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Feasibility, safety, and utility of bronchoscopy in patients with ARDS while in the prone position

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Prone positioning (PP) was shown to reduce mortality in mechanically ventilated (MV) patients with severe ARDS [1]. Despite its common use, safety concerns inhibit use of flexible bronchoscopy (FB) in patients with ARDS, and there are few reports of FB performed in PP [2]. We reviewed all adults receiving FB in PP in one institution between April 2016 and September 2017. The study was approved by the institutional review board. Four men and three women were identified (Table 1). In five patients, FB was indicated for clearance of thick secretions, and in two patients for microbial analysis. The mode of mechanical ventilation was not changed for FB, but FIO_2 was universally set to 100%. All subjects had invasive hemodynamic and pulse oximetry monitoring. End-tidal carbon dioxide ($EtCO_2$) was monitored in 3/7 subjects. With the subject's head tilted to the side, the bronchoscope was advanced into the airways, repeatedly, and in short cycles, allowing time for oxygenation, ventilation, and lung recruitment between insertions. Therapeutic aspiration was performed in 6/7 subjects. Bronchoalveolar lavage was performed in two subjects. No significant hemodynamic compromise was observed during any of the procedures. Significant oxygen desaturation and rising $EtCO_2$ were observed in one case (patient 4). Both derangements resolved with withdrawal of the bronchoscope and recruitment. No additional complications were documented. Figure 1 illustrates evolution of the PaO_2:FIO_2 ratio over time for each subject. Six subjects had antibiotics modified based on FB-obtained cultures. Consistent with previous data [3], 4/7 subjects survived 30 days following discharge from the ICU.

Although PP is lung-protective, it may result in mobilization of secretions into the airways, impairing oxygenation and providing nidus for infection [4]. Despite documented risks [5], FB may be beneficial in this situation.

Several limitations need to be addressed when interpreting our data. This is a retrospective analysis. Although physiologic monitoring was automatically captured, ventilator data were not and ventilator output during FB could not be accurately analyzed. Additionally, $EtCO_2$ was not measured in all cases during FB. Finally, PP was shown to reduce mortality in patients with moderate to severe ARDS, however, our study subjects' oxygenation had started to improve by the time FB was performed (Fig. 1, T1). This likely reflects reluctance to perform FB in subjects with severe hypoxemia due to excessive risks.

Our report demonstrates the feasibility of FB performed in brief increments in carefully monitored patients with ARDS ventilated in PP. Further studies are needed to better delineate optimal ventilator management during FB in PP.

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Table 1 Individual patient parameters, flexible bronchoscopy performance, and outcomes ($n = 7$)

Variable	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7
Age (years)	63	18	44	79	53	23	61
Sex	Female	Female	Male	Male	Male	Female	Male
Ethnicity	Black	Caucasian	Caucasian	Asian	Caucasian	Black	Caucasian
Etiology of ARDS	MRSA sepsis	Massive pulmonary embolism	Fulminant hepatic failure, *Klebsiella* sepsis	Pneumonia	Massive aspiration	Massive aspiration	Pneumonia
Total ICU LOS (days)/day of FB	27/9	30/13	97/32	35/29	9/2	49/11	16/1
Prone-positioning protocol (total hours)	28	18	16	236	20	133	18
30-day survival post ICU discharge	No	Yes	Yes	No	Yes	Yes	No
Ventilator-related parameters at FB[a]							
Mode	PRVC	PC/AC	VC/AC	PRVC	VC/AC	PC/AC	PC/AC
Peak pressure (cmH_2O)	32	29	24	37	30	20	32
Plateau pressure (cmH_2O)	27	NA	NA	30	26	NA	27
PEEP (cmH_2O)	11	12	15	8	10	10	14
FIO_2 (%)	100	100	100	100	100	100	100
FB-related data							
Δ-diameter ETT to bronchoscope (mm)	1.7	2.0	1.7	2.0	2.0	4.0	3.1
Therapeutic aspiration	Yes	Yes	Yes	No	Yes	Yes	Yes
Bronchial washings / BAL	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monitoring data							
MAP							
Baseline[a]	69	67	87	68	72	67	80
Trough during FB	69	64	72	66	71	67	68
SpO_2							
Baseline[a]	94	98	97	100	100	100	100
Trough during FB	94	92	97	87	99	99	100
$EtCO_2$							
Baseline[a]	48	30	NA	43	NA	NA	NA
Trough during FB	49	30	NA	51	NA	NA	NA
Change in antibiotic regimen based on culture results	De-escalation	De-escalation	No	Additional coverage	De-escalation	De-escalation	De-escalation

ARDS adult respiratory distress syndrome, *ICU* intensive care unit, *LOS* length of stay, *FB* flexible bronchoscopy, *MRSA* methicillin-resistant *Staphylococcus aureus*, *PRVC* pressure-regulated volume control, *PC/AC* pressure-cycled assist-controlled, *VC/AC* volume-cycled assist-controlled, *PEEP* positive end-expiratory pressure, *ETT* endotracheal tube, *BAL* bronchoalveolar lavage, *MAP* mean arterial pressure as measured with an arterial line, *NA* not available, SpO_2 oxygen saturation as measured with pulse oximetry, $EtCO_2$ end-tidal carbon dioxide,FIO_2 fractional concentration of inspired oxygen

[a]As documented prior to first bronchoscope insertion

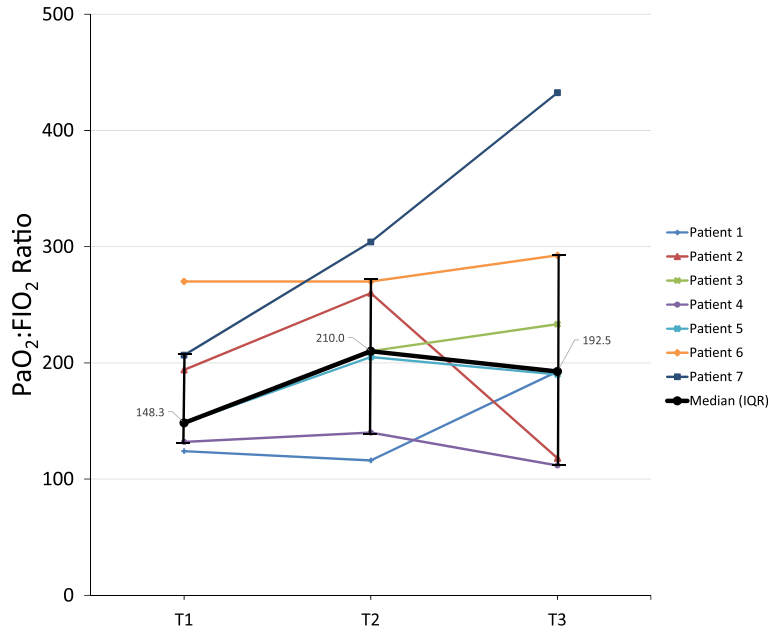

Fig. 1 Evolution of PaO_2 to FIO_2 ratio from pre bronchoscopy (T1) to 24 h (T2) and 72 h (T3) post bronchoscopy (n = 7). IQR interquartile range, PaO_2 partial pressure of arterial oxygen, FIO_2 fractional concentration of inspired oxygen

Abbreviations

ARDS: Acute respiratory distress syndrome; $EtCO_2$: end-tidal carbon dioxide; FB: Flexible bronchoscopy; FIO_2: Fraction of inspired oxygen; ICU: Intensive care unit; MV: Mechanical ventilation; PaO_2: Partial pressure of arterial oxygen; PP: Prone position

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

OK-D, AS, and EMP contributed to the study concept and design. OK-D, CBS, AS, and EMP contributed to acquisition of data. OK-D, CBS, JJ, AS, and EMP contributed to analysis and interpretation of data. OK-D contributed to drafting of the manuscript. All declared authors contributed to critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was conducted at University of Maryland Medical Center in accordance with Good Clinical Practice (Declaration of Helsinki 2002) and University of Maryland, Baltimore Campus Institutional Review Board approvals (IRB reference number HP-00073462). Patients were included from April 2016 to September 2017. A waiver of consent has been approved per 45 CFR 46.116(d).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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