Journal of Critical Care xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Postintubation hypotension in intensive care unit patients: A multicenter cohort study ☆,☆☆

Robert S. Green, MD, DABEM, FRCPC, FRCP (Edin) [a,b,c,*], Alexis F. Turgeon, MD, MSc, FRCPC [d,e], Lauralyn A. McIntyre, MD, MHSc, FRCPC [f,g], Alison E. Fox-Robichaud, MSc, MD, FRCPC [h], Dean A. Fergusson, PhD [f,i], Steve Doucette, MSc [j], Michael B. Butler, MSc [b], Mete Erdogan, PhD, MHI [c], On behalf of the Canadian Critical Care Trials Group (CCCTG)

[a] Department of Emergency Medicine, Dalhousie University, Halifax, Nova Scotia, Canada
[b] Department of Critical Care Medicine, Dalhousie University, Halifax, Nova Scotia, Canada
[c] Trauma Nova Scotia, Halifax, Nova Scotia, Canada
[d] CHU de Québec Research Center, Hôpital de L'Enfant-Jésus, Population Health and Optimal Health Practices Unit (Trauma–Emergency–Critical Care Medicine Group), Université Laval, Québec City, Québec, Canada
[e] Department of Anesthesiology, Division of Critical Care Medicine, Université Laval, Québec City, Québec, Canada
[f] Clinical Epidemiology Program, Ottawa Hospital Research Institute, University of Ottawa, Ottawa, Ontario, Canada
[g] Department of Medicine, Division of Critical Care Medicine, University of Ottawa, Ottawa, Ontario, Canada
[h] Thrombosis and Atherosclerosis Research Institute, Department of Medicine, McMaster University, David Braley Research Institute, Hamilton, Ontario, Canada
[i] Department of Medicine, Division of Clinical Epidemiology, University of Ottawa, Ottawa, Ontario, Canada
[j] Department of Community Health and Epidemiology (Capital Health, Dalhousie University, IWK Health Centre), Centre for Clinical Research, Halifax, Nova Scotia, Canada

ARTICLE INFO

Keywords:
Airway management
Intubation
Intratracheal
Hemodynamics
Intensive care units
Multicenter study

ABSTRACT

Purpose: To determine the incidence of postintubation hypotension (PIH) and associated outcomes in critically ill patients requiring endotracheal intubation.
Materials and Methods: Medical records were reviewed for 479 consecutive critically ill adult patients who required intubation by an intensive care unit (ICU) service at 1 of 4 academic tertiary care hospitals. The primary outcome measure was the incidence of PIH. Secondary outcome measures included mortality, ICU length of stay, requirement for renal replacement therapy, and a composite end point consisting of overall mortality, ICU length of stay greater than 14 days, duration of mechanical ventilation longer than 7 days, and renal replacement therapy requirement.
Results: Overall, the incidence of PIH among ICU patients requiring intubation was 46% (218/479 patients). On univariate analysis, patients who developed PIH had increased ICU mortality (37% PIH vs 28% no PIH, $P = .049$) and overall mortality (39% PIH vs 30% no PIH, $P = .045$). After adjusting for important risk factors, development of PIH was associated with the composite end point of major morbidity and mortality (odds ratio, 2.00; 95% confidence interval, 1.30-3.07; $P = .0017$).
Conclusions: The development of PIH is common in ICU patients requiring emergency airway control and is associated with poor patient outcomes.

1. Introduction

Critically ill patients commonly require endotracheal intubation (ETI) to support oxygenation and ventilation [1–3]. However, the need for ETI presents a physiologic challenge to an often unstable patient population that may poorly tolerate this procedure [4,5]. Compared with elective intubations, ETI in critically ill patients is associated with increased frequency of adverse events (AEs) including aspiration, bradycardia, intubation difficulty, hypoxemia, pneumothorax, and cardiac arrest. [6–14] The etiology of AEs is likely multifactorial including: patient illness, ETI medications, airway manipulation, and the physiologic derangements that follow positive pressure ventilation [15–18].

Airway manipulation under emergency conditions can induce life-threatening hemodynamic alterations [7,19,20]. The most common hemodynamic change after ETI is postintubation hypotension (PIH) [16]. Studies suggest that the degree and duration of hypotension are correlated with the occurrence of AEs, and that brief hypotension in acutely ill patients is associated with organ dysfunction and mortality [21–24].

☆ Conflicts of interest: None.
☆☆ Financial support: This study was funded by a Clinician Scientist Award from the Faculty of Medicine, Dalhousie University.

* Corresponding author at: Room 377 Bethune Building, 1276 South Park Street, Halifax, NS, Canada, B3H 2Y9. Tel.: +1 902 473 7157; fax: +1 902 473 5835.
E-mail addresses: greenrs@dal.ca (R.S. Green), alexis.turgeon@fmed.ulaval.ca (A.F. Turgeon), lmcintyre@ohri.ca (L.A. McIntyre), afoxrob@mcmaster.ca (A.E. Fox-Robichaud), dafergusson@ohri.ca (D.A. Fergusson), Steve.Doucette@nshealth.ca (S. Doucette), mbbutler@dal.ca (M.B. Butler), mete.erdogan@nshealth.ca (M. Erdogan).

http://dx.doi.org/10.1016/j.jcrc.2015.06.007
0883-9441/

Although PIH has received less attention in ETI investigations than intubation success rates and desaturation incidence, PIH may significantly impact patient outcomes including mortality, length of stay (LOS), and other outcomes in the hospital or intensive care unit (ICU) [25–27]. In a systematic review of PIH in emergency department (ED) and ICU patients including 17 observational studies and 1 randomized controlled trial, the incidence of PIH ranged from 0.5% to 44% with a pooled estimate of 11% [28].

Despite the assumption that ETI is a lifesaving procedure, the development of PIH in critically ill patients may result in increased morbidity and mortality [25,29]. Evidence from previous studies suggests that ETI in ICU patients is associated with high rates of immediate and severe life-threatening complications [30–33]. To date, most investigations of PIH have focused on the ED patient population [25–27]. Few data from the ICU patient population have been reported. The objective of this study was to determine the incidence of PIH in patients requiring ETI by an ICU service and its association with patient mortality, LOS in the hospital or ICU, and requirement for vasopressor administration or renal replacement therapy.

2. Materials and methods

2.1. Study design

This study is a Canadian multicenter, retrospective cohort of critically ill patients requiring ETI.

2.2. Study setting and population

Sites with the necessary resources and infrastructure were selected for participation by the investigative team of the Canadian Critical Care Trials Group. Chart reviews were performed between October 2006 and July 2010 at 4 academic tertiary care hospitals from 3 Canadian provinces (QEII Health Sciences Centre, Halifax, NS, Canada; CHU de Québec–Hôpital de l'Enfant-Jésus, Québec City, QC, Canada; The Ottawa Hospital, Ottawa, ON, Canada; Hamilton General Hospital, Hamilton, ON, Canada). Medical records were accessed for consecutive patients who were admitted to the ICU at each site and eligible for the study. Each participating center was asked to provide data for 100 to 250 consecutive patients who required ETI performed by the ICU service.

Inclusion criteria were all adult patients (age, >16 years) who required ETI performed by the ICU service at a participating hospital, regardless of where the patient was located within the hospital at the time. Exclusion criteria were all pediatric patients (age, <17 years) and any patients in whom a surgical airway was required without an initial intubation attempt. All methods of ETI were eligible for inclusion.

2.3. Measurements

All data for this study were collected from patient medical records using standardized electronic forms. We collected demographic data and patient comorbidities. Vital signs, intravenous (IV) fluids administered, and ETI medications administered in the 30 minutes before and after ETI were recorded. *Endotracheal intubation* was defined as the passage of an endotracheal tube through the patient's glottis via either the oral or nasal routes.

The primary measure for this study was the incidence of PIH. Based on previous research by the team of investigators [25], *PIH* was defined as the occurrence of any of the following during the 15-minute period after ETI: (*a*) a decrease in systolic blood pressure (SBP) to less than 90 mm Hg; (*b*) a reduction in SBP of 20% from baseline; (*c*) a decrease in mean arterial pressure to less than 60 mm Hg; or (*d*) the initiation of, or increase in infusion dosage of, any vasopressor medication (bolus or infusion). *Baseline SBP* was defined as the average of all SBP values recorded in the 30 minutes prior to ETI. *Pre-ETI hypotension* was defined as any SBP < 90 mm Hg in the 30 minutes prior to ETI. Patients with preexisting hypotension were included in the study population, with PIH determined by criteria (b-d) from the definition of PIH. Blood pressure measurements were recorded from invasive (arterial catheter) or noninvasive blood pressure (NIBP) means, which included both automated and nonautomated devices. All blood pressure measurements available in the medical record during the 30 minutes before and after intubation were extracted. Invasive blood pressure measurements were averaged together with NIBP measurements. *Endotracheal intubation complications* were defined as any event documented explicitly as a "complication" by the ICU service in the medical record (with the exception of PIH) and included aspiration, aspiration pneumonia, bradycardia, bronchospasm, cardiac arrest, delayed recognition or correction of esophageal intubation, dental trauma, equipment failure, esophageal intubation with immediate recognition and correction, hypertension (SBP > 160 mm Hg), injury or trauma to patient during ETI, more than 1 intubation attempt made, pneumothorax, premature ventricular contractions, right mainstem bronchus intubation tachycardia, or no recorded complication.

Secondary patient outcomes of interest were determined a priori by the investigative team and included overall mortality, ICU mortality, duration of mechanical ventilation, requirement for renal replacement therapy, hospital LOS, and ICU LOS. To provide an overall measure of adverse patient outcomes, we evaluated a composite end point consisting of overall mortality, ICU LOS greater than 14 days, mechanical ventilation longer than 7 days, and requirement for renal replacement therapy. *Overall mortality* was defined as death in hospital, whereas *ICU mortality* was defined as death during admission to the ICU. *Length of stay* was defined as total days spent in the hospital or ICU. The renal replacement therapy requirement outcome was defined as the institution of any type of renal replacement therapy at any time after ETI during patient stay in the ICU, excluding any patients on chronic dialysis.

2.4. Study protocol

Patients were identified through a combination of electronic and/or manual review of intubation databases, ICU clinical databases, and admission logs from the medical/surgical ICUs at each participating institution. After patient identification, a research associate at each center manually reviewed the medical record and patients who met eligibility criteria were retained. Each data abstractor underwent training under the supervision of the site investigator and the research team of the primary investigator prior to study initiation, which included instruction on study definitions, database usage, and abstraction of data from the electronic medical record. Data were abstracted into a standardized, computerized intubation database, and included demographic data, patient comorbidities, and outpatient medications. Patient data were recorded for at least 30 minutes before and after intubation, and included vital signs (eg, blood pressure, heart rate, and oxygen saturation), IV fluids administered, and medications used for ETI. In addition, the in-hospital mortality and discharge location were also recorded. Data from each participating institution were combined into a single database. Any discrepancies in the study data were resolved by consensus at prespecified data quality control meetings by the primary investigator.

2.5. Data analysis

Baseline characteristics of included patients were assessed in terms of age, sex, comorbidities, diagnosis, and preintubation hypotension, stratified by presence or absence of PIH. Variables not recorded in the medical record were coded as missing and were not inputed. The frequency of medications administered in the 15 minutes prior to ETI was also reported for the entire cohort and stratified by presence or absence of PIH. Baseline characteristics were compared using the Fisher exact test for categorical data and independent *t* tests for continuous data. Univariate analysis of outcome data was assessed using similar methods, as well as the Wilcoxon rank sum tests for nonnormally

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Table 1
Characteristics of study sites

Hospital	City (province)	Size of population served (approximate)	Trauma center designation	ED admissions per year[a] (approximate)	ICU admissions per year[b] (approximate)	Service performing majority of intubations[c]		
						Patients consulted from ED	Patients consulted from floor	Patients admitted to the ICU
QEII Health Sciences Centre	Halifax (NS)	1000000	Level 1	70000	1300	EM	ICU	ICU
Hamilton General Hospital	Hamilton (ON)	2300000	Level 1	40000	1300	EM	ICU/response team	ICU
CHU de Québec, Hôpital de l'Enfant-Jesus	Québec City (QC)	2200000	Level 1	65000	600	EM	ICU	ICU
The Ottawa Hospital	Ottawa (ON)	1000000	Level 1	160000	2400	EM	ICU/response team	ICU

EM indicates emergency medicine.
[a] Approximate number of ED admissions per year.
[b] Approximate number of ICU admissions per year.
[c] The service (ie, EM, ICU, anesthesia, other) at each site performing the majority of intubations in patients consulted from the ED, from the floor, or admitted to the ICU.

distributed continuous data. All tests were 2 sided, and a P value less than .05 was considered statistically significant. A multivariable logistic regression model was used to assess the association between PIH and secondary patient outcomes. The multivariable analysis was adjusted for the effects of age, sex, Acute Physiology and Chronic Health Evaluation (APACHE) II score, propofol dose (per 50-mg increase), comorbidities of chronic obstructive pulmonary disease, chronic renal failure and ischemic heart disease, and the presence of sepsis and trauma illness. The data analysis for this study was generated using SAS software, Version 9.4 of the SAS System for Windows. Copyright 2013 SAS Institute Inc SAS and all other SAS Institute Inc product or service names are registered trademarks or trademarks of SAS Institute Inc, Cary, NC.

2.6. Ethics

Ethics approval was obtained from the local research ethics board at each participating institution.

3. Results

A total of 519 ICU patients were screened for this study. Forty patients were excluded due to incomplete data in the medical record, leaving 479 patients from 519 charts screened (92%) who required intubation while admitted under the care of an intensivist at 1 of the 4 participating tertiary care hospitals (Table 1). The time frame required for data collection at each institution ranged between 4 months and 2 years.

The primary outcome of PIH was observed in 218 (46%) of 479 ICU patients during the 15-minute period after ETI. Table 2 shows patient demographics and characteristics for groups that did (PIH) or did not (no PIH) develop the primary outcome. Patients who developed PIH were similar to those who did not with respect to age, sex, APACHE II score, diagnosis, admission from the ED, and amount of IV fluids administered prior to ETI. Vasopressor medication was administered prior to intubation more frequently in the PIH group (39% PIH vs 25% no PIH, $P < .001$).

Intubation procedures performed on study patients are described in Table 3. Endotracheal intubation providers (attending physicians, residents, and other) and the methods used were similar in both patients with and without PIH. Patients with PIH had more ETI complications recorded in the medical record (39% PIH vs 27% no PIH, $P = .003$). Both groups received similar amounts of IV fluids prior to ETI; however, patients who developed PIH received more IV fluids within the 60-minute peri-intubation phase. Medications used to facilitate ETI are shown in Table 4. Both groups were similar with respect to medications administered; therefore, we did not analyze individual drug dosages. The most frequently administered analgesic was fentanyl (65% PIH vs 59% no PIH, $P = .14$), and the sedatives administered most were propofol (59% PIH vs 67% no PIH, $P = .07$) and benzodiazepines (56% PIH vs 58% no PIH, $P = .75$). Use of paralytics was similar in both groups, with rocuronium administered most often (10% PIH vs 13% no PIH, $P = .32$).

Univariate analysis of patients who developed PIH and secondary outcomes is shown in Table 5. Patients with PIH had greater incidence of ICU mortality (37% PIH vs 28% no PIH, $P = .049$) and overall mortality (39% PIH vs 30% no PIH, $P = .045$) compared with those without PIH. The median LOS in the ICU (10.0 days PIH vs 9.0 days no PIH, $P = .75$) or in-hospital (29.0 days PIH vs 23.0 days no PIH, $P = .50$) was similar in both groups, as was the median time required for mechanical ventilation (4.5 days PIH vs 4.0 days no PIH, $P = .49$) or renal replacement therapy (5.5 days PIH vs 6.0 days no PIH, $P = .74$). Because ETI was a criterion for study inclusion, it was not possible to compare outcomes with patients who had hypotension but did not require intubation. After adjustment for risk factors (Table 6), PIH was not associated with increased mortality (odds ratio [OR], 1.47; 95% confidence interval [CI], 0.97-2.22; $P = .07$), but was associated with the composite end point

Table 2
Demographics of study population

	PIH (n = 218)	No PIH (n = 261)	P
Age (y), mean ± SD	61 ± 15	59 ± 17	.08
Female, n (%)	86 (40)	106 (41)	.80
APACHE II score, mean ± SD	24 ± 10	24 ± 8	.55
Diagnosis[a]			
Central nervous system	24 (11%)	35 (14%)	.43
Endocrine	5 (2%)	9 (3%)	.46
Gastrointestinal	29 (13%)	31 (12%)	.63
Hematologic	6 (3%)	9 (3%)	.67
Malignancy	19 (9%)	13 (5%)	.10
Metabolic	4 (2%)	6 (2%)	.73
Non–central nervous system trauma	0 (0%)	1 (0.4%)	.36
Overdose	3 (1%)	2 (0.8%)	.51
Renal	20 (9%)	18 (7%)	.36
Respiratory	128 (59%)	137 (53%)	.16
Sepsis	32 (15%)	39 (15%)	.94
Toxic	3 (1%)	5 (2%)	.65
Trauma	14 (6%)	19 (7%)	.72
Vascular	5 (2%)	7 (2%)	.79
Other	24 (11%)	39 (15%)	.20
Resuscitation prior to ETI			
Vasopressor administration prior to intubation	86 (39%)	66 (25%)	<.001
IV fluids prior to ETI[b]			
Mean IV fluid administered (SD)[c]	457 (591)	438 (625)	.59

[a] Patients were grouped by most significant medical condition requiring ETI. Where possible, grouping was done by systems. Multiple diagnoses were included if appropriate.
[b] Refers to IV fluids administered in the 30 minutes prior to intubation.
[c] Calculated in milliliters and only for those patients who were administered IV fluids prior to ETI.

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Table 3
Peri-intubation resuscitation and intubation procedures used

	PIH (n = 218)	No PIH (n = 261)	P
ETI method[a]			
ETI with sedation and/or analgesic (no NMBA)	163 (75%)	189 (73%)	.80
ETI with sedation and/or analgesic and NMBA	29 (13%)	43 (17%)	
ETI with no medications	7 (3%)	7 (2%)	
Other[b]	17 (8%)	21 (8%)	
Device			
Laryngoscope	145 (66%)	169 (65%)	.53
Laryngoscope with Bougie	15 (7%)	14 (5%)	
Fiberoptic-flexible bronchoscope	7 (3%)	8 (3%)	
Fiberoptic-rigid bronchoscope	0 (0%)	1 (0.4%)	
I-LMA with intubation	0 (0%)	1 (0.4%)	
Lighted stylet	3 (1%)	11 (4%)	
Other[c]	16 (7%)	15 (6%)	
Missing	32 (14%)	42 (16%)	
ETI provider[d]			
Attending physician	47 (24%)	61 (26%)	.21
Resident physician	139 (72%)	159 (68%)	
Student	0 (0%)	4 (1%)	
Respiratory therapist	8 (4%)	8 (3%)	
Other	0 (0%)	3 (1%)	
ETI supervised by physician	90 (41%)	99 (40%)	.45
Recorded ETI AEs[e]			
ETI complications (yes vs no)	86 (39%)	70 (27%)	.003
Difficult airway	27 (12%)	35 (13%)	.74
Unsuccessful ETI attempts (yes vs no)	40 (18%)	51 (20%)	.74
Emergent invasive procedure			
Central line within 30 min before/after ETI	22 (13%)	21 (10%)	.42
Arterial catheter within 30 min before/after ETI	41 (21%)	37 (16%)	.19
IV fluids within 30 min before/after ETI[f]			
<1000 mL	38 (57%)	40 (80%)	.008
1000 + mL	29 (43%)	10 (20%)	

[a] NMBA refers to neuromuscular blocking agents.
[b] Three values for the ETI method were missing and not included in Table 2.
[c] Other devices included glidescope, extraglottic devices (LMA, King LT), and other indirect devices (I-LMA, optical stylet, airtrac).
[d] ETI provider could not be ascertained in 50 cases and were not included in Table 2.
[e] As indicated in the medical record, not including PIHI.
[f] Total IV fluids administered during the 30 minutes prior to and following intubation.

(OR, 2.00; 95% CI, 1.30-3.07; $P = .0017$). Other variables associated with overall morality in the multivariate analysis were age (OR, 1.02; 95% CI, 1.01-1.04; $P = .002$) and APACHE II score (OR, 1.04; 95% CI, 1.02-1.07; $P < .001$).

4. Discussion

This is the first multicenter study to examine the incidence of PIH and its association with clinically significant outcomes in patients requiring ETI by ICU clinicians. Our results provide evidence for PIH being associated with increased morbidity and mortality in ICU patients requiring ETI. Previous intubation studies have included both mechanical AEs (dental trauma, esophageal intubation, mainstem bronchus intubation, bronchospasm, and aspiration of gastric contents into the respiratory system) and broader life-threatening complications (hypotension, arrhythmia, and cardiac arrest) [6–14,25–27,30–36]. In patients requiring ETI, the AEs most commonly reported include tube misplacement or dislodgement, multiple ETI attempts, and failed ETI efforts [17,18,37]. Recent studies suggest that PIH is also a common occurrence in patients who undergo ETI and is associated with an increased risk of morbidity and mortality [25–27]. Our finding that PIH occurred in 46% of patients intubated by an ICU service confirms that PIH is a common event in this population.

Similar to our group's findings from a single-center ED study [25], PIH was not significantly associated with mortality in critically ill patients (after controlling for confounding factors). We did, however, observe increased ICU mortality (37% PIH vs 28% no PIH, $P = .049$) and overall mortality (39% PIH vs 30% no PIH, $P = .045$), associated with PIH. However, in this multicenter study of ICU patients requiring ETI, we observed PIH to be independently associated with increased odds of an unfavorable outcome using a composite end point. Our observation that chronic renal failure was associated with the composite end point is not surprising because renal replacement therapy was included as part of the composite end point. Our ICU findings mirror numerous studies that have reported increased morbidity and mortality in hypotensive ED patients [21–27]. Taken together, PIH is an important physiologic AE, whether in the ED or ICU.

Because of the often-chaotic nature of resuscitation, ETI proceeds in a rapid manner. One advantage of elective intubations in other settings is that clinicians are able to systematically control a patient's physiologic parameters. Although our study was not designed to address the issue of preintubation resuscitation, it is possible that time spent ensuring optimal physiologic intubating conditions prior to ETI may reduce the incidence of PIH and decrease the risk of patient morbidity and mortality. Previous research has demonstrated that implementation of an intubation management protocol can reduce immediate severe life-threatening complications associated with intubation of ICU patients [38]. In our study, we

Table 4
Medications used to facilitate ETI

	PIH (n = 218)	No PIH (n = 261)	P
Opioid			
Fentanyl	142 (65%)	153 (59%)	.14
Hydromorphone	25 (12%)	24 (9%)	.41
Morphine	4 (1%)	8 (3%)	.39
Any opiate	146 (67%)	164 (63%)	.35
Sedatives			
Propofol	128 (59%)	174 (67%)	.07
Benzodiazepines	123 (56%)	151 (58%)	.75
Ketamine	18 (8%)	10 (4%)	.04
Etomidate	1 (0.5%)	0 (0%)	.27
Any sedative	189 (87%)	227 (87%)	1.0
Paralytics			
Rocuronium	22 (10%)	34 (13%)	.32
Succinylcholine	19 (8%)	29 (11%)	.38
Other (vecuonium, atracurium, pancuronium)	0 (0%)	1 (0.4%)	.36
Any paralytic	35 (16%)	58 (22%)	.10

Table 5
Univariate analysis of adverse outcomes in study population

	PIH (n = 218)	No PIH (n = 261)	P
Mortality			
ICU mortality[a]	80 (37%)	73 (28%)	.049
Overall mortality[b]	85 (39%)	79 (30%)	.045
LOS[c]			
ICU LOS (d), median (IQR)	10.0 (4.2-19.1)	9.0 (4.9-16.6)	.75
Hospital LOS (days), median (IQR)	29.0 (13.0-49.0)	23.0 (13.0-50.0)	.50
Mechanical ventilation			
Mechanical ventilation in ICU (d), median (IQR)	4.5 (2.0-11.0)	4.0 (2.0-8.0)	.49
Renal replacement therapy requirement[d]			
Renal replacement therapy requirement, n (%)	34 (15%)	33 (12%)	.35
Total renal replacement therapy days in ICU, median (IQR)	5.5 (4-11)	6.0 (4-12)	.74
Composite end point[e]			
Composite end point (overall mortality/ventilation > 7 d/ICU LOS > 14 d/renal replacement therapy requirement)	165 (77%)	168 (63%)	.001

IQR indicates interquartile range.
[a] ICU mortality was defined as death during admission to the ICU.
[b] Overall mortality was defined as death in hospital regardless of patient location.
[c] LOS was defined as total days admitted to hospital.
[d] Renal replacement therapy requirement outcome was defined as the institution of renal replacement therapy at any time after ETI during patient stay in the ICU.
[e] Composite end point was composed of overall mortality, ICU LOS greater than 14 days, duration of mechanical ventilation longer than 7 days, and renal replacement therapy requirement.

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Table 6
Multivariate analysis of adverse patient outcomes after ETI

	Ventilation days > 7[a]		Renal replacement therapy[b]		ICU LOS > 14 d[c]		Overall mortality[d]		Composite[e] (ventilation/renal/ ICU LOS/death)	
	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
PIH	1.40 (0.93-2.10)	.10	1.23 (0.67-2.28)	.50	1.48 (0.99-2.22)	.06	1.47 (0.97-2.22)	.07	2.00 (1.30-3.07)	.0017
Age	0.99 (0.98-1.00)	.16	0.96 (0.94-0.98)	<.001	0.99 (0.97-1.00)	.09	1.02 (1.01-1.04)	.002	0.99 (0.97-1.00)	.10
Female sex	0.89 (0.59-1.35)	.59	1.17 (0.63-2.19)	.62	1.07 (0.71-1.62)	.73	1.26 (0.83-1.91)	.28	1.18 (0.76-1.81)	.46
APACHE II score	0.98 (0.96-1.01)	.13	1.12 (1.08-1.16)	<.001	0.98 (0.95-1.00)	.047	1.04 (1.02-1.07)	<.001	1.03 (1.01-1.06)	.010
Propofol dosage (per 50-mg unit increase)	0.97 (0.89-1.05)	.43	0.92 (0.79-1.06)	.24	0.96 (0.89-1.05)	.41	0.95 (0.86-1.04)	.28	0.9 (0.83-0.98)	.011
Ischemic heart disease	1.24 (0.62-2.48)	.54	3.85 (1.36-10.91)	.011	2.00 (1.03-3.90)	.042	0.56 (0.26-1.19)	.13	2.42 (1.06-5.49)	.035
Chronic obstructive pulmonary disease	0.76 (0.45-1.28)	.30	0.94 (0.42-2.11)	.88	0.89 (0.53-1.48)	.64	0.62 (0.36-1.04)	.07	0.54 (0.33-0.91)	.019
Chronic renal failure	0.85 (0.40-1.77)	.65	6.88 (3.00-15.77)	<.001	1.07 (0.52-2.17)	.86	1.43 (0.73-2.78)	.30	2.79 (1.11-7.01)	.028
Sepsis	1.26 (0.71-2.23)	.43	1.52 (0.72-3.18)	.27	1.29 (0.73-2.28)	.37	1.35 (0.76-2.39)	.30	1.16 (0.61-2.21)	.65
Trauma	3.23 (1.47-7.09)	.0035	N/A		2.50 (1.15-5.44)	.020	N/A		1.88 (0.77-4.55)	.16

N/A indicates not applicable.
[a] Duration of mechanical ventilation greater than 7 consecutive days after ETI.
[b] Renal replacement therapy requirement outcome was defined as the institution of renal replacement therapy after ETI.
[c] ICU mortality was defined as death during admission to the ICU.
[d] Overall mortality was defined as death in hospital regardless of patient location.
[e] Composite end point was composed of overall mortality, ICU LOS greater than 14 days, duration of mechanical ventilation longer than 7 days, and renal replacement therapy requirement.

found no difference in the amount of preintubation IV fluids that were administered; however, patients who developed PIH were more likely to have received preintubation vasopressor medications. Targeted IV fluid administration and/or vasopressor use before intubation may be potential resuscitation strategies to prevent PIH.

Medications used to facilitate ETI and positive pressure ventilation have potential to impact patient hemodynamics directly (eg, decrease in vascular tone and myocardial depression) or indirectly (eg, reduction in adrenal catecholamine release and decreased sympathetic outflow) [39]. In critically ill patients, sympathetic outflow is commonly increased due to hypercarbia, hypoxemia, and respiratory distress; this results in relative "hemodynamic stability" [40]. After induction, however, hypercarbia and hypoxemia generally improve, the work of breathing is diminished, and sympathetic outflow dramatically decreases, often resulting in hypotension in patients who require ETI [17]. We did not identify a strong association between medications used to facilitate ETI and the incidence of PIH in this study. Ketamine use was associated with an increased incidence of PIH; however, this medication was used in only 6% (28/479) of patients. Propofol, which is commonly viewed as a medication associated with hemodynamic instability, was not associated with increased PIH despite being given to 63% (302/479) of critically ill patients.

Our study has the limitations of a retrospective study of an existing data set and cannot be used to imply causality. Because of the relatively small size of the nonprobability sample of convenience obtained from each study center, it is likely that this study was underpowered and thus did not reach statistical significance. We found that patients with PIH were more likely to receive preinduction blood pressure medication; however, we cannot determine if these patients were more likely to become hypotensive because they had increased illness severity. Because the hemodynamic adverse effects of propofol are proportional to dose rate and age, another limitation of this study is that we were unable to analyze the individual dose rates of propofol. The incidence of PIH may have been underreported because patients with very low blood pressure may not have had it recorded, and this would have differentially occurred in the PIH group. Because this study was performed in 4 centers in 3 provinces, we acknowledge the possibility of inclusion and selection bias. However, despite differences in populations served and the ED and ICU admission rates between centers, intubation practices were similar between hospitals. We did not differentiate between invasive and NIBP measurements; clinically significant discrepancies can exist between these methods of measuring blood pressure [41].

Despite these limitations, our multicenter approach with detailed comorbidity, intubation procedure, and vital sign evaluation allows for a comprehensive analysis and generalizability. The definition of PIH was developed by the research team and used in previous studies [25,28]. Although we view our definition as a comprehensive and clinically relevant representation of PIH, we acknowledge that a universal definition has yet to be adopted by the medical community. Our finding of a high incidence of PIH (46%) in patients requiring ETI from an ICU service is due to a logical and clinically relevant definition that may be more sensitive to the incidence of PIH than other less comprehensive definitions [25,28]. We view the results of this study as preliminary findings to fuel future research into an area of patient care that is potentially lifesaving yet poorly understood. However, we believe that PIH is an important and potentially modifiable AE. Clinicians should consider therapeutic options including preintubation resuscitation in an attempt to minimize PIH and its associated poor patient outcomes.

5. Conclusions

Our results demonstrate that PIH is a common AE in critically ill patients requiring emergency airway control and is associated with unfavorable clinical outcomes. Further investigation is required to better understand the risks involved with ETI and to raise awareness among physicians of potential AEs associated with ETI such as PIH.

Acknowledgments

We thank the Canadian Critical Care Trials Group and the Critical Illness & Airway Management Group for their support, guidance, and critical review of this manuscript. We also acknowledge Stephanie St-Cyr and Madeline Franklin who assisted with collection of study data at the Ottawa site, and Enrico Rullo who assisted with data collection at the Hamilton site. We thank Dalhousie University for providing funding for this study through a Clinician Scientist Award from the Faculty of Medicine.

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Please cite this article as: Green RS, et al, Postintubation hypotension in intensive care unit patients: A multicenter cohort study, J Crit Care (2015), http://dx.doi.org/10.1016/j.jcrc.2015.06.007

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Please cite this article as: Green RS, et al, Postintubation hypotension in intensive care unit patients: A multicenter cohort study, J Crit Care (2015), http://dx.doi.org/10.1016/j.jcrc.2015.06.007