INCREASED INCIDENCE OF INHALATION BURN INJURY DURING THE COVID-19 PANDEMIC: A NATIONAL DATABASE STUDY

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ABSTRACT

The COVID-19 pandemic has forced many Americans to adapt their daily routines. In 2020, there was a significant increase in house fires according to the National Fire Prevention Association (NFPA). The objective of this study was to characterize the changes in suspected smoke inhalations during the first year of the pandemic in the National Emergency Medical Services Information System (NEMSIS). The NEMSIS database was queried for all EMS transports captured between 2017-2020. Differences in the incidences of suspected smoke inhalations and fire dispatches in 2020 were estimated using Poisson regression models. There was a 13.4% increase in the incidence of fire dispatches and a 15% increase in suspected smoke inhalations transported in 2020 compared to the previous 3 years. The IRR of both fire dispatches (1.271; 95% CI: 1.254-1.288; p<0.001) and suspected smoke inhalation (1.152; 95% CI: 1.070-1.241; p<0.001) was significantly elevated in 2020. The increases in fire dispatches and suspected smoke inhalations observed in the NEMSIS database are in concordance with other literature indicating the increase in fire incidence and morbidity observed during the pandemic. These results should inform fire prevention outreach efforts and resource allocation in burn centers in the event of future pandemic.

Key Words: suspected smoke inhalation, house fire, epidemiology, NEMSIS

INTRODUCTION

The COVID-19 pandemic has contributed to significant changes in the daily lives of Americans [1]. There have also been changes seen in patterns of traumatic injuries, delays in cancer diagnoses, and mental health [2–5]. Notably, the National Fire Prevention Association (NFPA) 2020 annual report noted the number of house fires increased significantly during the first year of the pandemic. The report, which describes a 5% increase in residential fires, suggests that changes in daily activities contributed to this increased fire incidence; many Americans are now spending more time at home, commuting less, and cooking more [6]. While the report also cites a decrease in per capita deaths due to fire, some studies in the literature have reported an increase in severity and morbidity during the pandemic. Yamamoto, et. al found an increase in in-hospital mortality, inhalation injuries, and total body surface area [7].

Inhalation injury (IH) is a major determinant of mortality from severe burn injuries, and represents increased morbidity and injury severity in victims of fires [8]. Management is challenging for healthcare providers and it creates a significant burden of disease to burn centers [8,9]. This injury pattern frequently presents in victims of house fires, as structural fires cause extreme air temperatures and generate smoke containing various chemicals, products of incomplete combustion, and aerosolized debris; fire victims that are confined to a closed space will have perpetuation of these injuries [10].

Currently, there are limited data examining the nationwide incidence of injuries from house fires during the pandemic period. We examined a national prehospital database in an effort to better characterize the changes in these injury patterns using suspected smoke inhalation (SSI) as a surrogate of morbidity from fires. We hypothesized that there was an increase in suspected smoke inhalation in 2020 and fire dispatches during the first year of the COVID-19 pandemic.

MATERIALS AND METHODS

Study design, data source and population

An institutional review board approval was obtained to perform a retrospective study using the National Emergency Medical Information System (NEMSIS). The NEMSIS is a convenience sample of emergency 911 activations nationwide, maintained by the National Highway Traffic Safety Administration (NHTSA) aimed at improving patient care through standardization, aggregation, and utilization of point of care EMS data at a local, state, and national level. It contains information on response characteristics, patient demographics, clinical presentation, interventions, and prehospital outcome data. Standard and state-level data collection have influenced participating states year to year, and thus data acquisition. We queried the years 2017-2020 and identified records pertaining to fire dispatches and transports of patients with inhalation injuries. This study was designed in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines for observational studies.

Covariates

Relevant covariates extracted were age, sex, race, scene type, and incident disposition.

Outcome measures

The number of fire dispatches and suspected smoke inhalations were used along with the total number of EMS activations, to calculate the raw annual incidence per 100,000 activations. The change in incidence was evaluated using the previous year's data. Poisson regression was then used to estimate the incidence rate ratio (IRR) for each year using 2017 as a baseline.

Statistical Analysis

Counts and proportions were used to summarize categorical variables and non-normally distributed continuous variables were reported as medians with interquartile ranges (IQR). Pearson's Chi squared test was used to compare each year's incidence with the previous year's data. Poisson regression was

used to evaluate whether there was an increase in the IRR of fire dispatches and suspected smoke inhalations during the pandemic. Model validation was then performed using deviance and Pearson goodness-of-fit tests. There was no missing data on outcomes of interest; a complete case analysis was undertaken. The threshold for statistical significance was set at $p<0.05$. Statistical analyses were performed using StataMP release 17 (College Station, TX).

RESULTS

We identified 397,258 fire dispatches out of 107,751,438 EMS dispatches over the study period. In 2020, there was an 8.4% increase in the incidence relative to 2019 ($p<0.001$) and a 13.4% increase over the average of the previous 3 years ($p<0.001$). The incidence rate ratio of fire dispatches was also increased in 2020 (1.271; 95% CI: 1.254-1.288; $p<0.001$; Table 2).

There were 11,732 patients with suspected smoke inhalations during the study period. Overall, the median age was 44 (IQR: 28-60), 54% were male, and 50% were of unknown race, 74% were injured at home, and 58% were transported to the hospital (Table 1). There was a relative increase of 1.06 per 10,000 from 2017-2020. In 2020, there was a 12% increase in the incidence relative to 2019 ($p<0.001$) and a 15% increase relative to the average of the previous 3 years ($p<0.001$). The incidence rate ratio also increased significantly (1.152; 95% CI: 1.070-1.241; $p<0.001$; Table 3).

DISCUSSION

The scope of the impact of COVID-19 on the United States healthcare system extends beyond resource utilization secondary to the disease itself; it also encompasses downstream effects of lockdown-related lifestyle modifications. Large scale changes in living patterns have led to changes in burn-related injury incidence and severity. Our study found an increase in the incidence and IRR of both fire dispatches and suspected smoke inhalations in a national prehospital database during the first year of the COVID-19 pandemic. These results have important public health implications and coupled with pandemic-associated decreases in fire prevention outreach suggest that more robust measures

should be taken in the event of future pandemics in order to reduce this burden on burn centers already strained by other stressors of the pandemic such as staff and equipment shortages.

There are no studies in the literature evaluating nationwide trends in burn injuries in the United States during the pandemic, though Yamamoto et. al. reported increases in flame burns, inhalation injuries, in-hospital mortality, as well as higher total body surface area of full-thickness burns during the lockdown period in Tokyo, Japan [7]. Our results also add context to the results of the 2020 NFPA report. Residential structure fires rose 5% from 2019 to 2020, while non-residential fires fell by eight percent and the rate of deaths per 1,000 home fires was 7.2, compared to 7.1 per 1,000 fires in 1980 [6].

The reasons for this observed increase are undoubtedly multifactorial. The NFPA report suggests changes in home-cooking increased the risk of house fires. Consumer reporting has suggested that up to 55% of Americans were eating at home during the pandemic compared to pre-lockdown [11]. As more Americans resorted to food preparation at home, it is understandable that this could have contributed to the increase in house fires. Further research will serve to delineate the causation of increased incidence of suspected smoke inhalation. We presume a change in fire prevention efforts also played a role. Many community fire departments across the country engage in outreach events such as home visits for smoke alarm inspection and large-scale community fire prevention events. As social distancing policies dictated events such as these could not be held, it is expected that the lack of fire prevention outreach coupled with more time spent at home engaging in higher risk activities such as cooking only exacerbated the problem. An important future area of research will be to further classify suspected smoke inhalation injuries by region, socioeconomic status, race, and other descriptive demographic data. This will allow better tailoring of community fire prevention measures. Finally, it is unknown whether burn centers in the United States suffered as a whole from the staffing shortages commonly seen during the pandemic. However, some anecdotal literature suggests that operative volume of burn patients increased during lock down periods and as a result the authors stress a need to maintain adequate staffing levels in burn units [12].

This study has the inherent limitations of a retrospective review. The NEMSIS database, though well cited in the literature, has several important limitations to consider. Principally, it is a convenience dataset meaning that not all EMS activations in the country are captured every year as data collection is highly dependent on cooperation from state health agencies. For example, in 2017 NEMSIS implemented its V3 data standard and as a result, not all states transitioned and were hence not represented. Another limitation is the method in which injury information is collected. Patient care reports in the prehospital setting are usually limited to 2 "provider impressions" which are collected by the data standard. Therefore, some inhalation injuries may not have been captured by the dataset if more severe injuries or conditions were recorded instead, superseding and functionally negating the diagnosis of inhalational injury. Finally, in using a national prehospital database, we did not capture suspected smoke inhalations that may have been transported by personal vehicle to an emergency department. It's also important to note that suspected smoke inhalation does not equal an inhalation injury. It is inherently difficult to diagnose an inhalational injury using clinical findings alone. Singed nasal hair for example is the most outward sign and realistically the one of the only signs of IH that can be recognized in the field. However, clinical findings such as these have been shown to have poor discriminatory capability in inhalation injury diagnosis when compared to gold standard bronchoscopy [13]. It is likely that since suspected smoke inhalation is not a true inhalation injury that the estimated incidence is likely an overestimate of true inhalation injury.

In summary, there was an increase in the suspected smoke inhalation exposures and fire dispatches seen in the prehospital setting during the first year of the COVID-19 pandemic compared to previous years. Though this effect is likely multifactorial, various public health and human behavioral factors associated with the pandemic are likely contributory. Further studies should also examine hospital level data to elucidate better the changes in morbidity and mortality at the national level. Our results should serve to inform public health agencies, fire departments, burn centers, and the general public to improve delivery of fire prevention efforts in the event future pandemics to mitigate these trends.

REFERENCES

[1]   Conroy DA, Hadler NL, Cho E, Moreira A, MacKenzie C, Swanson LM, et al. The

       effects of COVID-19 stay-at-home order on sleep, health, and working patterns: a

       survey study of US health care workers. J Clin Sleep Med 2021;17:185–91.

       https://doi.org/10.5664/jcsm.8808.

[2]   Habarth-Morales TE, Rios-Diaz AJ, Caterson EJ. Pandemic puppies: man's best

       friend or public health problem? A multidatabase study. J Surg Res 2022;276:203–7.

       https://doi.org/10.1016/j.jss.2022.02.041.

[3]   Patt D, Gordan L, Diaz M, Okon T, Grady L, Harmison M, et al. Impact of COVID-

       19 on Cancer Care: How the Pandemic Is Delaying Cancer Diagnosis and Treatment

       for American Seniors. JCO Clin Cancer Inform 2020;4:1059–71.

       https://doi.org/10.1200/CCI.20.00134.

[4]   Torales J, O'Higgins M, Castaldelli-Maia JM, Ventriglio A. The outbreak of COVID-

       19 coronavirus and its impact on global mental health. Int J Soc Psychiatry

       2020;66:317–20. https://doi.org/10.1177/0020764020915212.

[5]   Kaufman EJ, Holena D, Koenig G, Martin ND, Maish GO, Moran BJ, et al. Increase

       in Motor Vehicle Crash Severity: An Unforeseen Consequence of COVID-19. Am

       Surg 2021:31348211047466. https://doi.org/10.1177/00031348211047466.

[6]   National Fire Protection Association. Fire Loss in the United States During 2020.

       National Fire Protection Association; 2021.

[7]   Yamamoto R, Sato Y, Matsumura K, Sasaki J. Characteristics of burn injury during

COVID-19 pandemic in Tokyo: A descriptive study. Burns Open 2021.

https://doi.org/10.1016/j.burnso.2021.06.007.

[8]   Jones SW, Williams FN, Cairns BA, Cartotto R. Inhalation injury: pathophysiology,

diagnosis, and treatment. Clin Plast Surg 2017;44:505–11.

https://doi.org/10.1016/j.cps.2017.02.009.

[9]   Foncerrada G, Culnan DM, Capek KD, González-Trejo S, Cambiaso-Daniel J,

Woodson LC, et al. Inhalation injury in the burned patient. Ann Plast Surg

2018;80:S98–105. https://doi.org/10.1097/SAP.0000000000001377.

[10]   Sheridan RL. Fire-Related Inhalation Injury. N Engl J Med 2016;375:464–9.

https://doi.org/10.1056/NEJMra1601128.

[11]   Acosta. COVID-19: Reinventing How America Eats. Acosta, Inc.; 2020.

[12]   Codner JA, De Ayala R, Gayed RM, Lamphier CK, Mittal R. The Impact of the COVID-19

Pandemic on Burn Admissions at a Major Metropolitan Burn Center. J Burn Care Res

2021;42:1103–9. https://doi.org/10.1093/jbcr/irab106.

[13]   Ching, JA, Shah, JL, Doran, CJ, Chen, H, Payne, WG., Smith, DJ. Evaluation of Physical

Exam Findings in Patients Assessed for Suspected Burn Inhalation Injury. 2015; The Journal

of Burn Care & Research 36, 197–202. doi:10.1097/bcr.0000000000000175

TABLES

Table 1. Patient demographics of patients transported by emergency medical services after sustaining suspected smoke inhalation injury – National Emergency Medical Services Information System, United States, 2017-2020.

Abbreviations: IRR, incidence rate ratio; CI, confidence interval

Covariate	2017		2018		2019		2020		*p*
	Median (IQR)/ n (%)		Median (IQR)/ n (%)		Median (IQR)/ n (%)		Median (IQR)/ n (%)		
Age, y	43 (27.0, 59.0)		45 (29.0, 61.0)		44 (28.0, 60.0)		43 (27.0, 60.0)		0.028
Sex									0.71
Male	433	(54)	1,216	(55)	1,946	(54)	2,756	(54)	
Female	371	(46)	974	(44)	1,589	(44)	2,313	(45)	
Unknown/Not Applicable	5	(1)	27	(1)	45	(1)	57	(1)	
Race									<0.001
White	151	(19)	602	(27)	1,063	(30)	1,887	(37)	
Black or African American	54	(7)	147	(7)	410	(12)	740	(14)	
Hispanic or Latino	33	(4)	59	(3)	140	(4)	245	(5)	
American Indian or Alaska Native	4	(1)	6	(<1)	18	(1)	30	(1)	
Asian	3	(<1)	8	(<1)	15	(<1)	41	(1)	

Native Hawaiian or Other Pacific Islander	1	(<1)	3	(<1)	10	(<1)	6	(<1)	
Not Applicable	5	(1)	9	(<1)	56	(2)	69	(1)	
Not Recorded	558	(69)	1,383	(62)	1,868	(52)	2,108	(41)	
Scene Type									<0.0 01
Private Residence	548	(68)	1,588	(72)	2,651	(74)	3,938	(77)	
Institutional/Non-private Residence	8	(1)	50	(2)	76	(2)	98	(2)	
School	27	(3)	72	(3)	100	(3)	149	(3)	
Sports/Athletic Facility	1	(<1)	4	(<1)	4	(<1)	1	(<1)	
Street/Highway	68	(8)	168	(8)	203	(6)	339	(7)	
Trade/Service Area	48	(6)	135	(6)	192	(5)	227	(4)	
Industrial/Construction Area	9	(1)	32	(1)	65	(2)	52	(1)	
Farm	4	(1)	18	(1)	14	(0)	21	(<1)	
Recreation/Wilderness Area	45	(6)	47	(2)	60	(2)	87	(2)	
Unspecified Place	15	(2)	36	(2)	15	(<1)	19	(<1)	
Not Applicable/Not Recorded	36	(4)	67	(3)	200	(6)	195	(4)	
Incident Disposition									0.036
Assisting unit only	4	(1)	16	(1)	16	(0)	30	(1)	
Canceled prior to arrival	0	(0)	1	(<1)	4	(<1)	3	(<1)	

Patient Expired	4	(1)	5	(<1)	9	(<1)	14	(<1)
Patient refused treatment	298	(37)	856	(39)	1,431	(40)	2,148	(42)
Patient transport to hospital	501	(62)	1,337	(60)	2,106	(59)	2,905	(57)
Standby unit only	2	(<1)	2	(<1)	14	(<1)	26	(1)

Table 2. Annual Incidences and Incidence Rate Ratios Fire Dispatches – National Emergency Medical Services Information System, United States, 2017-2020.

Abbreviations: IRR, incidence rate ratio; CI, confidence interval

Year	Fire Dispatches	Total Dispatches	Raw Incidence (per 1,000/year)	*p*	IRR	95% CI			*p*
2017	24,132	7,878,714	3.06	*ref.*		*ref.*			
2018	81,985	22,445,766	3.65	<0.001	1.193	(1.176	-	1.210)	<0.001
2019	122,491	34,089,584	3.59	<0.001	1.173	(1.157	-	1.189)	<0.001
2020	168,650	43,337,374	3.89	<0.001	1.271	(1.254	-	1.288)	<0.001

Table 3. Annual Incidences and Incidence Rate Ratios of Inhalation Burns – National Emergency Medical Services Information System, United States, 2017-2020.

Abbreviations: IRR, incidence rate ratio; CI, confidence interval

Year	Suspected smoke inhalations	Total Dispatches	Raw Incidence (per 10,000/year)	*p*	IRR	95% CI			*p*
2017	809	7,878,714	1.03	*ref.*			*ref.*		
2018	2,217	22,445,766	0.99	0.345	0.962	(0.888	-	1.043)	0.345
2019	3,580	34,089,584	1.05	0.023	1.023	(0.948	-	1.104)	0.563
2020	5,126	43,337,374	1.18	<0.001	1.152	(1.070	-	1.241)	<0.001