for unequal variances. For non-normally distributed variables, including smoking pack-years and number of deployments, exact Wilcoxon Rank Sum tests were used. For dichotomous characteristics, χ^2 or Fisher exact tests were used to compare those with and without ECAC. *P*-values were considered statistically significant when $P < 0.003$ using a Bonferroni correction for 16 tests. We used logistic regression to examine the relationship between several important clinical findings and deployment exposures with ECAC, adjusting for demographic characteristics that significantly differed or are important covariates described in the medical literature. In addition, we examined the relationship between OSA and ECAC using logistic regression, considering that ECAC may lead to OSA. Potential outliers were examined in logistic regression models using influence and leverage diagnostics. *P*-values reported are from χ^2 tests. All analyses were carried out using SAS version 9.4.

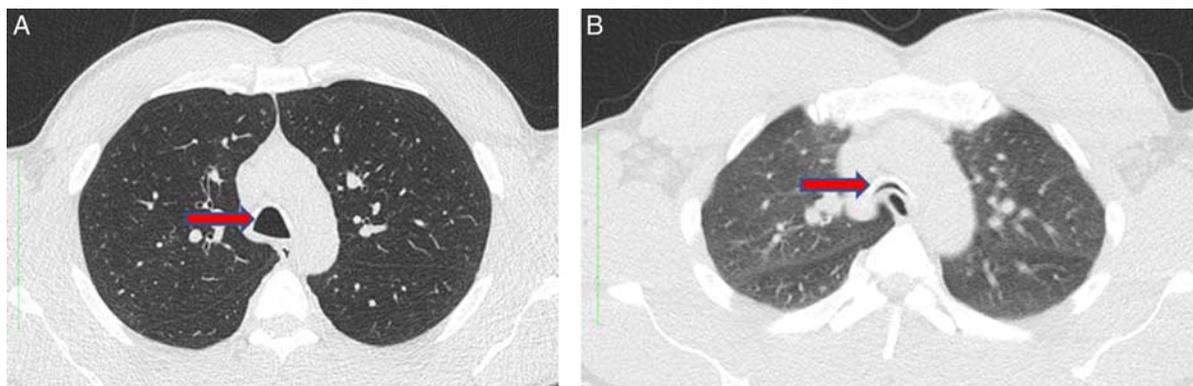


FIGURE 2. Axial CT images in a 45-year-old man who is a never smoker with EDAC. He worked as an Air Force firefighter with multiple deployments to Iraq, Afghanistan, and southwest Asia who developed new-onset dyspnea during deployment. He reported exposure to burn pit emissions and extinguishing fires of burning aircraft. A, Inspiratory CT image of distal trachea with the red arrow indicating the cross-section of the trachea. B, Marked EDAC of the trachea on end-expiratory view as shown by red arrow. [full color online](#)

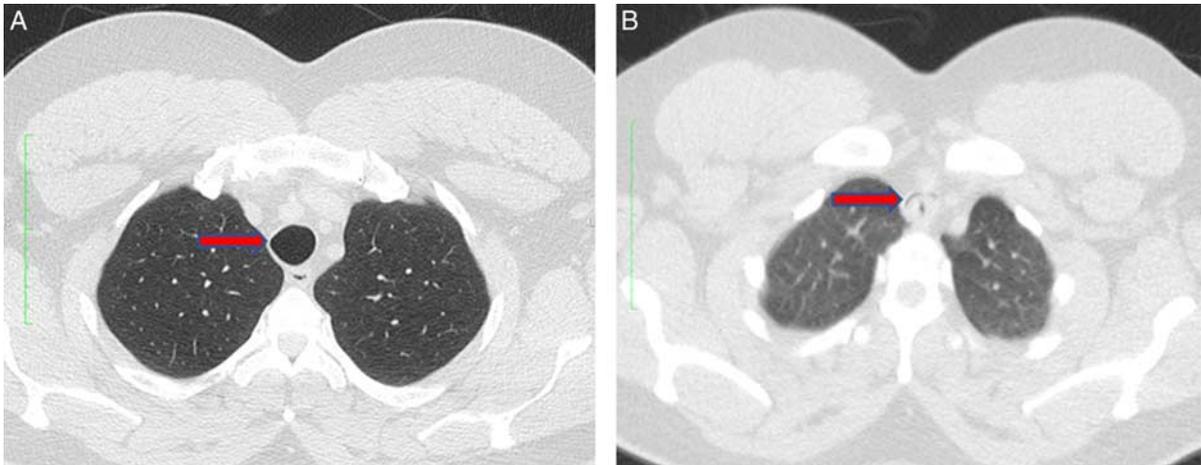


FIGURE 3. Axial CT images in a 40-year-old man with combined TBM and EDAC. He is a never smoker who served as a firefighter during military service and reported new-onset cough during his deployment to Iraq. His job duties included responding to aircraft fires, burn pit fire control, and hazardous spill containment/management. A, Inspiratory CT image with the red arrow showing the cross-section of the trachea. B, Severe TBM and EDAC with 99% tracheal collapse on dynamic expiratory CT imaging (see red arrow). [full color online](#)

RESULTS

Using well-defined imaging criteria, we found ECAC in 23 (37%) of 62 consecutive deployers with persistent respiratory symptoms. Of these, 3 fulfilled the criteria for severe ECAC of >85% tracheal collapse (Figs. 1–3). Fifty-seven percent (13/23) of affected deployers had TBM or combined TBM/EDAC, almost all with circumferential collapse and one having a saber-sheath tracheal morphology (Fig. 4). Nine deployers had EDAC alone. One with >70% collapse had a nonclassifiable morphology.

Our study included 62 deployers with a mean age of 42 years, most of whom were men (54/62, 89%). A substantial majority (42/62, 68%) reported never smoking. Physician-diagnosed GERD (48/62, 77%), obesity (31/62, 50%), OSA (35/62, 56%), and reported previous use of corticosteroid medications (53/59, 90%) were present in the majority of study participants. Most (55/62, 89%) had normal airflow based on measured FEV1 and calculated FEV1 percent predicted (FEV1PP). Air trapping was found in 35/61 (57%) study participants. The average number of deployments to southwest Asia was 2.5, and the mean total duration of deployment was 22.3 months. Exposure to explosive blasts during deployment was reported by 39/59 (66%) study participants.

Table 1 shows the comparative demographic, clinical, and exposure characteristics of the 2 study groups based on the presence or absence of ECAC. Adjusting for multiple comparisons, none of the differences were statistically significant. Those with ECAC were on average 6 years older

than those without ECAC (mean age, 45.82 vs. 40.20) and had slightly higher BMI (mean 31.89 vs. 30.77). The proportion of those who ever smoked cigarettes was low and similar between groups (7/23, 30% vs. 13/39, 33%), as were total pack-years of smoking (mean 9.73 vs. 8.00). OSA was more common (15/23, 65% vs. 20/39, 51%) in those with ECAC. Lung function and imaging findings of air trapping were similar between those with and without ECAC (12/23, 52% vs. 23/38, 61%). Deployment-related asthma was more common in those without ECAC compared with those with tracheal collapse (12/35, 34% vs. 2/22, 9%). The number of deployments did not differ between groups (mean 2.57 vs. 2.41), but the total months deployed were ~5 months longer on average in those with ECAC (mean, 23.67 vs. 18.84 mo). Blast exposure was less common among those with ECAC (12/21, 57% vs. 27/38, 71%). Bronchiectasis was rare (2/62, 3% overall). Tracheal wall thickness in millimeters was measured 1 cm above the carina and at maximum thickness. The mean tracheal thicknesses were wider among those with ECAC compared with those without ECAC, although this finding was not statistically significant. No study participants reported previous procedures linked to extrinsic tracheal compression (eg, intubation, lung surgery or airway stenting, or radiation to the neck or thorax).

We analyzed for differences among those with TBM (n=13), EDAC (n=9), and those with neither (n=39). Although none of the findings reached statistical significance, the rates of GERD (11/13, 85% vs. 29/39, 74%) and obesity (8/13, 62% vs. 19/39, 49%) were elevated in those with TBM



FIGURE 4. Classification of Tracheal Morphology (n=23)*. Note: Arrows show the direction of luminal collapse characteristic of the various ECAC morphologies. The top of the images represents the anterior tracheal membrane on HRCT scan and the bottom of the images represents the posterior tracheal membrane. *One patient had ECAC that had a nonclassifiable tracheal morphology. [full color online](#)

TABLE 1. Demographic, Clinical, and Deployment Characteristics in 62 Consecutive Symptomatic Patients With and Without ECAC

	No ECAC (n = 39)	ECAC (n = 23)	P*
Demographics			
Age (range) (y)	40.20 ± 11.16 (21.43-69.51)	45.82 ± 7.18 (35.13-64.84)	0.0192
Male	35 (90%)	20 (87%)	1.0000 [†]
Non-Hispanic white race/ethnicity‡	26/38 (68%)	18/22 (82%)	0.2581
BMI (range)	30.77 ± 4.98 (23.05-43.40)	31.89 ± 4.35 (26.06-43.58)	0.3607
Current/former smoker	13 (33%)	7 (30%)	0.8136
Smoking pack-years	8.00 ± 14.51	9.73 ± 13.34	0.3604
Median (IQR)	3.50 (0.75-7.50)	5.83 (1.54-8.64)	
Clinical characteristics			
GERD	29 (74%)	19 (83%)	0.4530
Obesity	19 (49%)	12 (52%)	0.7926
Obstructive sleep apnea	20 (51%)	15 (65%)	0.2851
Inhaled or oral steroids‡	33/37 (89%)	20/22 (91%)	1.0000 [†]
FEV1pp	92.90 ± 18.80	87.52 ± 11.64	0.1697
Air trapping‡	23/38 (61%)	12 (52%)	0.5226
Deployment characteristics			
Deployment-related asthma diagnosis‡	12/35 (34%)	2/22 (9%)	0.0315
Number of deployments	2.41 ± 1.63	2.57 ± 1.70	0.7679
Median (IQR)	2 (1-3)	2 (1-4)	
Total months deployed§	18.84 ± 10.35	23.67 ± 15.99	0.2116
Median (IQR)	17.97 (9.99-27.00)	19.94 (13.04-30.19)	
Blast exposure‡	27/38 (71%)	12/21 (57%)	0.2798

Values presented are the mean ± SD or the count (percent) unless otherwise indicated. The median and the interquartile range (IQR) are included for any skewed variables.

*P-values are from *t* tests for continuous variables using the Satterthwaite result for unequal variances between groups. Categorical variables were compared using the χ^2 test or Fisher Exact test (indicated with[†]). For non-normally distributed variables (smoking pack-years and number of deployments), exact Wilcoxon Rank Sum tests were used. A Bonferroni-adjusted threshold (<0.003) was used to evaluate statistical significance.

‡Data not available in all study participants; the denominator is the number of participants for whom these data were available.

§One outlier with over 10 years deployed that had a strong influence on the results was excluded from analyses.

compared with those without ECAC. On average, FEV1PP was lower (82.54%) among those with TBM. Inhaled or oral steroid use did not differ between groups.

We explored potential associations between relevant clinical characteristics and imaging findings of ECAC (Table 2). FEV1PP, an indicator of COPD, was not significantly associated with a diagnosis of ECAC in unadjusted analyses or after adjusting for smoking pack-years. Similarly, findings of air trapping were not significantly associated with a diagnosis of ECAC even after adjusting for differences in age. We found that ECAC was not significantly associated with OSA in unadjusted or adjusted analyses that accounted for age and BMI. However, the odds of having a diagnosis of OSA were 1.6 times as likely (95% confidence interval [CI]: 0.5, 4.8; *P*=0.43) among those with ECAC compared with those without ECAC.

We evaluated whether deployment exposure characteristics were associated with odds of ECAC (either TBM or EDAC), adjusting for age, BMI, and GERD (Table 2). For each additional year of deployment in southwest Asia, the odds of ECAC increased 1.5 times (95% CI: 0.9, 2.5; *P*=0.08). Those exposed to explosive blasts had 0.5 times lower odds of ECAC compared with those who were not exposed (95% CI: 0.2, 1.7; *P*=0.3); however, these findings were not statistically significant.

DISCUSSION

To our knowledge, this is the first study using an optimized imaging acquisition protocol combined with a well-standardized, quantitative approach to chest CT scoring to characterize tracheal abnormalities in symptomatic post-9/11 military deployers. Our findings suggest that TBM and EDAC are more common than previously recognized in

military personnel who return from deployment to southwest Asia and Afghanistan with persistent respiratory symptoms.^{1,2} Notably, the odds of developing tracheal abnormalities appear to increase with each additional year of deployment to these austere environments.

The pathogenesis and mechanisms of TBM and EDAC have been broadly classified into 3 major categories: mechanical, inflammatory, and congenital.^{30,31} Except for tobacco smoking, few studies have examined effects of occupational exposures on large airway integrity. In one study of 300 Iranian civilian victims of wartime exposure to mustard gas, 11 of 13 with TBM had concurrent findings of air trapping on chest CT imaging.¹⁸ In that exposed population, air trapping was much more common than TBM. The authors concluded that both TBM and air trapping after mustard gas exposure likely were related to the same pathogenic mechanisms of epithelial injury affecting both the large and small airways. Similarly, we found that air trapping was more common in symptomatic deployers than either TBM or EDAC, although both large and small airways abnormalities were present in the majority. Our findings suggest that military deployment exposures may injure the trachea and the distal airways, either together or separately. Although the mechanisms are unclear, review of the available medical literature suggests that some hazardous inhalants interact with nucleic acids and damage the structural integrity of cartilage and muscle of the airway.³² Notably, 2 of 3 cases of severe ECAC occurred in military personnel who worked as firefighters during their service, with frequent exposure to burn pit combustion products and to smoke from extinguishing aircraft fires. Future investigation of specific job duties and risk for ECAC in military firefighters may provide additional mechanistic insights.

TABLE 2. Association Between Common Clinical Findings, Deployment Characteristics, and ECAC

Predictor Variable	Comparison Group or Increase	Outcome Variable	Unadjusted			Adjusted		
			Odds of Outcome	95% Confidence Interval	P	Odds of Outcome	95% Confidence Interval	P
FEV1pp	+ 1%predicted	ECAC	0.980	0.949, 1.012	0.2281	0.980	0.950, 1.013	0.2295
Air trapping	No air trapping	ECAC	0.711	0.250, 2.023	0.5232	0.674	0.226, 2.010	0.4791
ECAC	No ECAC	OSA	1.781	0.615, 5.158	0.2873	1.568	0.516, 4.759	0.4274
Deployment duration*	+1 y	ECAC	1.432	0.864, 2.371	0.1633	1.452	0.855, 2.467	0.1673
Blast exposure	No blast exposure	ECAC	0.543	0.179, 1.653	0.2825	0.514	0.160, 1.652	0.2641

*One outlier with over 10 years deployed that had a strong influence on the results was excluded from analyses.

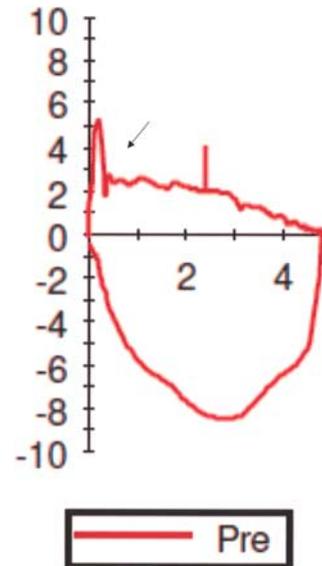


FIGURE 5. Abnormal flow-volume loop with arrow denoting the notched biphasic expiratory limb noted in the same deployed firefighter with EDAC from Figure 2. [full color online](#)

The prevalence of tracheal collapse was much higher in our study population than has been previously described. In an earlier study using bronchoscopy with minimal sedation, EDAC was found in 6 of 240 active-duty United States military personnel who had been deployed to Iraq or Afghanistan. However, only 6 who had audible or auscultatory wheezing were evaluated for ECAC. Although study participants completed a high-resolution chest CT scan, only 3 of the 6 with bronchoscopy-confirmed ECAC underwent dynamic CT with forced expiration, and imaging findings of ECAC were not defined or quantified.⁴ In contrast, all 62 consecutive patients in our study population underwent dynamic imaging with forced expiration and quantitative image scoring, enhancing the detection rate of tracheal collapse and suggesting that these disorders may be more common than previously recognized. ECAC was confirmed in 2 who underwent subsequent bronchoscopy. Future studies are needed to assess correlations between these 2 different ECAC diagnostic modalities.

Underlying comorbidities linked to excessive tracheal collapse include GERD, obesity, and OSA. Adjusting for age and BMI, we found that deployers with ECAC had 1.6 times the odds (95% CI: 0.5, 4.8) for OSA. Although not statistically significant, our findings suggest that tracheal collapsibility and sleep apnea may be clinically significant comorbidities for which clinicians should have a high index of suspicion, especially in the deployed military population.³³

Asthma was less common in symptomatic deployers with tracheal disorders compared with those without ECAC. This suggests that, in patients with respiratory symptoms who do not respond to conventional asthma therapy or have significant airways reactivity, the possibility of tracheal abnormalities should be considered. In our deployer population, abnormal spirometry was not sensitive in distinguishing those with and without ECAC, and both pulmonary function test and flow-volume loops were normal in the majority. However, when the expiratory limb of the spirometric flow-volume curve shows a biphasic or notched expiratory loop (Fig. 5), ECAC should be investigated.³⁴

Our study had several strengths. Standardized image acquisition and quantitative scoring by a thoracic radiologist helped assure diagnostic accuracy and comparability among participants. We used a well-defined imaging protocol for the assessment of airway collapsibility with the currently accepted threshold of 70%.³⁵ We evaluated consecutive symptomatic deployers, thus avoiding problems with selection bias. Although our sample size was not large, our study represents the largest to date describing tracheal abnormalities on dynamic expiratory CT imaging in post-9/11 deployers.

Our study has a number of limitations. First, all of the deployers had chest symptoms, and there were no asymptomatic exposed or unexposed comparison groups. Consequently, our study design precluded a clear understanding of the contribution of ECAC to reported chest symptoms. Second, although we did not find statistically significant relationships between ECAC and any of the demographic, clinical, or deployment characteristics examined, our estimates and 95% CIs suggest that there may be important relationships between deployment duration, OSA, and ECAC that warrant further investigation in a larger cohort. Although we did not perform dynamic bronchoscopy to supplement chest CT imaging findings in most of our study participants, previous research shows high interobserver and intraobserver agreement in CT imaging assessment for ECAC, supporting this approach to diagnosis.³⁶ Finally, deployment exposures are self-reported and may have been subject to recall bias and/or awareness bias.

Our findings have a number of important implications. We found a higher prevalence of ECAC than previously reported in United States military personnel with dyspnea after post-9/11 Iraq and Afghanistan deployment. Although neither deployment duration nor reported exposure to explosive blasts was significantly associated with ECAC, the odds of developing tracheal abnormalities increased with each additional year of deployment. Other deployment inhalational exposures (including those linked to military service-related firefighting) in addition to those considered in our study may be relevant to risk for large airway injury and should be explored in future studies. We also demonstrate that tracheal collapse is not limited to EDAC involving the posterior tracheal membrane alone, but that TBM is common. Our findings suggest that ECAC may contribute to persistent exertional dyspnea and cough reported by military deployers to the southwest Asia theater of operations. In addition to respiratory symptoms, ECAC is associated with impaired secretion clearance, increased incidence of acute respiratory events, and diminished respiratory quality of life.¹⁵ Clinicians caring for military deployers should consider HRCT with dynamic expiratory imaging to help elucidate potential factors contributing to persistent respiratory symptoms.

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