

# Impact of prehospital mechanical ventilation

## A retrospective matched cohort study of 911 calls in the United States

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### Abstract

Prehospital use of ventilators by emergency medical services (EMS) during 911 calls is increasing. This study described the impact of prehospital mechanical ventilation on prehospital time intervals and on mortality.

This retrospective matched-cohort study used 4 consecutive public releases of the US National Emergency Medical Services Information System dataset (2011–2014). EMS activations with recorded ventilator use were randomly matched with activations without ventilator use (1 to 1) on age (range  $\pm 2$  years), gender, provider's primary impression, urbanicity, and level of service.

A total of 5740 EMS activations were included (2870 patients per group). Patients in the ventilator group had a mean age of 69.1 ( $\pm 17.3$ ) years with 49.4% males, similar to the non-ventilator group. Activations were mostly in urban settings (83.8%) with an advanced life support level of care (94.5%). Respiratory distress (77.8%) and cardiac arrest (6.8%) were the most common provider's primary impressions. Continuous positive airway pressure was the most common mode of ventilation used (79.2%).

Mortality was higher at hospital discharge (29.0% vs 21.1%,  $P = .01$ ) but not at emergency department (ED) discharge (8.4% vs 7.4%,  $P = .19$ ) with prehospital ventilator use. Both total on-scene time and total prehospital time intervals increased with reported ventilator use (4.10 minutes (95% confidence interval [CI]: 2.71–5.49) and 3.59 minutes (95% CI: 3.04–4.14), respectively).

Ventilator use by EMS agencies in 911 calls in the US is associated with higher prehospital time intervals without observed impact on survival to ED discharge. More EMS outcome research is needed to provide evidence-based prehospital care guidelines and targeted resource utilization.

**Abbreviations:** ALS = advanced life support, AMS = air medical services, BIPAP = bilevel positive airway pressure, BLS = basic life support, CMS = Center for Medicare and Medicaid Services, CPAP = continuous positive airway pressure, ED = emergency department, EDD = emergency department disposition, EMS = emergency medical services, HD = hospital disposition, NEMSIS = National Emergency Medical Services Information System, NIV = noninvasive ventilation, PSAP = public safety answering point, SCT = specialty care transport.

**Keywords:** emergency medical services, NEMSIS, outcome, prehospital, ventilator

### 1. Introduction

Ventilators are increasingly used by emergency medical services (EMS) in the United States in the prehospital setting for a variety

of emergency conditions.<sup>[1,2]</sup> Prehospital treatment protocols are gradually including different modes of ventilation mainly noninvasive and for some conditions controlled mechanical ventilation. Continuous positive airway pressure (CPAP) and noninvasive ventilation (NIV) including bilevel positive airway pressure (BIPAP) are recommended for patients with acute dyspnea secondary to suspected pulmonary edema or chronic obstructive pulmonary disease (COPD) exacerbation.<sup>[3,4]</sup> Early application of noninvasive ventilation aims to prevent endotracheal intubation and reduce hospital length of stay.<sup>[1]</sup> Ventilator use in intubated patients with controlled mechanical ventilation mode is also frequently reported during critical care transports but rarely during 911 emergency scene responses.<sup>[5]</sup>

Studies examining the impact of prehospital ventilator use have focused mostly on noninvasive ventilation and have yielded conflicting results. While there is a consensus that the use of prehospital ventilation, mainly CPAP and NIV, improves vital signs in patients with acute respiratory distress with a trend towards decreased intubation rates, the impact on mortality is unclear.<sup>[1,6]</sup> A recent systematic review of controlled studies by Bakke et al reported no difference in mortality and a trend towards reduced intubation rates in patients with prehospital supplemental CPAP when compared to those with standard medical treatment alone.<sup>[1]</sup> This review also reported on the weak evidence provided by studies examining this topic with the majority demonstrating small samples and, thus, lacking sufficient power to detect a significant difference in outcomes.<sup>[1]</sup> Another systematic review and meta-analysis by Mal et al

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reported decreased mortality and reduced need for in-hospital invasive ventilation with the use of prehospital noninvasive ventilation.<sup>[6]</sup> Similarly, a meta-analysis by Goodacre et al reported reduced mortality in patients with prehospital CPAP use.<sup>[7]</sup>

The impact of ventilator use on prehospital time intervals is also not well studied. Two small studies evaluating the use of CPAP or NIV showed contradicting results with shorter prehospital time intervals in 1<sup>[8]</sup> and no difference in the other.<sup>[9]</sup>

Most of the studies are also limited to specific emergency conditions such as acute respiratory distress and do not report on ventilator use for other emergency conditions such as cardiac arrest, altered level of consciousness, or traumatic injury where controlled mechanical ventilation is initiated after endotracheal intubation.

Additionally, with increasing portability of emergency transport ventilators, the use of ventilators in the prehospital field is expected to increase and will require additional training and regular skill maintenance for prehospital providers on ventilator operations.<sup>[10,11]</sup> Evaluating the impact of this intervention on important outcomes mainly mortality and prehospital time intervals is therefore needed.

The National Emergency Medical Services Information System (NEMSIS) is the largest EMS US database. At present, NEMSIS collects activations from EMS agencies in 49 states and territories in the US.<sup>[12]</sup> Data from NEMSIS is publicly released every year. This study used 4 consecutive releases of the NEMSIS database (2011 through 2014) to describe the impact of ventilator use in the prehospital field on 2 main outcomes: mortality (at emergency department [ED] discharge) and prehospital time intervals (total on-scene time and total prehospital time intervals).

## 2. Methods

### 2.1. Study design

We carried out a retrospective matched cohort study using combined NEMSIS datasets (2011 through 2014). An exemption from Institutional Review Board at the American University of Beirut was obtained for the use of this dataset.

### 2.2. Study setting

NEMSIS constitutes a convenience sample of EMS activations collected from 49 States and territories in the US. Approximately 83 variables are collected and the information is maintained through standardized definitions and formats for patient care reports.<sup>[12]</sup> Data are initially collected by local EMS agencies then aggregated at the State level and submitted to the NEMSIS national database.<sup>[12]</sup> Participating States have different inclusion criteria and proportions of submitted EMS activations.<sup>[13,14]</sup> Each EMS record in NEMSIS corresponds to a unique activation submitted by a single responding vehicle. Thus, if multiple EMS vehicles respond to the same event, multiple records for the same event will reside in the national database. NEMSIS database is, therefore, a collection of EMS activations rather than a collection of unique patients.<sup>[12–14]</sup>

### 2.3. Study population

The combined NEMSIS public datasets include information on 83,936,070 EMS activations. In this study, we analyzed only EMS activations that met the following inclusion criteria: the type of service requested is “911 response (scene),” information is

available on procedures performed (ventilator use is coded in NEMSIS under procedures), information is available on primary endpoint (ED disposition) and information is complete for matched variables (age, gender, provider’s primary impression, urbanicity, and Center for Medicare and Medicaid Services [CMS] service level). We excluded activations with “call cancelled,” or where no patient was found, or if the patient refused treatment. We also excluded activations where the transport destination type was different than “hospital” or “other EMS responder (air or ground)”. Figure 1 shows the sample selection which yielded a total of 5740 activations that were included in the final analysis.

### 2.4. Available data

Ventilator use is reported in the NEMSIS as “Airway Ventilator Operation,” “Airway Ventilator with PEEP,” “Airway BIPAP” or “Airway CPAP.”<sup>[15]</sup> The primary endpoints of this study were ED disposition (mortality at ED discharge) and prehospital time intervals (total on-scene time and total prehospital time intervals). A secondary endpoint included hospital disposition (mortality at hospital discharge). Primary and secondary endpoints are reported elements in the NEMSIS database.

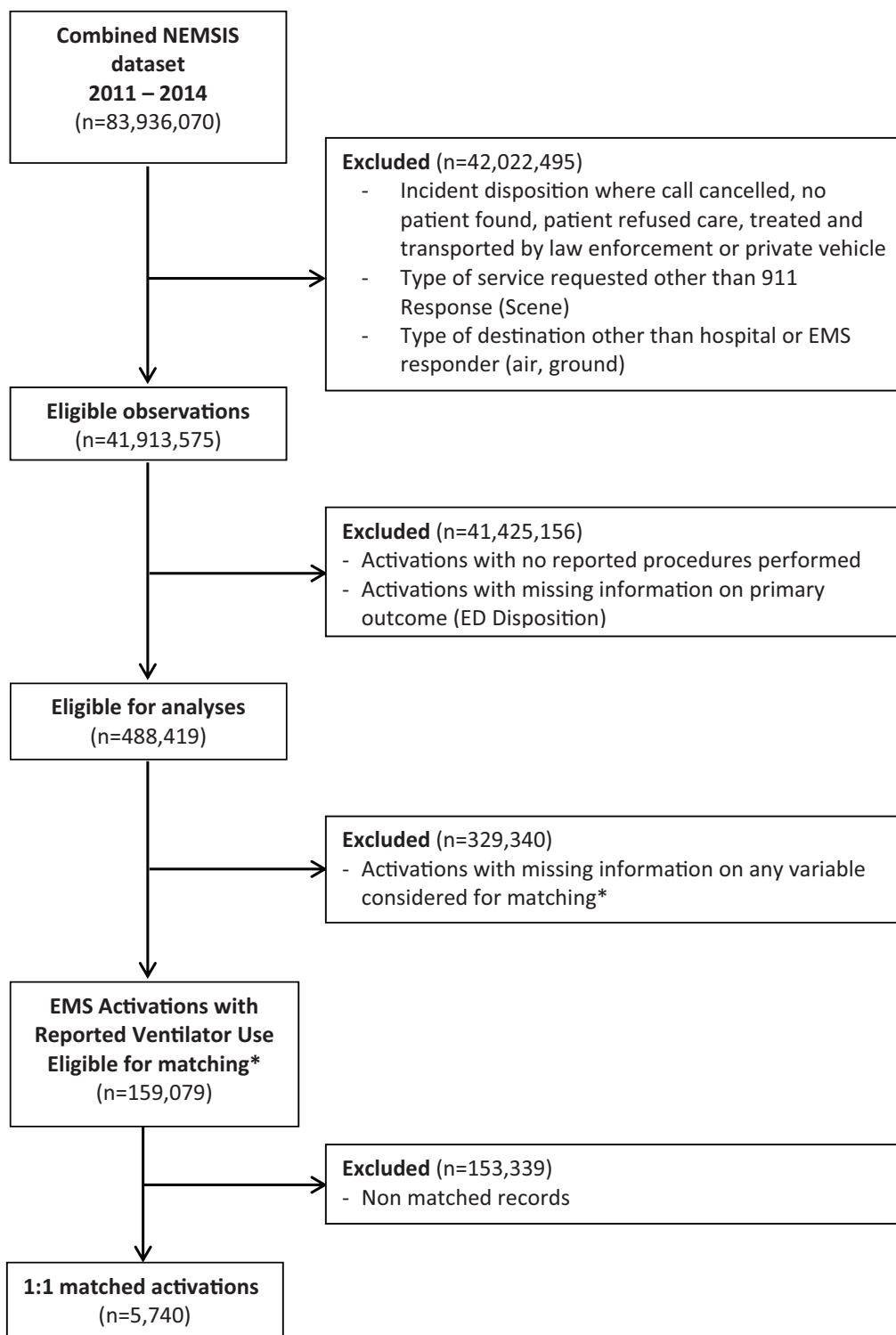
The urbanicity of an EMS agency service area is based on United States Department of Agriculture urbanicity codes and Medicare and Medicaid Services (CMS) EMS service levels on Office of Management and Budget definitions.<sup>[12–14]</sup>

Additionally, event-related variables such as patient age and sex, complaint reported by dispatch, provider’s primary impression (preliminary diagnosis), and the type of destination were analyzed. Specific time intervals were also collected or calculated including “public safety answering point” (PSAP) to “unit in route” (call to ambulance dispatch), PSAP to “on-scene time” (call to ambulance arrival on scene), “total on scene time interval” (time from ambulance arrival to scene to time initiating transport to hospital), “transport time interval” (transport from scene to hospital), and “total prehospital time interval” (PSAP to arrived at destination).

### 2.5. Data analysis

Data from the NEMSIS files were extracted and imported into the Statistical Analysis Software version 9.1 for data management and analyses. After identifying the study population using the above sample selection criteria, random matching (1:1) independent of the exposure and response variable was done from the group with no reported ventilator use based on the following variables: age range of  $\pm 2$  years, gender, provider’s primary impression, urbanicity, and CMS service level.

We then carried out binary descriptive analyses presenting number and percent for categorical variables and mean and standard deviation for continuous variables. For a comparison between the 2 groups, the Chi-square test was used for categorical variables and the independent Student *t* test used for continuous variables to determine significance. Three different regression analyses were then conducted for primary and secondary endpoints to assess the relationship between ventilator use and different dependent variables. Logistic regression was carried out for categorical outcomes with 2 levels of response, whereas multinomial regression analyses were carried out for those with more than 2 levels. Data for this analysis was presented as odds ratio and 95% confidence interval (CI). On the other hand, linear regression was carried out for continuous outcomes, and results



\*matching on: age range of  $\pm 2$  years, gender, provider’s primary impression, urbanicity and level of service

Figure 1. Constitution of the study group.

were presented as a beta coefficient ( $\beta$ ) and 95% CI. A  $P$ -value  $< .05$  was used to indicate statistical significance.

### 3. Results

A total of 5740 EMS activations were included in the study after matching EMS activations with reported ventilator use using a

1:1 ratio. Patients in the group with reported ventilator use had a mean age of 69.1 ( $\pm 17.3$ ) years with nearly half being male (49.4%, Table 1). EMS activations in this group were mostly in an urban setting (83.8%) and cared for by advanced life support-level services (94.5%). Breathing problem was the most common complaint reported by dispatch (73.8%) followed by chest pain

**Table 1****General characteristics of patients included in the study by ventilator use.**

General characteristics	Ventilator – (n=2870)	Ventilator + (n=2870)	P-value
Age (n=5740)	68.8 ± 17.9	69.1 ± 17.3	.55
Gender (n=5740)			
Female	1451 (50.6)	1451 (50.6)	1.00
Male	1419 (49.4)	1419 (49.4)	
Urbanicity (n=5740)			
Urban	2405 (83.8)	2405 (83.8)	
Rural	312 (10.9)	312 (10.9)	
Suburban	100 (3.5)	100 (3.4)	1.00
Wilderness	53 (1.8)	53 (1.8)	
CMS level (n=5740)			
ALS	2713 (94.5)	2713 (94.5)	
AMS	96 (3.3)	96 (3.3)	
BLS	42 (1.5)	42 (1.5)	1.00
SCT	19 (0.7)	19 (0.7)	
Incident/patient disposition (n=5740)			
Treated, transported by EMS	2844 (99.1)	2839 (98.9)	.51
Others	26 (0.9)	31 (1.1)	
Ventilator use (n=5740)			
Airway-ventilator operation		805 (28.0)	
Airway-ventilator with PEEP		18 (0.6)	
Airway-BiPAP		71 (2.5)	
Airway-CPAP		2274 (79.2)	

ALS=advanced life support, AMS=air medical support, BiPAP = bilevel positive airway pressure, BLS=basic life support, CPAP = continuous positive airway pressure, SCT=specialty care transport.

(4.5%). CPAP was the most common mode of ventilation used (79.2%).

The most common provider's primary impressions for which ventilator use was reported included respiratory distress (77.8%), cardiac arrest (6.8%), traumatic injury (3.4%), and altered level of consciousness (3.2%, Table 2). Patients in the group without reported ventilator use demonstrated similar characteristics, except for a slightly different composition of complaints reported by dispatch.

### 3.1. Primary outcomes

In the regression modeling, after matching for potential confounders, ventilator use by EMS agencies during 911 calls was associated with increased prehospital time intervals ( $P < .0001$ ) but not with increased mortality at ED discharge (8.4% vs 7.4%,  $P = .19$ , Table 3). There was an increase in the total on-scene time interval by 3.59 minutes (95% CI: 3.04–4.14) and in the total prehospital time interval by 4.10 minutes (95% CI: 2.71–5.49) in the group with reported ventilator use.

### 3.2. Secondary outcomes

A significant increase in mortality rates was however noted at hospital discharge in the group with reported prehospital ventilator use compared to EMS activations without reported ventilator use (29.0% vs 21.1%,  $P = .01$ ).

## 4. Discussion

EMS agencies utilize ventilators during 911 calls for different conditions mainly respiratory distress but also cardiac arrest, traumatic injury, and altered mental status. This study is the first to examine the impact of ventilator use in the prehospital field during emergency response on a population of patients with a variety of EMS conditions. More specifically, it examined the

impact on mortality at ED discharge and on prehospital time intervals (ie, on-scene time and total prehospital time intervals).

Ventilator use by EMS agencies during emergency response was not associated with improved survival to ED discharge. The impact on mortality rates at ED discharge was not significantly different between the 2 matched groups. Ventilator use was associated with higher mortality at hospital discharge (29.0% vs 21.1%,  $P = .01$ ). This study is the first to report the impact of ventilator use on mortality using a heterogeneous sample of patients with different EMS conditions. Previous studies have reported conflicting results: In patients with acute respiratory failure prehospital CPAP was associated with decreased in-hospital mortality<sup>[1,7,16–18]</sup> while prehospital supplemental noninvasive ventilation did not show an impact on in-hospital mortality.<sup>[11]</sup> The evidence regarding BiPAP and supplemental NIV was inconclusive.<sup>[1,7]</sup> These studies were however limited to patients with acute respiratory failure secondary to heart failure, pneumonia, and exacerbation of COPD. To our knowledge, no previous study has examined the impact of ventilator use on patients with other EMS conditions including but not limited to cardiac arrest, traumatic injury or altered mental status. Although respiratory distress constituted the main indication for ventilator use in this study, there were other provider impressions for which ventilator use was reported. Our study findings, therefore, reflect the impact of the actual practice in a setting where ventilator use is incorporated in different EMS protocols and different modalities of mechanical ventilation are used for different indications.

Prehospital ventilator use was associated with increased in-hospital mortality in our study. Nevertheless, this finding might simply reflect higher clinical severity in patients for whom prehospital ventilator use was reported or the presence of additional clinical confounders related to care in the in-hospital that are not part of the NEMESIS public dataset and that were not accounted for. In addition, this secondary outcome was not

**Table 2**  
**Event related characteristics of patients included in the study by ventilator use.**

Event related characteristics	Ventilator – (n=2870)	Ventilator + (n=2870)	P-value
Complaint reported by dispatch (n=5609)			
Breathing problem	1873 (66.8)	2071 (73.8)	
Chest pain	168 (6.0)	126 (4.5)	
Unconscious/fainting	126 (4.5)	88 (3.1)	
Cardiac arrest	107 (3.8)	86 (3.1)	
Transfer/interfacility/palliative care	51 (1.8)	86 (3.1)	
Traumatic injury	53 (1.9)	82 (2.9)	<.0001
Sick person	139 (5.0)	79 (2.8)	
Unknown problem Man down	55 (2.0)	40 (1.4)	
Heart problems	38 (1.4)	32 (1.1)	
Others	194 (6.9)	115 (4.1)	
Provider's primary impression (n=5740)			
Respiratory distress	2234 (77.8)	2234 (77.8)	
Cardiac arrest	196 (6.8)	196 (6.8)	
Traumatic injury	97 (3.4)	97 (3.4)	
Altered level of consciousness	92 (3.2)	92 (3.2)	
Cardiac rhythm disturbance	75 (2.6)	75 (2.6)	
Chest pain/discomfort	52 (1.8)	52 (1.8)	
Respiratory arrest	49 (1.7)	49 (1.7)	
Stroke/CVA	16 (0.6)	16 (0.6)	
Seizure	12 (0.4)	12 (0.4)	
Syncope/fainting	10 (0.3)	10 (0.3)	1.00
Airway obstruction	8 (0.3)	8 (0.3)	
Abdominal pain/problems	7 (0.2)	7 (0.2)	
Hypovolemia/shock	7 (0.2)	7 (0.2)	
Poisoning/drug ingestion	7 (0.2)	7 (0.2)	
Allergic reaction	2 (0.1)	2 (0.1)	
Behavioral/psychiatric disorder	2 (0.1)	2 (0.1)	
Diabetic symptoms (hypoglycemia)	2 (0.1)	2 (0.1)	
Hypothermia	1 (0.0)	1 (0.0)	
Smoke inhalation	1 (0.0)	1 (0.0)	
Type of destination (n=5740)			
Hospital	2863 (99.8)	2859 (99.6)	
Other EMS responder (air)	6 (0.2)	8 (0.3)	.58
Other EMS responder (ground)	1 (0.0)	3 (0.1)	
Time intervals, min			
Call to ambulance dispatch (n=3917)	3.5±10.4	3.7±10.3	.50
Call to ambulance arrival on scene (n=3915)	11.2±12.4	11.6±11.8	.35
Transport from scene to hospital (n=5692)	13.0±12.7	13.4±14.0	.24

CVA=cerebrovascular accident, EMS = emergency medical services, EMS responder=ambulance.

**Table 3**  
**Impact of ventilator use on primary and secondary outcomes.**

	Regressions on matched sample			Measure of association	P-value
	Ventilator – (n=2870)	Ventilator + (n=2870)	P-value		
Primary outcomes					
EDD_Death*	213 (7.4)	240 (8.4)	.19	1.14 (0.94–1.38)	.19
EDD_Survival*	2657 (92.6)	2630 (91.6)	.19	0.88 (0.72–1.06)	.19
Total on scene time interval †(2850 vs 2860)	17.1±8.9	20.7±12.1	<.0001	3.59 (3.04–4.14)	<.0001
Total prehospital time interval ‡ (1927 vs 1976)	41.1±21.2	45.2±23.1	<.0001	4.10 (2.71–5.49)	<.0001
Secondary outcome‡ (n=969)					
HD_Survival_death	112 (21.1)	127 (29.0)	.01	Reference	
HD_Survival_transfer	309 (58.2)	235 (53.6)		0.67 (0.49–0.91)	.01
HD_Survival_discharge	110 (20.7)	76 (17.3)		0.61 (0.41–0.90)	.01

EDD=emergency department disposition, HD=hospital disposition, On scene time interval=time from ambulance arrival to scene to time initiating transport to hospital.

\* Logistic regression, measure of association reported as odds ratio (OR) and 95% confidence interval (CI).

† Linear regression, measure of association reported as beta coefficient (β) and 95% confidence interval (CI).

‡ Multinomial logistic regression.

available for a large subset of the study population since NEMSIS is primarily a prehospital database.

This study also examined the impact of prehospital ventilator use on prehospital time intervals, more specifically on total scene time and total prehospital time intervals. Even though the “call to arrival on scene” and the “scene to destination” time intervals were comparable in both groups, ventilator use was associated with a significant increase in both the “total on scene” and “total prehospital” time intervals. The application of ventilator in the prehospital field was therefore associated with a delay in arrival to destination without observed improvement in survival. Very few studies have previously examined this outcome with 1 study showing a mild decrease in “prehospital treatment time” by less than 1 minute (CPAP=30.3 minutes; non-CPAP=30.8 minutes;  $P<.01$ )<sup>[8]</sup> and another showing no impact on “out of hospital treatment time” (NIV, 31.4 vs 31.2 minutes;  $P=.931$ ).<sup>[9]</sup> When different modalities of mechanical ventilators were examined on different EMS conditions, ventilator use resulted in an increase of 4 minutes during prehospital care and transport. The clinical significance of this increase ultimately depends on the type of EMS conditions for which a ventilator is applied: this increase might not be justified in patients with traumatic injury who usually require immediate transport while it might be considered insignificant for patients with acute respiratory distress who would benefit clinically (in terms of improved vital signs and comfort) en route to hospital. Viewed in general, an increase in prehospital times without significant impact on survival should be investigated further.

The findings of this study are important in showing the potential impact of a specific intervention (prehospital ventilator use) on a heterogeneous sample of patients extracted from a national database. This study evaluated the actual EMS practice in the US and its findings are useful for EMS medical directors and administrators to reflect on and to scrutinize expanding an intervention to several conditions when the evidence is present for only 1 specific condition. Assessing specific ventilator modalities in specific EMS conditions, not only acute respiratory failure, is needed to provide the justification and the evidence for expanding the scope of application and increasing the indications of this treatment intervention.

## 5. Limitations

Our study demonstrates limitations inherent to a retrospective study design. We also did not assess for other important outcomes related to ventilator use mainly intubation rates and improvement in vital signs. Measures of patient physiology are not available in version 2 of the NEMSIS national dataset. Similarly, the impact on in-hospital mortality should be viewed with caution since NEMSIS is a prehospital database with limited availability and sharing of inpatient data elements related to in-hospital care. Elements related to long-term patient outcomes are also lacking. Although matching was carried out for several patients’ and events’ characteristics such as provider’s impression and level of service, potential selection bias could have affected the results due to the lack of matching on clinical severity. This might have led to the nonventilator group having lower clinical severity when compared to the ventilator group which would potentially lead to overestimation of the observed difference in outcomes. Matching for clinical severity was however not possible for this public dataset since a measure of clinical severity is lacking in version 2 of NEMSIS. This highlights the need for incorporating validated clinical severity scoring systems in EMS

software and in State and National data sets to allow for more accurate evaluation of the impact of a clinical intervention on patient outcomes in the prehospital field. Finally, the study examined different modes of ventilation in a heterogeneous group of patients with possible reporting of different modes for conditions where there is no clear indication such as NIV in a patient with cardiac arrest during the prearrest phase or during CPR. It is therefore difficult to estimate the true impact of ventilation modes on the specific groups included in this study because of the heterogeneity of the sample and lack of stratification by mode of ventilation.

## 6. Conclusion

Ventilator use by EMS agencies during 911 calls is associated with increased prehospital time intervals without observed impact on survival to ED discharge. The application of this treatment modality should be targeted and evidence-based while examining expected important clinical outcomes such as mortality. Future studies comparing ventilator use impact on different EMS conditions is needed to provide the evidence for expanding the use of this technology in the field.

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