ORIGINAL ARTICLE

Implementation of a Revised Montpellier Bundle on the Outcome of Intubation in Critically Ill Patients: A Quality Improvement Project

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Abstract

Introduction: The feasibility of implementing a revised Montpellier intubation bundle incorporating recent evidences was tested in a quality-improvement project. It was hypothesized that this "Care Bundle" implementation would reduce intubation-related complications.

Materials and methods: The project was conducted in an 18-bedded multidisciplinary intensive care unit (ICU). Baseline data for intubations were collected over 3-month "Control Period". During the 2-month "Interphase", a revised intubation bundle was developed, and staff members involved in the intubation process were extensively trained on different aspects of intubation with emphasis on bundle components. Various components of the bundle were pre-intubation fluid loading, pre-oxygenation with NIV plus PS, positive-pressure ventilation post-induction, succinylcholine as a first-line induction agent, routine use of stylet, and lung recruitment within 2 minutes of intubation. Intubation data were collected again in the 3-month "Intervention Period".

Results: Data were collected for 61 and 64 intubations, respectively, during control and intervention periods. There was significant improvement in compliance to five of six-bundle components; improvement in pre-intubation fluid loading during the intervention period did not reach statistical significance. Overall, at least 3 components of the bundle were complied within over 92% of intubations in the intervention period. However, whole-bundle compliance was limited to 14.3%. Incidences of major complications were reduced significantly in the intervention period (23.8% vs 45.9%, $p = 0.01$). There was significant reduction in profound hypotension (21.77% vs 29.51%, $p = 0.04$) and a nonsignificant 11.89% reduction in profound hypoxemia. There were no differences in minor complications.

Conclusion: Implementation of an evidence-based revised Montpellier intubation bundle is feasible and it reduces major complications related to endotracheal intubation.

Keywords: Endotracheal intubation, Intensive care unit, Intubation bundle, Intubation complications, Quality improvement.

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Highlights

- There is a need for incorporating newer evidences as a "care bundle" during endotracheal intubations in critically ill patients.
- Implementation of a revised bundle is feasible even in ICUs outside the developed world.
- Bundle implementation demonstrates reduction in the rate of major intubation-related complications.

Introduction

Compared with the operating room (OR), endotracheal intubation in the ICU is associated with a higher rate of complications. This is related to the emergent nature of the procedure, poor physiological reserve of critically ill patients, and at least in some places lack of experience of physicians performing the procedure.[1] In the multicenter INTUBE study, as high as 45.2% of the ICU intubations were complicated by at least one major adverse event.[2] There are wide variations in the incidences of major complications reported in different studies – severe hypoxemia in 9.3–26%,[2,3] profound hypotension in 9–46.2%,[2–4] and cardiac arrest in 2–3.1% of patients.[2,3,5] Apart from patient-related factors, risk of complications increases with poor pre-oxygenation technique, duration of intubation, number of attempts at intubation, and immediate post-intubation care.

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An effective way to reduce complications is to optimize cardiovascular and respiratory status to the best-possible level prior to and during intubation and also by minimizing the number of attempts to shorten the duration of intubation. Efficacy of a "care bundle" was first demonstrated by Jaber and colleagues, who could demonstrate significant reductions in the number of peri-intubation complications, by "employing a group of evidence-based interventions" (now famous "Montpellier Bundle").[6] Montpellier bundle was based mostly on evidence available in anesthesia literature and experiences in the operating room.

A curtailed version of Montpellier bundle had also shown to significantly improve first-pass intubation success.[7] However, with newer evidence showing benefits of several other interventions during ICU endotracheal intubation, we felt it necessary to revisit the Montpellier bundle.[8–10] We hypothesized that incorporating these recent evidence-based interventions in a revised Montpellier bundle would improve the outcome of endotracheal intubation. We, therefore, conducted a quality-improvement project to determine the feasibility of implementing this revised bundle and the efficacy of its implementation on the intubation outcome during the intervention period.

Materials and Methods

The project was conducted in the 18-bed multidisciplinary ICU of a tertiary care private hospital from northern India. Round-the-clock coverage in the ICU is provided by a critical care team led by a consultant intensivist. All decisions regarding endotracheal intubation are taken by the ICU consultant. Relevant data for all endotracheal intubations performed on adult patients (≥18 years) during the "Control Period" and "Intervention Period" were collected prospectively. The study was approved by Institutional Ethics Committee (EC/2021/28 dated 08 October 2021), and the need for written consent was waived off. The study was registered in the national clinical trial registry of India (CTRI/2021/11/038089).

Study Intervention

Control Period

A prospective audit was carried out, starting from 16 June, 2021, for a period of 3 months, looking into different aspects of endotracheal intubation, using a standard proforma. During this period ("Control Period"), no written protocol was in place for endotracheal intubation in the unit. However, a number of interventions suggested by the original Montpellier bundle were loosely followed. At least 2 operators are always available during all ICU intubations.

Interphase

During this period, we developed a 6-point "Endotracheal Intubation Bundle" based on the review of airway-management literature for critically ill patients, with an aim to reduce peri-intubation complications.[8–13] Components of the 6-point bundle are shown in Table 1. In the period between 16 September 2021 and 15 November 2021, the critical care team (consultants, fellows, and nurses) was provided with extensive training on endotracheal intubation processes, including classroom lectures, written material, and training regarding the implementation of different components of the bundle.

Intervention Period

In the 3-month "Intervention Period" (16 November 2021–15 February 2022), the intubation procedure was protocolized aiming to implement the 6-point care bundle. However, implementation of an individual component of the bundle was at the discretion of the consultant intensivist, keeping in mind what is best for the patient in the prevailing circumstances.

Measurements

Before endotracheal intubation, baseline characteristics were recorded for all intubation procedures: age, gender, presence of obesity, reason for ICU admission, APACHE-II score at intubation, maximum heart rate, lowest systolic blood pressure and lowest oxygen saturation recorded within 10 minutes of intubation, and any need for vasopressor or oxygen support at intubation.

During the procedure, indication and emergency nature of intubation (real, relative, or deferred), timing of intubation (regular hour or out of hour), level of experience of the operator, any fluid loading once intubation is planned, pre-oxygenation methods before induction of anesthesia or oxygenation post-induction, anesthetic drugs used, use of Sellick's maneuver, type of laryngoscopy (conventional or video), planned use of stylet, number of operators, number of attempts, number and type of rescue equipment used, Cormack–Lehane grading at laryngoscopy,[14] and level of intubation difficulty[15] were recorded. Data on recruitment maneuver performed immediately post-intubation were collected during the intervention period.

Complications during and within 1 hour of intubation were recorded and categorized as severe life-threatening or mild-to-moderate complications, as described in the earlier study.[6] Definitions of terms used in the study are provided in Table 2. At discharge from the hospital, patient outcome data, including hospital mortality, ICU, and hospital length of stay, were collected.

Table 1: Endotracheal intubation bundle

Pre-intubation
1. Fluid loading with 500 mL of balanced isotonic fluid (Ringer's lactate, plasmalyte, or sterofundin) over 15 minutes in patients with relative and deferred emergency, unless contraindicated, e.g., in obvious fluid overload or cardiogenic pulmonary edema.
2. Preoxygenation for 3 minutes with NIV plus PS, especially in patients with acute hypoxemic or hypercapnic respiratory failure, unless there is high risk of aspiration (face-mask interface, ICU ventilator, FiO_2 100%, pressure support set between 5 cm and 15 cm H_2O to obtain an expiratory tidal volume between 6 mL and 8 mL/kg of predicted body weight, and PEEP of 5 cm H_2O).
Post-induction
3. Rapid sequence induction: • *Sedation:* Intravenous etomidate 0.2–0.3 mg/kg or ketamine 1.5–3 mg/kg or propofol 1–2.5 mg/kg. • *Analgesia:* Intravenous fentanyl: 1–2 μg/kg. • *Muscle relaxant:* Intravenous succinylcholine 1–1.5 mg/kg should be the first-line induction agent, unless contraindicated. Rocuronium 0.6 mg/kg is to be used where Succinylcholine is contraindicated.
4. Post-induction: BMV with positive pressure or NIV with VCV mode using face mask and an ICU ventilator (100% FiO_2, tidal volume 6 mL/kg of predicted body weight, respiratory rate 12–15/min and PEEP 5 cm H_2O).
5. Routine use of stylet during intubation.
Post-intubation
6. Recruitment maneuver within 2 minutes of intubation (CPAP 40 cm H_2O for 30 seconds) unless contraindicated (e.g., patients with pre-existing hypotension).

FiO_2, fractional inspiratory oxygen; NIV, noninvasive ventilation; PEEP, positive end-expiratory pressure; PS, pressure support; VCV, volume control ventilation

Statistical Analysis

Baseline characteristics, intubation processes (including bundle compliance), outcomes of intubation for all intubation procedures, and hospital outcomes for all patients included in control and

Table 2: Definition of terms used

- *Emergency nature of intubation*: It was defined as real emergency if intubation is required without any delay, a relative emergency if intubation is required within 1 hour, and deferred emergency if the intubation can wait for >1 hour.
- *Time of intubation*: Regular hour was defined as between 9 am and 5 pm from Monday to Saturday, except on holidays. All other times were considered as out of hour.
- *Operator experience:* Operators were classified as "Experienced" if they were working in the ICU >5 years with experience in endotracheal intubation or with postgraduate training in anesthesiology plus working in the ICU for at least 1 year with experience in endotracheal intubation. Other operators were classified as "Trainees" and they were allowed to perform intubation only under supervision of an experienced staff. Trainee operators who had undergone 3-year postgraduate training in anesthesiology were further classified as "Anesthesia Trainee Operator".
- *Attempt:* Each attempt of advancing the endotracheal tube toward the glottic opening was considered as an attempt.
- *Cormack–Lehane grading*: Airway was classified based on direct laryngoscopic view, as described by Cormack and Lehane in their original paper.[14]
- *Intubation difficulty scale*: Level of difficulty during intubation was graded as described earlier by Adnet and colleagues based on number of attempts or operators, number of alternative techniques used, Cormack–Lehane grade, lifting forces required during laryngoscopy, any BURP maneuver performed and vocal cord mobility.[15]
- *Profound hypoxemia*: Profound hypoxemia was defined as any fall in SpO_2 below 80% or fall of SpO_2 by 10 percentage points for patients in whom SpO_2 value was <90% following 3 minutes of pre-oxygenation.
- *Profound hypotension*: Profound hypotension was defined as fall of SBP below 65 mm Hg (for any duration) or below 90 mm Hg that did not improve after 500 mL crystalloid bolus or any hypotension that requires initiation of vasopressor support or need for an increase in vasopressor (for patients already on vasopressor pre-intubation).
- *Arrhythmias*: New-onset atrial fibrillation or atrial flutter, ventricular premature complex at a rate >6/min, or new-onset bigeminy/trigeminy or ventricular tachycardia (sustained or nonsustained) will be included in this category.
- *Aspiration*: Visible migration of stomach content into the lung.

intervention periods were compared. All categorical variables were summarized as numbers and percentages (%). On the other hand, quantitative variables with normally distributed data were summarized as mean ± standard deviation (SD) and quantitative data with non-normal distribution were presented as median with 25th and 75th percentiles [interquartile range, (IQR)]. Data normality was checked by using Kolmogorov–Smirnov test.

Qualitative variables were compared using Chi-square test. Non-normally distributed quantitative variables were compared using Mann–Whitney test (for two groups), and independent *t* test was used for comparison of normally distributed data between two groups. If any cell had a value of less than 5, then Fisher's exact test was used. Two-tailed *p*-value of <0.05 was taken as level of statistical significance.

Data entry was done in Microsoft EXCEL spreadsheet. The final analysis was done with the use of Statistical Package for Social Sciences (SPSS) software, IBM manufacturer, Chicago, USA, version 21.0.

Results

Baseline Characteristics

We compared data from 61 intubations completed on 54 patients in the control period with 63 intubations done on 57 patients in the intervention period. Apart from clinically nonsignificant differences in the number of obese patients and reasons for ICU admissions, all baseline variables before intubation were similar (Table 3).

Intubation Procedure

Different aspects of intubation procedures are reported in Table 4. Compared with the control period, there was significant increase in the compliance to all individual components of the bundle during the intervention period with the sole exception of fluid loading prior to intubation. In the intervention period, compliance to all components of the bundle was observed in 14.3% of intubations and complete noncompliance was seen in 3.2% (Fig. 1). In 58 of 63 intubations (92.06%), at least 3 components of the bundle were applied. Physicians' self-reported reasons for noncompliance to individual components are shown in Table 5.

Outcomes of Intubation

Table 6 shows the outcome of intubation procedures. No significant differences were observed in the first-attempt success, number of operators, rescue equipment used, or level of intubation difficulty between two periods.

In total, 28 of 61 intubations in the control period were complicated by at least one major adverse event, compared with 15 of 63 intubations in the intervention period (45.9% vs 23.8%, $p = 0.01$). The incidence of profound hypotension was significantly lower in the intervention period (29.51% vs 21.77%, $p = 0.04$) (Fig. 2). There was 11.89% reduction in profound hypoxemia incidence during the intervention period, however, this difference did not reach statistical significance. Two patients, who died during intubation (both in the control period), had cardiac arrest as the indication for the procedure. Five intubations were complicated by cardiac arrest (2 in control period and 3 in intervention period), return of spontaneous circulation (ROSC) was achieved in all of them. There was no difference in minor complications (Fig. 3). In the intervention period, there were two esophageal intubations, out of which one was associated with profound hypoxemia.

In the overall cohort, rate of first-pass success was 81.82% in 66 patients where stylet was proactively used, compared with 74.14% in 58 patients where it was not used, however, this difference was not statistically significant ($p = 0.301$). In total, 30 of 97 intubations with first-pass success had some complications, compared with 13 of 27 intubations requiring multiple attempts (30.92% vs 48.14%, $p = 0.096$). Overall, 14 of 70 patients who received fluid loading developed profound hypotension, compared with 13 of 54 patients who did not receive it (20% vs 24.07%, $p = 0.586$).

Table 3: Baseline characteristics before endotracheal intubation

	Control period (N = 61)	*Intervention period (N = 63)*	*Total (N = 124)*	*p-value*
Age (in years) (mean, SD)	63.41 ± 15.61	61.49 ± 15.28	62.44 ± 15.41	0.491*
Female gender (No, %)	25 (40.98%)	22 (34.92%)	47 (37.90%)	0.487§
Obesity (No, %)	2 (3.28%)	11 (17.46%)	13 (10.48%)	0.016‡
APACHE II	21.52 ± 7.6	20.56 ± 6.86	21.03 ± 7.22	0.457*
Reasons for ICU admission (No, %)				
Advanced malignancy	0 (0%)	3 (4.76%)	3 (2.42%)	0.009‡
Airway compromise	0 (0%)	1 (1.59%)	1 (0.81%)	
Circulatory shock	5 (8.20%)	8 (12.70%)	13 (10.48%)	
Complications of CKD	2 (3.28%)	1 (1.59%)	3 (2.42%)	
Complications of CLD	3 (4.92%)	0 (0%)	3 (2.42%)	
Quadriparesis	0 (0%)	1 (1.59%)	1 (0.81%)	
Respiratory failure	28 (45.90%)	30 (47.62%)	58 (46.77%)	
Seizure	0 (0%)	1 (1.59%)	1 (0.81%)	
Stroke	8 (13.11%)	14 (22.22%)	22 (17.74%)	
Trauma	2 (3.28%)	2 (3.17%)	4 (3.23%)	
Other	13 (21.31%)	2 (3.17%)	15 (12.10%)	
Heart rate (median, IQR)	112 (100–138.25)	106 (92–129)	110 (98–131.5)	0.226†
Systolic blood pressure (in mm Hg) (median, IQR)	110 (90–141)	114.5 (100–130)	113 (98–138)	0.513†
Need for vasopressor (No, %)	14 (22.95%)	16 (25.40%)	30 (24.19%)	0.751§
SpO_2 (%) (median, IQR)	86 (77.25–91)	90 (83–93.25)	88 (80.25–92)	0.038†
O_2 supplement prior to initiation of intubation at ICU (No, %)				
None	6 (9.84%)	11 (17.46%)	17 (13.71%)	0.485‡
Bag-mask valve	1 (1.64%)	0 (0%)	1 (0.81%)	
High-flow nasal oxygen	6 (9.84%)	6 (9.52%)	12 (9.68%)	
Low-flow oxygen	40 (65.57%)	34 (53.97%)	74 (59.68%)	
LMA + Bag	0 (0%)	1 (1.59%)	1 (0.81%)	
Noninvasive ventilation	8 (13.11%)	11 (17.46%)	19 (15.32%)	

*Independent *t* test; †Mann Whitney test; ‡Fisher's exact test; §Chi-square test; APACHE, acute physiology and chronic health evaluation; CKD, chronic kidney disease; CLD, chronic liver disease; IQR, interquartile range; LMA, laryngeal mask airway; SD, standard deviation

Outcome of Patients

Patients who were intubated in the ICU during the control period had significantly higher mortality at hospital discharge (66.67% vs 42.11%, $p = 0.009$). In the intervention period, one patient who achieved ROSC following peri-intubation cardiac arrest died on the following day. There was no difference in ICU [median, 6 (4–8) vs 6 (5–10) days, $p = 0.063$] or hospital length of stay [median, 11 (8.25–13.75) vs 10 (8–15) days, $p = 0.925$].

Discussion

Development, training, and implementation of an evidence-based intubation bundle are feasible in ICUs. There was over 90% compliance to at least 3 components of the bundle during the intervention period with a significant increase in the compliance to almost all components (with the exception of fluid loading pre-intubation). With extensive training and implementation of the bundle, the incidence of life-threatening complications during and within 1 hour of endotracheal intubation could be reduced by half. The incidence of profound hypotension was significantly lower during the intervention period. There was also a nonsignificant reduction in the incidence of profound hypoxemia by 11.89 percentage points.

Rationale for 6-component "Care Bundle"

Fluid Loading Pre-induction

Profound hypotension is common during ICU intubation, especially in older and more severely ill patients.[16] In the Montpellier protocol, routine fluid loading pre-induction was included as part of a comprehensive intervention strategy and the strategy showed a reduction in the incidence of profound hypotension.[6] However, a recent study by Janz and colleagues looking into the effect of fluid loading on severe hypotension was stopped early because of futility.[17] We decided to include fluid loading before endotracheal intubation in our intubation bundle, since it was already part of routine strategy in our ICU. From the crude analysis of data from our overall cohort, the incidence of profound hypotension was not lowered with fluid loading (24.07% without fluid loading versus 20% with fluid loading; nonsignificant). However, we observed a significant decrease in profound hypotension incidence in the intervention period, which may be explained by overall improvement in the intubation process and a numerical increase in the rate of first-pass success during the intervention period.

Preoxygenation for 3-minutes with Noninvasive Ventilation

Noninvasive pressure-support ventilation (NIV plus PS) with a face mask using an ICU ventilator is a useful preoxygenation strategy

Table 4: Comparison of intubation processes between control and intervention periods

	Control period (N = 61)	*Intervention period (N = 63)*	*Total (N = 124)*	*p-value*
Indication for intubation				
Airway compromise	19 (31.15%)	22 (34.92%)	41 (33.06%)	0.152‡
Cardiac arrest	3 (4.92%)	0 (0%)	3 (2.42%)	
Circulatory shock	3 (4.92%)	8 (12.70%)	11 (8.87%)	
Planned general anesthesia	1 (1.64%)	0 (0%)	1 (0.81%)	
Hypoxemic respiratory failure	24 (39.34%)	18 (28.57%)	42 (33.87%)	
Hypercapnic respiratory failure	11 (18.03%)	15 (23.81%)	26 (20.97%)	
Emergency nature of intubation				
Real	33 (54.10%)	30 (47.62%)	63 (50.81%)	0.156‡
Relative	22 (36.07%)	31 (49.21%)	53 (42.74%)	
Deferred	6 (9.84%)	2 (3.17%)	8 (6.45%)	
Time of intubation				
Regular	28 (45.90%)	28 (44.44%)	56 (45.16%)	0.871§
Out of hour	33 (54.10%)	35 (55.56%)	68 (54.84%)	
Experience of operator				
Experienced	61 (100%)	57 (90.48%)	118 (95.16%)	0.043‡
ICU trainee anesthesia	0 (0%)	4 (6.35%)	4 (3.23%)	
ICU trainee nonanesthesia	0 (0%)	2 (3.17%)	2 (1.61%)	
Fluid loading pre-intubation	31 (50.82%)	39 (61.90%)	70 (56.45%)	0.213§
Pre-oxygenation with NIV	13 (21.31%)	55 (87.30%)	68 (54.84%)	<0.0001§
Alternative pre-oxygenation				
BMV - positive pressure	41 (85.42%)	5 (62.50%)	46 (82.14%)	0.007‡
BMV + positive pressure	3 (6.25%)	0 (0%)	3 (5.36%)	
HFNO	4 (8.33%)	0 (0%)	4 (7.14%)	
None	0 (0%)	3 (37.50%)	3 (5.36%)	
Positive pressure post-induction				
None	33 (54.10%)	4 (6.35%)	37 (29.84%)	<0.0001§
BMV + positive pressure	18 (29.51%)	6 (9.52%)	24 (19.35%)	
NIV + VCV	10 (16.39%)	53 (84.13%)	63 (50.81%)	
Sedative agents				
Etomidate	52 (85.25%)	57 (90.48%)	109 (87.90%)	0.544‡
Propofol	5 (8.20%)	2 (3.17%)	7 (5.65%)	
None	4 (6.56%)	4 (6.35%)	8 (6.45%)	
Analgesic agents				
Fentanyl	43 (70.49%)	43 (68.25%)	86 (69.35%)	0.787§
None	18 (29.51%)	20 (31.75%)	38 (30.65%)	
Succinylcholine for induction	1 (1.64%)	10 (15.87%)	11 (8.87%)	0.009‡
Alternative neuromuscular blocker				
Rocuronium	55 (91.67%)	51 (94.44%)	106 (92.98%)	1‡
Atracurium	1 (1.67%)	0 (0%)	1 (0.88%)	
No neuromuscular blocker	4 (6.67%)	3 (5.56%)	7 (6.14%)	
Sellick's maneuver	12 (19.67%)	0 (0%)	12 (9.68%)	0.0001‡
Initial laryngoscopy				
Conventional	55 (90.16%)	57 (90.48%)	112 (90.32%)	0.953§
Video	6 (9.84%)	6 (9.52%)	12 (9.68%)	
Pre-emptive use of stylet	11 (18.03%)	55 (87.30%)	66 (53.23%)	<0.0001§
Post-intubation recruitment maneuver	0 (0%)	46 (73.02%)	46 (37.10%)	<0.0001‡

‡Mann Whitney test; §Chi-square test; BMV, bag-mask valve; HFNO, high-flow nasal oxygen; NIV, noninvasive ventilation; VCV, volume control ventilation

and can potentially reduce the incidence of severe hypoxemia in the peri-intubation period. Two possible explanations for this improvement are delivery of high oxygen concentration and recruitment of collapsed alveoli. In a multicenter French study, compared with the usual bag-valve mask strategy, preoxygenation with NIV plus PS had shown to improve oxygenation both before induction and throughout intubation and also to reduce the incidence of severe peri-intubation hypoxemia.[11] A subsequent study reconfirmed this finding, but failed to show any impact of this strategy on organ function in subsequent 7 days post-intubation.[18] We observed a significant improvement in compliance to preoxygenation strategy with NIV plus PS, without any increase in the incidence of visible aspiration.

Positive Pressure Ventilatory Support during Period of Apnea Post-induction

There is a potential delay of 45–90 seconds between administering the induction agent and laryngoscopy. Providing positive-pressure ventilatory support either by volume-control ventilation with facemask or by bag-valve-mask ventilation during that period can potentially maintain oxygenation better during intubation. In a multicenter study from the United States, the lowest oxygen level from induction to 2 minutes after intubation was higher when ventilation was delivered to the patient post induction with a bag-valve-mask device compared with no ventilation.[9] The use of this strategy was also found to be safe, as it did not increase visible aspiration or new infiltrate in post-intubation chest X-ray.[9] We observed a significant improvement in compliance (93.65%) to this strategy during the intervention period without any increase in incidences of visible aspiration. Another strategy that could be utilized for post-induction oxygenation is the utilization of high-flow nasal cannula oxygenation.[19] But we decided against including this strategy in our bundle, because of resource limitation.

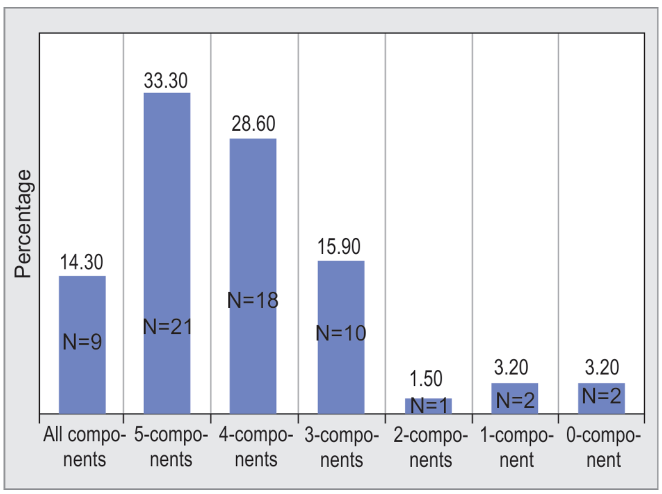

Fig. 1: Compliance to different components of "Intubation Bundle"

Succinylcholine for Rapid Sequence Induction (RSI)

Because of rapid onset of action (40–60 seconds) and short duration of effect (6–10 minutes), succinyl choline is preferred as a muscle relaxant during RSI in the operating room. However, there are several limitations for its widespread use in critically ill patients. Rocuronium has been the preferred relaxant for RSI in our unit. However, in a single-center Swiss study in critically ill patients, succinyl choline use was shown to reduce total duration of intubation compared with rocuronium.[12] Moreover, in a recent Cochrane review, RSI with succinyl choline was found to produce better and more acceptable condition for intubation compared with rocuronium.[13] Based on these evidences, we decided to include succinyl choline as the first-line induction agent in our care bundle. Although, there was a significant increase in succinyl choline use during the intervention period, in 56% of intubations, physicians reported some contraindications to its uses, and in another 23.4%, physicians preferred not to use it without any specific reason.

Routine Use of Stylet

Routine use of stylet during intubation has shown to improve first-pass success rate for intubation in recently published STYLETO study.[10] The association between first-attempt success and lower complication rates is now clearly established.[20] In our study, compared with control period pre-emptive use of stylet increased significantly during the intervention period (18.03% vs 87.30%, $p = 0.001$). In the overall cohort, first-pass was achieved in 54 of 66 intubations (81.81%) when stylet was used compared with 43 of 58 intubations (74.13%) when it was not used. Though this 7.68 percentage-point difference was not statistically significant, it is comparable with the 6.7 percentage point in the first-pass success observed in STYLETO study.[10]

Table 5: Reasons cited by operators for noncompliance with specific component of the bundle

Fluid loading pre-intubation	*NIV pre-oxygenation*	*Positive pressure during apnea*	*Succinylcholine for induction*	*Routine stylet*	*Recruitment maneuver post-intubation*
1. No time for the same (emergency). $N = 10$ 2. Fluid overload. $N = 9$ 3. Profound hypoxia. $N = 3$ 4. Severe LV dysfunction. $N = 2$	1. No specific reason mentioned. $N = 5$ 2. No pre-oxygenation. $N = 2$ 3. Patient oxygenated with LMA. $N = 1$	1. No specific reason mentioned. $N = 4$	1. No specific reason mentioned. $N = 15$ 2. Renal failure with suspected hyperkalemia. $N = 9$ 3. Confirmed hyperkalemia. $N = 8$ 4. Prolonged immobilization. $N = 5$ 5. Suspected raised ICP. $N = 11$ 6. Severe acidosis. $N = 3$ 7. No NMB used. $N = 2$	1. Planned use of bougie. $N = 1$ 2. No specific reason mentioned. $N = 7$	1. No specific reason mentioned. $N = 4$ 2. Suspected pneumothorax. $N = 1$ 3. Profound hypotension. $N = 6$ 4. Raised ICP. $N = 6$

Table 6: Outcome of endotracheal intubation in control and intervention period

	Control period (N = 61)	*Intervention period (N = 63)*	*Total (N = 124)*	*p-value*
Cormack–Lehane grading				
Grade I	33 (54.10%)	50 (79.37%)	83 (66.94%)	0.005‡
Grade II	17 (27.87%)	9 (14.29%)	26 (20.97%)	
Grade III	11 (18.03%)	3 (4.76%)	14 (11.29%)	
Grade IV	0 (0%)	1 (1.59%)	1 (0.81%)	
Number of attempts				
1 attempt	46 (75.41%)	51 (80.95%)	97 (78.23%)	0.535‡
2 attempts	11 (18.03%)	7 (11.11%)	18 (14.52%)	
3 or more attempts	4 (6.56%)	5 (7.94%)	9 (7.25%)	
Number of operators				
Single operator	60 (98.36%)	59 (93.65%)	119 (95.97%)	0.244‡
2 operators	0 (0%)	3 (4.76%)	3 (2.42%)	
3 operators	1 (1.64%)	1 (1.59%)	2 (1.61%)	
Rescue equipments/Measures used				
Rescue VL	2 (3.28%)	5 (7.94%)	7 (5.65%)	0.44‡
Rescue stylet	6 (9.84%)	0 (0%)	6 (4.84%)	0.012‡
Rescue bougie	10 (16.39%)	6 (9.52%)	16 (12.90%)	0.254§
Rescue LMA	1 (1.64%)	1 (1.59%)	2 (1.61%)	1‡
Fiber-optic bronchoscopy	1 (1.64%)	1 (1.59%)	2 (1.61%)	1‡
Emergency tracheostomy	1 (1.64%)	1 (1.59%)	2 (1.61%)	1‡
Intubation level of difficulty				
Easy	36 (59.02%)	44 (69.84%)	80 (64.52%)	0.591‡
Slight difficulty	19 (31.15%)	13 (20.63%)	32 (25.81%)	
Moderate to major	5 (8.20%)	5 (7.94%)	10 (8.06%)	
Impossible	1 (1.64%)	1 (1.59%)	2 (1.61%)	
Life-threatening complications				
Death	2 (3.28%)	0 (0%)	2 (1.61%)	0.24‡
Profound hypoxemia	15 (24.59%)	8 (12.70%)	23 (18.55%)	0.089§
Profound hypotension	18 (29.51%)	9 (14.29%)	27 (21.77%)	0.04§
Cardiac arrest	2 (3.28%)	3 (4.76%)	5 (4.03%)	1‡
Mild-to-moderate complications				
Esophageal intubation	0 (0%)	2 (3.17%)	2 (1.61%)	0.496‡
Cardiac arrhythmia	0 (0%)	0 (0%)	0 (0%)	–
Orodental trauma	0 (0%)	1 (1.59%)	1 (0.81%)	1‡
Aspiration	0 (0%)	0 (0%)	0 (0%)	–
Airway trauma	2 (3.28%)	0 (0%)	2 (1.61%)	0.24‡
Other complications	0 (0%)	0 (0%)	0 (0%)	–

LMA, laryngeal mask airway; VL, video laryngoscopy

Recruitment Maneuver Post-intubation

Large increase in the airway and alveolar pressure for a brief period ["Recruitment Maneuver (RM)"] can potentially recruit lung volume, reduced during induction of general anesthesia. In a single-center Swiss study, routine RM at 40 cm H_2O for 30 seconds within 2 minutes of intubation had shown to improve oxygenation at 5 minutes post-intubation without any increase in incidences of hemodynamic compromise.[8] In our study, post-intubation RM was not performed in one-fourth of intubation episodes during the intervention period, mostly because of contraindications to RM.

Strengths and Limitations

To the best of our knowledge, this is the first-of-its kind study outside any developed country, that looked into quality improvement

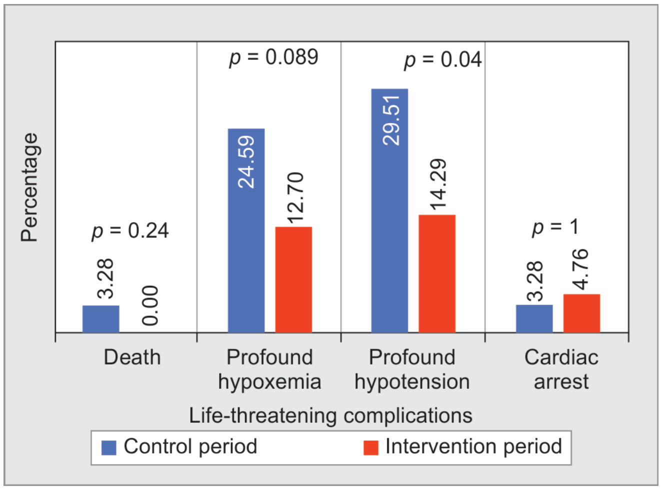

Fig. 2: Life-threatening complications in control and intervention period

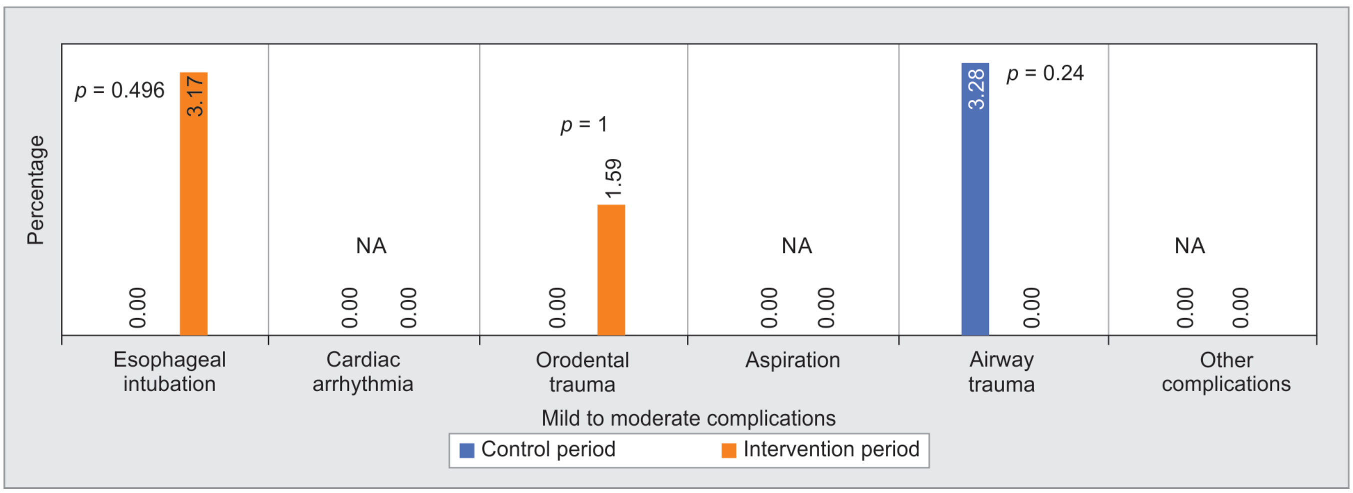

Fig. 3: Mild-to-moderate complications in control and intervention period

during endotracheal intubation processes in critically ill patients. The strength of our study includes incorporation of newer evidence-based interventions in the care bundle and the same group of consultant intensivists participating in both control and intervention period. Also, by including all adult patients undergoing intubation, our study more closely reflects real-life scenarios.

However, the current study is limited by its single-center design. Another major limitation of our study is reliance on physician's self-reporting of intubation processes and complications, with possibility of reporting bias. However, our rates of major complications are comparable to studies reported earlier.[6,7] Finally, as we evaluated the effects of implementing several interventions as a bundle, our study's ability to draw any conclusion on individual component of the bundle is limited.

Conclusion

In this quality-improvement project, most components of the revised Montpellier intubation bundle could be implemented in the intervention period. Implementation of the revised bundle could significantly reduce rates of major complications related to intubation compared with an unwritten strategy closely resembling the original Montpellier bundle. There was a significant reduction in the incidence of profound hypotension during the intervention.

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References

1. Simpson GD, Ross MJ, McKeown DW, Ray DC. Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. Br J Anaesth 2012;108:792–799.
2. Russotto V, Myatra SN, Laffey JG, Tassistro E, Antolini L, Bauer P, et al. Intubation practices and adverse peri-intubation events in critically ill patients from 29 Countries. JAMA 2021;325(12):1164–1172. DOI: 10.1001/jama.2021.1727.

3. Jaber S, Amraoui J, Lefrant JY, Arich C, Cohendy R, Landreau L, et al. Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: A prospective, multiple-center study. Crit Care Med 2006;34(9):2355–2361. DOI: 10.1097/01.CCM.0000233879.58720.87.
4. Griesdale DE, Bosma TL, Kurth T, Isac G, Chittock DR. Complications of endotracheal intubation in the critically ill. Intensive Care Med 2008;34(10):1835–1842. DOI: 10.1007/s00134-008-1205-6.
5. De Jong A, Rolle A, Molinari N, Paugam-Burtz C, Constantin JM, Lefrant JY, et al. Cardiac arrest and mortality related to intubation procedure in critically ill adult patients: A multicenter cohort study. Crit Care Med 2018;46(4):532–539. DOI: 10.1097/CCM.0000000000002925.
6. Jaber S, Jung B, Corne P, Sebbane M, Muller L, Chanques G, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: A prospective, multiple-center study. Intensive Care Med 2010;36(2):248–255. DOI: 10.1007/s00134-009-1717-8.
7. Corl KA, Dado C, Agarwal A, Azab N, Amass T, Marks SJ, et al. A modified Montpellier protocol for intubating intensive care unit patients is associated with an increase in first-pass intubation success and fewer complications. J Crit Care 2018;44:191–195. DOI: 10.1016/j.jcrc.2017.11.014.
8. Constantin JM, Futier E, Cherprenet al, Chanques G, Guerin R, Cayot-Constantin S, et al. A recruitment maneuver increases oxygenation after intubation of hypoxemic intensive care unit patients: A randomized controlled study. Crit Care 2010;14(2):R76. DOI: 10.1186/cc8989.
9. Casey JD, Janz DR, Russell DW, Vonderhaar DJ, Joffe AM, Dischert KM, et al. Bag-mask ventilation during tracheal intubation of critically ill adults. N Engl J Med 2019;380(9):811–821. DOI: 10.1056/NEJMoa1812405.
10. Jaber S, Rollé A, Godet T, Terzi N, Riu B, Asfar P, et al. Effect of the use of an endotracheal tube and stylet versus an endotracheal tube alone on first-attempt intubation success: A multicentre, randomised clinical trial in 999 patients. Intensive Care Med 2021;47(6):653–664. DOI: 10.1007/s00134-021-06417-y.
11. Baillard C, Fosse JP, Sebbane M, Chanques G, Vincent F, Courouble P, et al. Non-invasive ventilation improves preoxygenation before intubation of hypoxic patients. Am J Respir Crit Care Med 2006;174(2):171–177. DOI: 10.1164/rccm.200509-1507OC.
12. Marsch SC, Steiner L, Bucher E, Pargger H, Schumann M, Aebi T, et al. Succinylcholine versus rocuronium for rapid sequence intubation in intensive care: A prospective, randomized controlled trial. Crit Care 2011;15(4):R199. DOI: 10.1186/cc10367.
13. Tran DT, Newton EK, Mount VA, Lee JS, Wells GA, Perry JJ. Rocuronium versus succinylcholine for rapid sequence induction intubation. Cochrane Database Syst Rev 2015;2015(10):CD002788. DOI: 10.1002/14651858.CD002788.pub3.
14. Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anaesthesia 1984;39(11):1105–1111. PMID: 6507827.
15. Adnet F, Borron SW, Racine SX, Clemessy JL, Fournier JL, Plaisance P, et al. The intubation difficulty scale (IDS): Proposal and evaluation of a new score characterizing the complexity of endotracheal intubation. Anesthesiology 1997;87(6):1290–1297. DOI: 10.1097/00000542-199712000-00005.
16. Perbet S, De Jong A, Delmas J, Futier E, Pereira B, Jaber S, et al. Incidence of and risk factors for severe cardiovascular collapse after endotracheal intubation in the ICU: A multicenter observational study. Crit Care 2015;19(1):257. DOI: 10.1186/s13054-015-0975-9.
17. Janz DR, Casey JD, Semler MW, Russell DW, Dargin J, Vonderhaar DJ, et al. Effect of a fluid bolus on cardiovascular collapse among critically ill adults undergoing tracheal intubation (PrePARE): A randomised controlled trial. Lancet Respir Med 2019;7(12):1039–1047. DOI: 10.1016/S2213-2600(19)30246-2.
18. Baillard C, Prat G, Jung B, Futier E, Lefrant JY, Vincent F, et al. Effect of preoxygenation using non-invasive ventilation before intubation on subsequent organ failures in hypoxemic patients: A randomised clinical trial. Br J Anaesth 2018;120(2):361–367. DOI: 10.1016/j.bja.2017.11.067.
19. Jaber S, Monnin M, Girard M, Conseil M, Cisse M, Carr J, et al. Apnoeic oxygenation via high-flow nasal cannula oxygen combined with non-invasive ventilation preoxygenation for intubation in hypoxemic patients in the intensive care unit: The single-centre, blinded, randomised controlled OPTINIV trial. Intensive Care Med 2016;42(12):1877–1887. DOI: 10.1007/s00134-016-4588-9.
20. De Jong A, Rolle A, Pensier J, Capdevila M, Jaber S. First-attempt success is associated with fewer complications related to intubation in the intensive care unit. Intensive Care Med 2020;46(6):1278–1280. DOI: 10.1007/s00134-020-06041-2.