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Short communication

Temporal trends and outcomes of prolonged invasive mechanical ventilation and tracheostomy use in acute myocardial infarction with cardiogenic shock in the United States☆

Saraschandra Vallabhajosyula [a,b,*], Shannon M. Dunlay [a,c], Kianoush Kashani [b,d], Shashaank Vallabhajosyula [b], Saarwaani Vallabhajosyula [a], Pranathi R. Sundaragiri [e], Allan S. Jaffe [a], Gregory W. Barsness [a]

[a] Department of Cardiovascular Medicine, Mayo Clinic, Rochester, MN, United States of America
[b] Division of Pulmonary and Critical Care Medicine, Department of Medicine, Mayo Clinic, Rochester, MN, United States of America
[c] Department of Health Science Research, Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery, Mayo Clinic, Rochester, MN, United States of America
[d] Division of Nephrology and Hypertension, Department of Medicine, Mayo Clinic, Rochester, MN, United States of America
[e] Division of Hospital Internal Medicine, Department of Medicine, Mayo Clinic, Rochester, MN, United States of America

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ABSTRACT

Background: There are limited data on prolonged invasive mechanical ventilation (IMV) and tracheostomy use in intubated acute myocardial infarction with cardiogenic shock (AMI-CS) patients.

Methods: Using the National Inpatient Sample, all admissions with AMI-CS requiring IMV between January 1, 2000, and December 31, 2014, were included. Prolonged IMV was defined as IMV use >96 h. Outcomes of interest included temporal trends in use of prolonged IMV and tracheostomy, in-hospital mortality, and resource utilization.

Results: In this 15-year period, 185,589 intubated AMI-CS admissions met the inclusion criteria. Prolonged IMV (>96 h) and tracheostomy use were noted in 68,544 (36.9%) and 10,645 (5.7%), respectively. Prolonged IMV and tracheostomy were used more commonly in younger patients. The cohort with prolonged IMV had higher organ failure and greater use of cardiac and non-cardiac organ support. Temporal trends showed a decline in prolonged IMV (adjusted odds ratio {aOR} 0.61 [95% confidence interval {CI} 0.57–0.65]) and tracheostomy use (aOR 0.80 [95% CI 0.70–0.90]) in 2014 compared to 2000. Prolonged IMV (aOR 0.45 [95% CI 0.44–0.47]; $p < 0.001$) and tracheostomy (aOR 0.28 [95% CI 0.27–0.29]; $p < 0.001$) were associated with lower in-hospital mortality with a decreasing trend between 2000 and 2014 in intubated AMI-CS admissions. Patients with prolonged IMV and tracheostomy use had nearly three-fold higher health care costs, and four-fold longer hospital stays.

Conclusions: In this cohort of intubated AMI-CS admissions, prolonged IMV and tracheostomy showed a temporal decrease between 2000 and 2014. Prolonged IMV and tracheostomy use was associated with high resource utilization.

1. Introduction

Acute myocardial infarction (AMI) continues to contribute to nearly 80% of all cardiogenic shock (CS) patients seen in contemporary practice and is associated with high mortality and morbidity [1,2]. Patients with AMI-CS frequently develop respiratory failure due to cardiogenic pulmonary edema and inflammatory syndromes resulting in the need for invasive mechanical ventilation (IMV) [3]. Prior data have demonstrated an increase in respiratory failure and IMV use in CS [1–3]. Use of prolonged IMV in unselected critically ill population is associated with nearly 30% mortality and significantly higher resource utilization [4]. Furthermore, these patients typically need a tracheostomy to decrease sedation and facilitate early mobilization [5]. There are limited large-scale epidemiological data on prolonged IMV and tracheostomy use from the United States in critically ill populations [4,5]. Using a 15-year nationally representative database, we sought to assess the contemporary incidence, temporal trends, and outcomes of prolonged IMV (≥96 h) and tracheostomy use in patients with AMI-CS. We hypothesized that during this 15-year study period, improvements in clinical care and patient selection have resulted in a declining need for prolonged respiratory support.

2. Material and methods

The Healthcare Cost and Utilization Project - Nationwide/National Inpatient Sample (HCUP-NIS) is the largest all-payer database of hospitalized inpatients in the United

☆ All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

* Corresponding author at: Department of Cardiovascular Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, United States of America.
E-mail address: Vallabhajosyula.Saraschandra@mayo.edu (S. Vallabhajosyula).

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States, containing discharge data from 20% non-federal hospitals [6]. A retrospective cohort of admissions with a primary diagnosis of AMI (International Classification of Diseases 9 Clinical Modification [ICD-9CM] 410.x) with a secondary diagnosis of CS (ICD-9CM 785.51) was identified between January 1, 2000, and December 31, 2014 [7]. We included all admissions receiving IMV (ICD-9CM 96.7, 96.70, 96.71, 96.72) [4,5,8]. Previously validated methodology was used to identify prolonged IMV (ICD-9CM 96.72), and tracheostomy (ICD-9CM 31.1x, 31.21, and 31.29) use [4,5,8]. Prolonged IMV was defined as IMV use >96 h [4]. The Deyo's modification of the Charlson Comorbidity Index was used to identify co-morbid diseases (Supplementary Table 1) [9]. Previously validated methodology was used to identify acute organ failure and use of cardiac and non-cardiac procedures [2,10,11]. The primary outcome was the incidence and temporal trends of prolonged IMV and tracheostomy use in AMI-CS. Secondary outcomes included in-hospital mortality, length-of-stay, use of do-not-resuscitate (DNR) status, and resource utilization.

2.1. Statistical analysis

Trend weights provided by the HCUP-NIS were used to re-weight the data to adjust for the 2012 HCUP-NIS re-design [12]. Chi-square and *t*-tests were used to compare categorical and continuous variables respectively. Data were presented as odds ratio (OR) and 95% confidence intervals (CI). Adjusted temporal trends were calculated using multivariable hierarchical logistic regression analysis incorporating age, sex, race, admission year, primary payer status, socio-economic stratum, hospital characteristics, comorbidities, acute organ dysfunction, cardiac procedures, mechanical circulatory support and hemodialysis (referent year 2000). For the multivariate modeling, multivariable hierarchical logistic regression analysis with purposeful selection of statistically ($p < 0.20$ by univariate analysis) and clinically relevant variables was conducted. Two-tailed $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS version 25.0 (IBM Corp, Armonk NY).

3. Results

There were 185,589 admissions for AMI-CS receiving IMV in this 15-year period that met the inclusion criteria. Prolonged IMV (IMV use >96 h) and tracheostomy use were noted in 68,544 (36.9%) and 10,645 (5.7%), respectively. The 15-year unadjusted and adjusted temporal trends are presented in Fig. 1A and B. The baseline characteristics of the cohorts are presented in Table 1. Compared to those with IMV use <96 h, admissions receiving prolonged IMV and tracheostomy were more likely to be younger, of non-White race, with non-ST elevation AMI-CS and admitted to large urban hospitals (all $p < 0.001$). Tracheostomy was performed at 16 (interquartile range 7–25) days after admission or 14 (interquartile range 6–22) days after endotracheal intubation. Admissions with prolonged IMV had greater acute kidney injury (54.5% vs. 37.0%), acute neurological failure (29.4% vs. 19.5%), use of coronary angiography (70.9% vs. 61.9%), percutaneous coronary intervention (46.3% vs. 42.2%), invasive hemodynamic monitoring

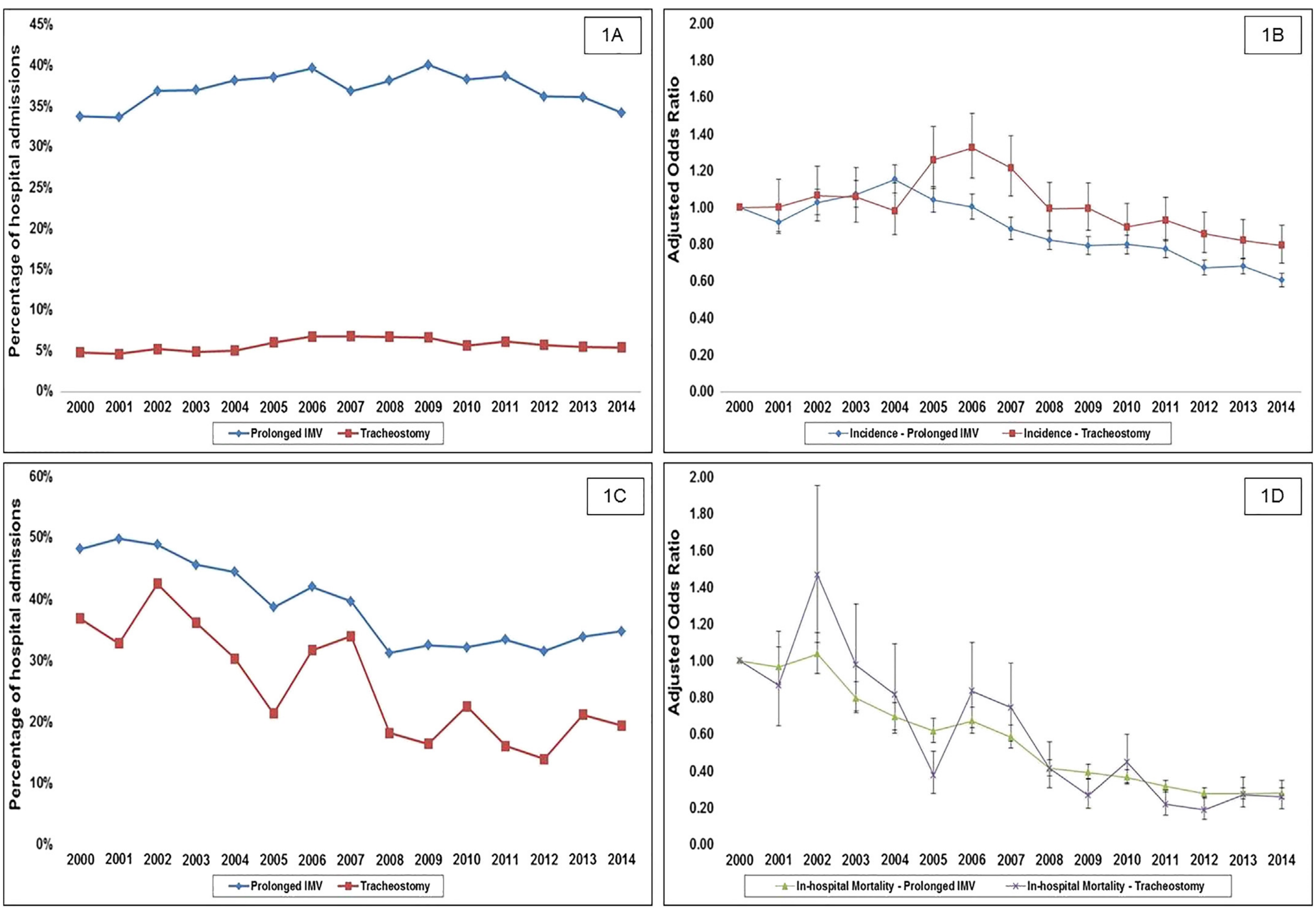

Fig. 1. Unadjusted and adjusted 15-year temporal trends for the incidence and in-hospital mortality with prolonged IMV and tracheostomy in intubated AMI-CS patients Legend: 1A: Unadjusted temporal trends of prolonged IMV and tracheostomy use in AMI-CS; 1B: Adjusted temporal trends of prolonged IMV and tracheostomy use in AMI-CS (referent year 2000) *; 1C: Unadjusted temporal trends in the in-hospital mortality with prolonged IMV and tracheostomy use in AMI-CS; 1D: Adjusted temporal trends of in-hospital mortality in prolonged IMV and tracheostomy use in AMI-CS (referent year 2000)^; all $p < 0.001$ for trend *Adjusted for age, sex, race, primary payer, socio-economic status, hospital location/teaching status, hospital bedsize, hospital region, comorbidity, acute kidney injury, acute hepatic failure, acute neurological failure, cardiac arrest, use of coronary angiography, percutaneous coronary interventions, invasive hemodynamic monitoring, mechanical circulatory support, and hemodialysis ^Adjusted for age, sex, race, primary payer, socio-economic status, hospital location/teaching status, hospital bedsize, hospital region, comorbidity, acute kidney injury, acute hepatic failure, acute neurological failure, cardiac arrest, use of coronary angiography, percutaneous coronary interventions, invasive hemodynamic monitoring, mechanical circulatory support, hemodialysis, and do-not-resuscitate status Abbreviations: AMI: acute myocardial infarction; CS: cardiogenic shock; IMV: invasive mechanical ventilation.

Table 1
Baseline and hospital characteristics of intubated AMI-CS admissions with prolonged IMV and tracheostomy use.

Characteristic		Prolonged IMV (N = 68,544)	No prolonged IMV (N = 117,045)	p	Tracheostomy (N = 10,645)	No tracheostomy (N = 57,899)	p
AMI type	ST-elevation	63.5	69.1	<0.001	61.5	67.4	<0.001
	Non-ST elevation	36.5	30.9		38.5	32.6	
Age (years)		67.2 ± 12.2	69.6 ± 12.6	<0.001	67.0 ± 11.9	68.8 ± 12.6	<0.001
Female sex		34.5	40.1	<0.001	37.6	38.1	<0.001
Race	White	62.3	64.5	<0.001	61.1	63.9	<0.001
	Non-White[a]	37.7	35.5		38.9	36.1	
Primary payer	Medicare	58.2	63.2	<0.001	59.4	61.5	<0.001
	Medicaid	8.7	6.3		9.9	7.0	
	Others	33.1	30.5		30.7	31.5	
Quartile of median household income for zip code	0-25th	23.7	23.0	<0.001	24.3	23.2	<0.001
	26th–50th	25.7	26.5		24.5	26.3	
	51st-75th	24.8	25.1		25.0	25.0	
	75th–100th	25.8	25.4		26.2	25.5	
Charlson Comorbidity Index	0–3	22.0	22.5	<0.001	20.2	22.4	<0.001
	4–6	58.3	56.9		61.1	57.2	
	≥7	19.7	20.6		18.7	20.4	
Hospital teaching status and location	Rural	3.4	7.0	<0.001	2.3	5.8	<0.001
	Urban non-teaching	36.3	42.4		31.6	40.6	
	Urban teaching	60.3	50.7		66.1	53.5	
Hospital bed-size	Small	6.1	7.9	<0.001	5.7	7.3	<0.001
	Medium	20.6	22.9		19.4	22.2	
	Large	73.2	69.2		74.8	70.4	
Hospital region	Northeast	20.3	19.1	<0.001	21.8	19.4	<0.001
	Midwest	22.4	22.7		20.9	22.7	
	South	35.2	36.3		38.4	35.7	
	West	22.1	21.9		18.9	22.1	

Legend: represented as percentage or mean ± standard deviation.
Abbreviations: AMI: acute myocardial infarction; CS: cardiogenic shock; IMV: invasive mechanical ventilation.
[a] Black, Hispanic, Asian or Pacific Islander, Native American, Others.

(29.6% vs. 20.5%), mechanical circulatory support (55.4 vs. 40.5%), and hemodialysis (9.8% vs. 3.3%), but lower rates of cardiac arrest (25% vs. 30.5%) (all $p < 0.001$). Admissions with tracheostomy use had greater acute kidney injury (60.6% vs. 42.4%), acute neurological failure (34.6% vs. 19.5%), mechanical circulatory support (53.6% vs. 45.5%), and hemodialysis (12.1 vs. 5.3%), but lower rates of cardiac arrest (22.9% vs. 28.8%), coronary angiography (62.4% vs. 65.4%) and percutaneous coronary intervention (39.2% vs 44%) (all $p < 0.001$).

In-hospital mortality was lower in patients with prolonged IMV (38.3% vs. 56.3%; OR 0.48 (0.47–0.49); $p < 0.001$) compared to those with IMV duration <96 h. The 15-year unadjusted and adjusted temporal trends of in-hospital mortality are presented in Fig. 1C and D. Admissions with prolonged IMV and tracheostomy had longer lengths of stay, greater hospital costs, lesser use of DNR status, and were discharged more frequently to skilled nursing facilities (Table 2). In a multivariable hierarchical logistic regression analysis, prolonged IMV (OR 0.45 [95% CI 0.44–0.47]; $p < 0.001$) and tracheostomy (OR 0.28 [95% CI 0.27–0.29]; $p < 0.001$) were associated with lower in-hospital mortality.

4. Discussion

In this nationally-representative population of intubated AMI-CS patients, we noted a temporal decrease in the use of prolonged IMV and tracheostomy. Nearly 1/3rd admissions with IMV use needed prolonged IMV, of which 15% required tracheostomy. Prolonged IMV and tracheostomy were seen more commonly in younger patients. Patients with prolonged IMV and tracheostomy had lower in-hospital mortality with a decline in adjusted temporal trends. Prolonged IMV and tracheostomy use were associated with nearly three-fold higher health care costs, and four-fold longer hospital stays. Just over half the admissions with prolonged IMV use and 3/4th of the admissions with tracheostomy were discharged to skilled nursing facilities.

This study is consistent with prior works that note prolonged IMV and tracheostomy to be associated with high resource utilization [4,5,8,13]. Unlike in unselected critically ill patients, the rates of prolonged IMV and tracheostomy have decreased in this AMI-CS population [5]. This may be due to, (i) a concomitant rise in the use of palliative care resulting in better end-of-life care [4]; (ii) earlier extubation due to

Table 2
Clinical outcomes of intubated AMI-CS admissions with prolonged IMV and tracheostomy use.

Characteristic		Prolonged IMV (N = 68,544)	No prolonged IMV (N = 117,045)	p	Tracheostomy (N = 10,645)	No tracheostomy (N = 57,899)	p
In-hospital mortality		38.3	56.3	<0.001	24.8	51.2	<0.001
Median length of stay (days)		19.1 ± 16.8	6.4 ± 6.9	<0.001	37.5 ± 26.2	10.0 ± 9.8	<0.001
Median hospitalization costs (US Dollars)		247,169 ± 227,047	91,293 ± 101,535	<0.001	435,286 ± 329,999	131,471 ± 145,725	<0.001
Do-not-resuscitate status		6.3	3.8	<0.001	5.6	1.5	<0.001
Discharge disposition	Home	21.9	38.7	<0.001	6.6	33.4	<0.001
	Transferred to other hospitals	10.0	19.5		9.9	15.7	
	Skilled nursing facility	51.9	24.3		76.0	33.1	
	Home with home health care	15.4	16.8		6.7	17.1	
	Against medical advice	0.6	0.5		0.1	0.5	

Legend: represented as percentage or mean ± standard deviation.
Abbreviations: AMI: acute myocardial infarction; CS: cardiogenic shock; IMV: invasive mechanical ventilation; US: United States.

lower need for sedation and hence delirium episodes [1]; (iii) earlier reperfusion and aggressive management of CS contributing to faster respiratory stabilization; and (iv) effective use of non-invasive mechanical ventilation for pulmonary edema. Prior registries have evaluated the role of non-invasive ventilation and IMV in patients with CS [3,14]. Compared to other critically ill cohorts, patients requiring IMV in AMI-CS often have higher rates of acute neurological failure, more severe shock as evidenced by higher lactate levels and metabolic acidosis [3]. Furthermore, biventricular dysfunction may result in complex hemodynamics since IMV decreases left ventricular afterload, but also increases pulmonary vasoconstriction resulting in increased right ventricular afterload [15,16]. Currently, there are limited data on the optimal mode of IMV in these patients [1]. Our data are of incremental value to prior studies that address the use of IMV in AMI-CS [3,17]. Importantly, we note that AMI-CS patients who need prolonged IMV often have poorer outcomes compared to those without prolonged IMV. These patients also have higher rates of concomitant organ failure and non-cardiac organ support use. Consistent with non-CS populations, we demonstrated that these patients are discharged more often to skilled nursing facilities [5,13]. These patients typically have multiple hospital readmissions and gradual deterioration of health status during long-term follow-up [13].

Even though prolonged IMV and tracheostomy were associated with lower in-hospital mortality, this cohort may represent a self-selected younger population that physicians and families believe will benefit from prolonged respiratory support. This is further substantiated by the significantly lower use of DNR status in these cohorts. However, these factors need to be weighed against the significantly higher use of resources and poor overall trajectory in patients with prolonged IMV [13]. Early identification of this cohort remains crucial to aid in the development of strategies for respiratory care. Use of low-tidal volume lung protective ventilation remains crucial in these patients to prevent barotrauma and volutrauma in these patients independent of concomitant acute respiratory distress syndrome [18,19]. There is a significant need to develop early risk-stratification paradigms that will aid in palliative care consultation to help in the judicious use of healthcare resources [4].

4.1. Limitations

This study has several limitations, despite the HCUP-NIS attempts to mitigate potential errors by using internal and external quality control measures. Echocardiographic data, mechanical ventilation settings, sedation, and paralysis information were unavailable in this database. Due to the administrative nature of this database, we are unable to assess terminal extubation, duration of IMV and weaning of IMV which are crucial determinants of clinical outcomes in this population. There is wide variability in tracheostomy use between centers in the United States which could influence the utilization and timing of this therapy [5]. Cultural, familial and religious beliefs that drive decision-making regarding the use of IMV and conversion to tracheostomy that impact decision-making were not assessed in this database. The additional burden of out-of-hospital costs and re-admissions was not captured in this single admission database.

5. Conclusions

In this large cohort of nationally representative mechanically ventilated AMI-CS admissions over 15-years, we noted a decrease in prolonged IMV and tracheostomy. These admissions were associated with significantly higher in-hospital and post-hospitalization resource utilization. Further dedicated research is needed to aid in early identification of this high-risk cohort to optimize respiratory support resources.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2019.03.008.

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Conflicts of interest

ASJ presently or has in the past consulted for most of the major diagnostic companies. All other authors report no financial or intellectual conflicts of interest related to this manuscript.

Abbreviations

AMI acute myocardial infarction
CI confidence interval
CS cardiogenic shock
DNR do-not-resuscitate
HCUP Healthcare Cost and Utilization Project
ICD-9CM International Classification of Diseases-9 Clinical Modification
IMV invasive mechanical ventilation
NIS National/Nationwide Inpatient Sample
NSTEMI non-ST-elevation myocardial infarction
OR odds ratio

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Author contributions

Study design, literature review, data analysis, statistical analysis: SV, KK, SV, SV, PRS

Data management, data analysis, drafting manuscript: SV, SV, SV, PRS

Access to data: SV, SMD, KK, SV, SV, PRS, ASJ, GWB

Manuscript revision, intellectual revisions, mentorship: SMD, KK, ASJ, GWB

Final approval: SV, SMD, KK, SV, SV, PRS, ASJ, GWB

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