Comparison of Postextubation Complications Between Positive-Pressure and Suctioning Techniques: A Systematic Review

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BACKGROUND: Several studies have investigated postextubation complications of the positive-pressure and suctioning techniques; however, these studies yielded inconsistent results. Therefore, in this systematic review, we aimed to assess and compare the risk of complications between these techniques after extubation. METHODS: This study was registered with the International Prospective Register of Systematic Reviews (CRD42021272068). We searched for randomized controlled trials (RCT) or observational studies that compared positive-pressure and suctioning extubation techniques in medical literature databases. Our search was conducted from the databases' inception to July 7, 2022. The included studies were assessed for quality by using a risk of bias tool. RESULTS: Six RCTs and 1 non-randomized controlled study were included in this systematic review (*N* = 1,575 subjects), wherein the positive-pressure and suctioning techniques were applied to 762 and 813 subjects, respectively. Three studies were conducted in operating rooms, and 4 studies were conducted in ICUs. Five studies were conducted among adults, and 2 studies were conducted among children or neonates. All the studies except 1 RCT showed that the positive-pressure technique tended to have a lower but not statistically different risk of complications, including desaturation, airway obstruction, pneumonia, aspiration, atelectasis, and re-intubation, than the suctioning technique. Three of the 6 RCTs were determined to have a high risk of bias and the 1 non-randomized controlled study was determined to have a serious risk of bias. CONCLUSIONS: The positive-pressure technique tended to have a lower risk of complications than the suctioning technique. Further high-quality studies are warranted. *Key words: Airway management; extubation complications; extubation technique; positive pressure technique; suctioning technique; systematic review.* [Respir Care 2023;68(3):429–436.

Introduction

Generally, endotracheal extubation is a high-risk procedure.[1,2] In recent years, because of the COVID-19 pandemic, attention has been focused on extubation to minimize aerosolization and droplet expulsion from patients.[3] During extubation, mild-to-severe complications, including tooth damage, hypoxic encephalopathy, and death, can occur.[4,5] Extubation failure is associated with a longer duration of mechanical ventilation, higher medical costs, and a higher mortality rate.[6]

Various extubation techniques, including a positive-pressure technique, suctioning technique, extubation in the semi-Fowler position, and extubation with sedative drugs, have been reported.[7-9] The positive-pressure technique comprises application of positive pressure through the airway during cuff deflation and extubation, whereas the suctioning technique comprises the introduction of a suction catheter into an endotracheal tube and application of continuous suctioning during cuff deflation and extubation. Questionnaire surveys of ICU staff members in the United Kingdom and Argentina revealed that the suctioning technique was most frequently performed.[10,11] However, some studies reported that the positive-pressure technique is superior to the suctioning technique.[12,13]

To the best of our knowledge, there has been no previous systematic review of studies that investigated extubation techniques. Given the inconclusive findings in the studies reported to date, this topic has remained controversial. Therefore, we conducted a systematic review of randomized controlled trials (RCT) and observational studies to assess and compare the risk of complications after extubation between the positive-pressure and suctioning techniques. The findings of this review could be meaningful to determine the optimal extubation technique for use within this high-risk medical procedure.

Methods

This study was registered with the International Prospective Register of Systematic Reviews (CRD42021272068, Centre for Reviews and Dissemination, University of York, York, UK) and is reported in accordance with PRISMA guidelines.[14]

Eligibility Criteria

We searched for RCTs or observational studies that (1) were published in peer-reviewed journals, (2) targeted subjects who were intubated as the study population, (3) compared positive-pressure and suctioning techniques, and (4) investigated postextubation complications as outcomes. Reviews, editorials, conference articles, comments, stand-alone abstracts, and nonhuman studies were excluded and considered to be beyond the scope of this review.

Search Strategy

The Medical Literature Analysis and Retrieval System Online (PubMed), Excerpta Medica Database (EMBASE), Cochrane Central Register of Controlled Trials, Web of Science, and Google Scholar databases were searched without language restriction from databases' inception to July 7, 2022. The following search terms were used: (extubat* or trachea* or endotrachea* or cuff or deflat*) and (positive or pressur* or inflat* or cough) and (suction* or aspirat*). A detailed description of the search strategy for each database is provided in Appendix 1 (see the supplementary materials at http://www.rcjournal.com).

Study Selection

Two authors (KS and RI) independently conducted a comprehensive literature screening by using EndNote (Clarivate Analytics, Philadelphia, PA and London, UK) and Rayyan (Rayyan Systems Inc., Cambridge, MA). The reference lists of the included articles were also screened for additional eligible studies. In the case of discrepancies, consensus was reached through discussion with a third reviewer (MI). In cases in which it was not clear whether the study was eligible for inclusion in this review or when the study did not report sufficient data, we contacted the corresponding authors for clarification.

Data Extraction

We extracted data on the characteristics of the studies (publication year and country, study design and setting, and inclusion and exclusion criteria), participant characteristics (age, sex, and complications), interventions (positive-pressure and suctioning technique definitions), and postextubation complications (desaturation, airway obstruction, pneumonia, aspiration, atelectasis, and re-intubation).

Risk of Bias Assessment

Two of us (KS and RI) independently assessed the risk of bias in the evaluated RCTs by using the Cochrane Risk of Bias tool.[15,16] The studies were rated as having a low risk of bias, some concerns with regard to bias, or a high risk of bias across the following domains: the randomization process, departures from the intended intervention, missing outcome data, outcome measurements, and selection of the reported results. The overall risk of bias was rated as high when one or more of the evaluated domains was rated as high risk and was rated as low when all domains were rated as low risk. Any disagreements were resolved through discussion. Similarly, the Cochrane Risk of Bias tool was used to assess the risk of bias of non-randomized controlled studies or observational studies.[17] The overall risk of bias was rated as low risk of bias, moderate risk of bias, serious risk of bias, critical risk of bias, and no information. We used the Risk-of-Bias VISualization tool to create risk of bias plots.[18]

Results

Study Selection

The study selection process is summarized in Figure 1. After the screening process, 18 of the 4,267 identified studies were considered potential candidates for inclusion in the systematic review.[7,10,11,19-33] Five studies were excluded because they were surveys on extubation techniques or airway management.[10,11,19-21] In addition, 6 studies were excluded because they did not compare positive-pressure and suctioning techniques.[22-27] A total of 7 studies, 6 RCTs[7,28-32] and 1 non-randomized controlled study,[33] were finally included in the systematic review.

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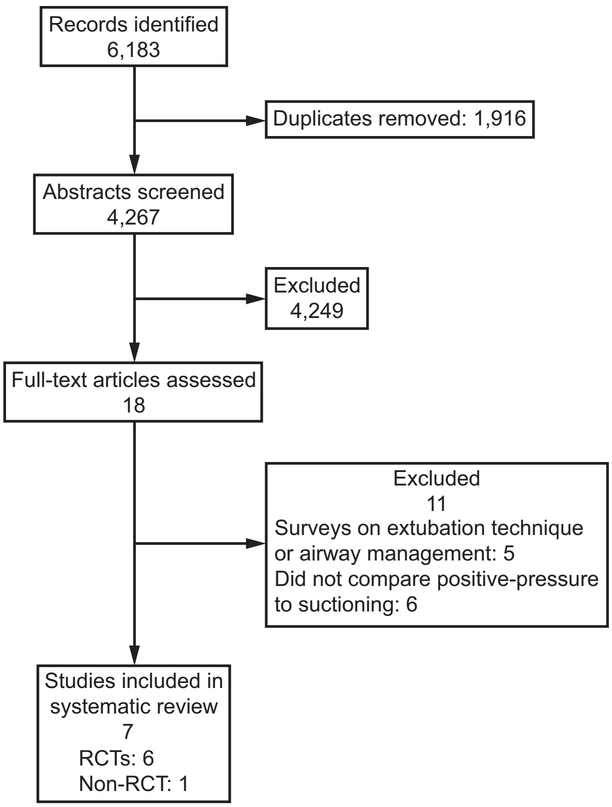

Fig. 1. Flow chart. RCT = randomized controlled trial.

Study Characteristics

These 7 studies included 1,575 subjects; 762 and 813 subjects were treated with the positive-pressure and suctioning techniques, respectively (Table 1). One of the studies was conducted in an operating room in Switzerland (Keller[28] [$N = 70$, adult population]) and 2 were conducted in operating rooms in France (Guglielminotti et al[29] [$N = 120$, pediatric population] and L'Hermite et al[30] [$N = 68$, adult population]). The other 4 studies were conducted in ICUs in Argentina (Andreu et al[31] [$N = 240$, adult population] and Andreu et al[7] [$N = 725$, adult population]) and Iran (Yousefshahi et al[33] [$N = 252$, adult population] and Farhadi et al[32] [$N = 100$, neonate population]).

Interventions

With regard to the definition of the applied positive-pressure technique, the cuff was deflated and subjects were extubated immediately after manual inflation of the lungs in the studies by Keller,[28] Guglielminotti et al,[29] and L'Hermite et al,[30] and there was no mention of a specific pressure value. In the 4 studies conducted by Yousefshahi et al,[33] Andreu et al,[7,31] and Farhadi et al,[32] the cuff was deflated and subjects were extubated under mechanically controlled pressure (with an inspiratory pressure of 20 cm H_2O and a PEEP of 15 cm H_2O in the study by Yousefshahi et al,[33] an inspiratory pressure of 15 cm H_2O and a PEEP of 10 cm H_2O in the 2 studies by Andreu et al,[7,31] and a T-piece resuscitator adjusted by adjusting the PEEP valve to 5 cm H_2O in the study by Farhadi et al[32]). With regard to the suctioning techniques, there was no difference among the studies.

Outcomes

The outcomes of the included studies are shown in Table 2.

Desaturation and P_{aO_2}/F_{IO_2}. The definitions of oxygen desaturation after extubation were as follows: an S_{pO_2} of <92% within 5 min in the study by Guglielminotti et al,[29] S_{pO_2} of ≤92% within 10 min in the study by L'Hermite et al,[30] and S_{pO_2} of < 90% or a 4% decrease in S_{pO_2} relative to the pre-extubation value within 15 min in the studies by Andreu et al.[7,31] In the studies by Andreu et al,[7,31] F_{IO_2} after extubation was adjusted to be the same as that before extubation, whereas in the other studies, the F_{IO_2} before extubation was 1.0, with no oxygen administered after extubation. Yousefshahi et al[33] did not assess oxygen desaturation but rather assessed the $P_{aO_2}/F_{IO_2} < 150$ mm Hg at several points in time.

The pediatric study by Guglielminotti et al[29] and the adult studies by Andreu et al[7,31] showed a lower incidence of early desaturation in the positive-pressure technique group than in the suctioning technique group (Guglielminotti et al[29] 45.8% vs 65.6%, Andreu et al[7,31] 22.5% vs 25.0% and 20.4% vs 24.6%), whereas the adult study by L'Hermite et al[30] showed a higher incidence of early desaturation in the positive-pressure technique group than in the suctioning technique group (48.5% vs 42.9%). The incidence of the $P_{aO_2}/F_{IO_2} < 150$ mm Hg was lower in the positive-pressure technique group than in the suctioning technique group closer to the time from extubation (0% vs 4.6% at 1 h after extubation and 0% vs 6.3% at 4 h after extubation), whereas the difference almost disappeared further from the time of extubation (10.5% vs 9.8% at 12 h after extubation).

Airway Obstruction. Andreu et al[7,31] showed a lower incidence of airway obstruction in the positive-pressure technique group than in the suctioning technique group (5.8% vs 13.3%[31] and 4.9% vs 5.6%[7]), whereas L'Hermite et al[30] showed the opposite result (3.0% vs .0%).

Pneumonia. Andreu et al[7,31] also showed a slightly lower incidence of pneumonia in the positive-pressure technique group than in the suctioning technique group (2.5% vs 6.7%[31] and 6.0 vs 6.7%[7]).

Aspiration. Aspiration was assessed by Keller[28] by using radiographs with a contrast agent, and the risk of aspiration was lower in the positive-pressure technique group than in

Table 1. Characteristics of the included studies for evaluating aspiration with a radiograph that uses contrast agents*

Study	Year	Country	Study Type	Setting	Age, mean ± SD: PPT	Age, mean ± SD: ST	Males, *n* (%): PPT	Males, *n* (%): ST	Total Sample Size, *N*	PPT		ST		Other Subject Characteristics
										n	Method	*n*	Method	
Keller[28]	1987	Switzerland	RCT	Operating room	34 ± 13 y*; 40 ± 16 y†	40 ± 13 y*; 39 ± 15 y†	NA	NA	70	35	Manual inflation	35	Negative pressure via a suction catheter	Adults (≥20 and ≤60 y), ASA-PS I–II, general or orthopedic surgeries with general anesthesia
Guglielminotti et al[29]	1998	France	RCT	Operating room	5.4 y	5.2 y	NA	NA	120	59	Manual inflation	61	Negative pressure via a suction catheter (–150 mm Hg)	Children, ASA-PS I–III, elective surgery with general anesthesia
Yousefshahi et al[33]	2012	Iran	Non-randomized	ICU	59.1 ± 10.1 y	61 ± 8.9 y	74 (75.5)	113 (73.4)	252	98	Mechanical inflation (inspiratory pressure of 20 cm H_2O and PEEP 15 cm H_2O)	154	Negative pressure via a suction catheter	After on-pump CABG without any co-surgery, intubated in the operating room
L'Hermite et al[30]	2018	France	RCT	Operating room	58 ± 9 y	56 ± 10 y	19 (57.6)	19 (54.3)	68	33	Manual inflation	35	Negative pressure via a suction catheter	Adults (> 18 and < 65 y), ASA-PS I–II, elective orthopedic surgery
Andreu et al[31]	2019	Argentina	RCT	ICU	55.5 (40–70) y‡	58 (36.5–72) y‡	70 (57.5)	82 (65.8)	240	120	Mechanical inflation (inspiratory pressure of 15 cm H_2O and PEEP 10 cm H_2O)	120	Negative pressure via a suction catheter	Adults (>18 y)
Andreu et al[7]	2022	Argentina	RCT	ICU	64 (52.0–74.0) y‡	63 (51.0–73.2) y‡	221 (60.2)	224 (62.6)	725	367	Mechanical inflation (inspiratory pressure of 15 cm H_2O and PEEP 10 cm H_2O)	358	Negative pressure via a suction catheter	Adults (>18 y)

(Continued)

Table 1. Continued

Study	Year	Country	Study Type	Setting	Age, mean ± SD: PPT	Age, mean ± SD: ST	Males, *n* (%): PPT	Males, *n* (%): ST	Total Sample Size, *N*	PPT		ST		Other Subject Characteristics
										n	Method	*n*	Method	
Farhadi et al[32]	2022	Iran	RCT	ICU	13.0 ± 0.8 d	13.6 ± 10.8 d	30 (60.0%)	32 (64.0)	100	50	Mechanical inflation (PEEP 5 cm H_2O)	50	Negative pressure via a suction catheter (−100 mm Hg)	Neonates, under mechanical ventilation for at least 24 h

* For evaluating aspiration with x-ray that uses contrast agents.
† For evaluating partial pressure of arterial oxygen.
‡ Median (interquartile range).
PPT = positive-pressure technique
ST = suctioning technique
RCT = randomized controlled trial
NA = not available
ASA-PS = American Society of Anesthesiologists Physical Status
CABG = coronary artery bypass grafting

the suctioning technique group (5.0% vs 10.0%). However, this study only included 40 subjects for this outcome and, therefore, was limited in terms of statistical power.

Atelectasis. Farhadi et al[32] assessed atelectasis in neonates by using a radiograph taken 24 h after extubation and found that the risk of atelectasis was ~50% lower in the positive-pressure technique group than in the suctioning technique group (24.0% vs 46.0%). In this study, a radiologist and a neonatologist who were not aware of the intervention allocation made diagnoses based on the evidence of a new post-extubation pulmonary collapse instead of a pre-extubation chest radiograph.

Re-intubation. Andreu et al[7,31] and Farhadi et al[32] showed a higher risk of re-intubation in the positive-pressure technique group than in the suctioning technique group (Andreu et al[7,31] 12.5% vs 14.2% and 13.1% vs 14.2%, and Farhadi et al[32] 6.0% vs 20.0%), whereas L'Hermite et al[30] showed no difference in the incidence (.0% vs .0%).

Risk of Bias

The risk of bias assessment is presented in Figures 2 and 3. In the overall assessment of RCTs, 3 studies (Keller,[28] Guglielminotti et al,[29] and L'Hermite et al[30]) showed a high risk of bias mainly because the allocation was not concealed until just before the participants were assigned to the intervention and because the measurement of the study outcomes was not blinded. One study (Andreu et al[31]) showed some concerns in that the allocation sequence was not well explained. Two studies (Andreu et al[7] and Farhadi et al[32]) had a low risk of bias. In the overall assessment of non-randomized controlled study, 1 study (Yousefshahi et al[33]) showed a serious risk of bias because outcome assessors were aware of the allocation of the interventions and the primary outcome was not defined.

Discussion

This systematic review summarizes the incidence of postextubation complications for the positive-pressure and suctioning techniques. All the included studies (except 1 RCT, by L'Hermite et al[30]) showed that the positive-pressure technique tended to have a lower risk of complications, including desaturation, airway obstruction, pneumonia, aspiration, atelectasis, and re-intubation, than the suctioning technique.

The following trends were observed. In the studies conducted among adults (Keller,[28] Yousefshahi et al,[33] L'Hermite et al,[30] and Andreu et al[7,31]), only small differences in the incidence of complications were observed and the results varied from study to study. Conversely, in studies conducted among children or neonates (Guglielminotti et al[29] and Farhadi et

Table 2. Outcomes of the included studies

Study	Year	Intervention, n		Desaturation, n (%)		Airway Obstruction, n (%)		Pneumonia, n (%)		Aspiration, n (%)		Atelectasis, n (%)		Re-intubation, n (%)	
		PPT	ST	PPT	ST	PPT	ST	PPT	ST	PPT	ST	PPT	ST	PPT	ST
Keller[28]	1987	20[*]	20[*]	NA	NA	NA	NA	NA	NA	1 (5.0)	2 (10.0)	NA	NA	NA	NA
		15[†]	15[†]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Guglielminotti et al[29]	1998	59	61	27 (45.8)	40 (65.6)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yousefshahi et al[33]	2012	98	154	0 (0.0)[‡]	7 (4.6)[‡]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
L'Hermite et al[30]	2018	33	35	16 (48.5)	15 (42.9)	1 (3.0)	0 (0)	NA	NA	NA	NA	NA	NA	0 (0)	0 (0)
Andreu et al[31]	2019	120	120	27 (22.5)	30 (25.0)	7 (5.8)	16 (13.3)	3 (2.5)	8 (6.7)	NA	NA	NA	NA	15 (12.5)	17 (14.2)
Andreu et al[7]	2022	367	358	75 (20.4)	88 (24.6)	18 (4.9)	20 (5.6)	22 (6.0)	24 (6.7)	NA	NA	NA	NA	48 (13.1)	51 (14.2)
Farhadi et al[32]	2022	50	50	NA	NA	NA	NA	NA	NA	NA	NA	12 (24.0)	23 (46.0)	3 (6.0)	10 (20.0)

* For evaluating aspiration with a radiograph that uses contrast agents.
† For evaluating partial pressure of arterial oxygen.
‡ P_{aO_2}/F_{IO_2} < 150 mm Hg at 1 h after extubation.
PPT = positive-pressure technique
ST = suctioning technique

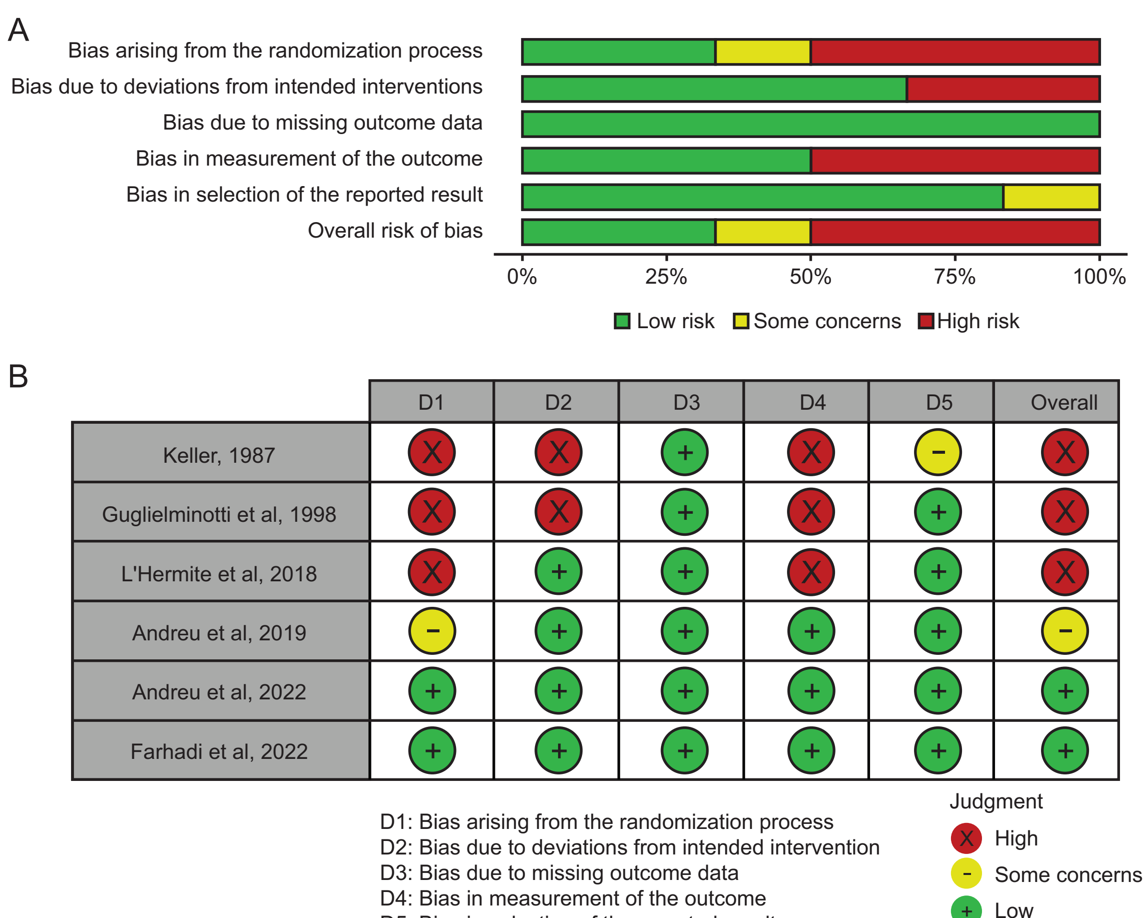

Fig. 2. Risk of bias of the included randomized controlled trials.

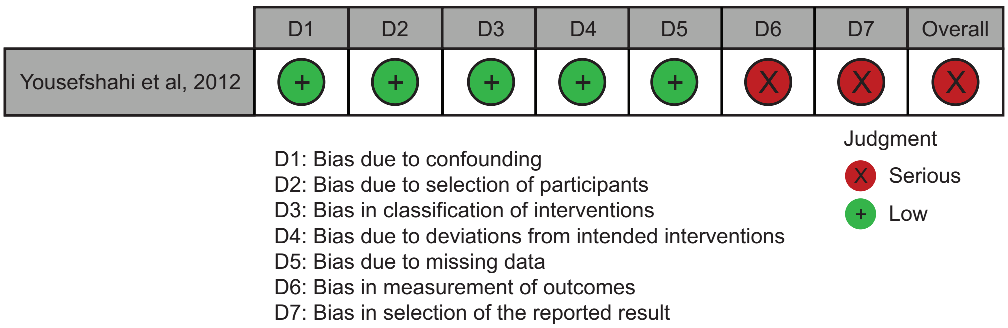

Fig. 3. Risk of bias of the included non-randomized controlled study.

al[32]), there were fewer complications of early desaturation, atelectasis, and re-intubation in the positive-pressure technique group than in the suctioning technique group, and the difference between the 2 groups tended to be larger than that in the studies conducted among adults.

These trends suggest that the lung and airway protective effects of the positive-pressure technique in children or neonates are greater than those in adults. Some studies showed that endotracheal suctioning under oxygen administration can cause atelectasis,[34] and the suctioning technique has a limited effect in reducing aspiration.[12] In contrast, lung inflation owing to positive pressure was shown to improve atelectasis, and positive pressure itself as well as coughing caused by the inflation may prevent the aspiration of secretions on the cuff.[12] Because vital capacity is small in children and neonates,[35] these factors may have a greater impact in children and neonates than in adults. The trends observed in this review can be explained to some extent as described above. Future studies that compare the 2 extubation techniques are warranted and should focus on age-related differences.

In recent years, because of the unique risks associated with the COVID-19 pandemic, new techniques have been explored to minimize aerosolization and droplet expulsion from patients during extubation. Two techniques have been reported: the mask-over tube extubation technique (covering the patient's face with a face mask with an airway filter after extubation)[36] and the deep extubation technique (extubation under deep anesthesia).[37] Although new extubation methods have been proposed, the comparison of conventional extubation methods provided in this systematic review is important both in its own right and for future comparisons between new and conventional extubation methods.

This study had some limitations. First, 4[28-30] of the 7 studies[7,28-33] included in the systematic review had a high or serious risk of bias. Because 3[28-30] of these high or serious risk studies were conducted in the operating room, the results with regard to extubation in the operating room should be interpreted carefully. Second, although almost no difference was noted in the suctioning technique used among all studies, differences were noted in the positive-pressure technique between the operating room[28-30] and ICU studies.[7,31-33] Namely, as positive-pressure technique, manual inflation was used in the operating room studies[28-30] and mechanical PEEP was used in the ICU studies.[7,31-33]. Because there have been no studies that compared differences between these positive-pressure techniques, it remains unknown whether they can be treated as the same techniques. Third, 7 studies included 1,575 subjects; however, more than half of the subjects were from the same institution.[7,31] Therefore, the external validity of our results needs to be proved in future studies. Finally, although a previous study reported the efficacy of a specially designed endotracheal tube for the aspiration of subglottic secretions in ventilator-associated pneumonia,[38] none of the studies included in the current systematic review mentioned the use of these endotracheal tubes. Thus, the results of our review may not be applicable to patients managed with such endotracheal tubes.

Conclusions

We summarized the currently available studies that compared postextubation complications in subjects managed with the positive-pressure and suctioning techniques. Further high-quality studies with a robust study design and large sample sizes are warranted.

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REFERENCES

1. Artime CA, Hagberg CA. Tracheal extubation. Respir Care 2014;59 (6):991-1002; discussion 1002-1005.
2. Difficult Airway Society Extubation Guidelines Group; Popat M, Mitchell V, Dravid R, Patel A, Swampillai C, Higgs A. Difficult Airway Society guidelines for the management of tracheal extubation. Anaesthesia 2012;67(3):318-340.
3. Dhillon RS, Rowin WA, Humphries RS, Kevin K, Ward JD, Phan TD, et al; Clinical Aerosolisation Study Group. Aerosolisation during tracheal intubation and extubation in an operating theatre setting. Anaesthesia 2021;76(2):182-188.

4. Cook TM, Scott S, Mihai R. Litigation related to airway and respiratory complications of anaesthesia: an analysis of claims against the NHS in England 1995–2007. Anaesthesia 2010;65(6):556-563.
5. Epstein RH, Dexter F, Lopez MG, Ehrenfeld JM. Anesthesiologist staffing considerations consequent to the temporal distribution of hypoxemic episodes in the postanesthesia care unit. Anesth Analg 2014;119(6):1322-1333.
6. Torrini F, Gendreau S, Morel J, Carteaux G, Thille AW, Antonelli M, Dessap AM. Prediction of extubation outcome in critically ill patients: a systematic review and meta-analysis. Crit Care 2021;25(1):391.
7. Andreu M, Bertozzi M, Bezzi M, Borello S, Castro D, Giorgio VD, Aguirre M. Comparison of two extubation techniques in critically ill adult subjects: the ExtubAR randomized clinical trial. Respir Care 2022;67(1):76-86.
8. Zhu Q, Huang Z, Ma Q, Wu Z, Kang Y, Zhang M, et al. Supine versus semi-Fowler's positions for tracheal extubation in abdominal surgery-a randomized clinical trial. BMC Anesthesiol 2020;20(1):185.
9. Kim SH, Kim YS, Kim S, Jung KT. Dexmedetomidine decreased the post-thyroidectomy bleeding by reducing cough and emergence agitation - a randomized, double-blind, controlled study. BMC Anesthesiol 2021;21(1):113.
10. Hodd J, Doyle A, Carter J, Albarran J, Young P. Extubation in intensive care units in the UK: an online survey. Nurs Crit Care 2010;15(6):281-284.
11. Andreu MF, Bezzi M, Pedace P, Fredes M, Salvati I, Leoz A, Aguirre M. Survey on the extubation procedure in intensive care units in Buenos Aires. Argentina. Rev Bras Ter Intensiva 2019;31(2):180-185.
12. Hodd J, Doyle A, Carter J, Albarran J, Young P. Increasing positive end expiratory pressure at extubation reduces subglottic secretion aspiration in a bench-top model. Nurs Crit Care 2010;15(5):257-261.
13. Andreu MF, Salvati IG, Donnianni MC, Ibañez B, Cotignola M, Bezzi M. Effect of applying positive pressure with or without endotracheal suctioning during extubation: a laboratory study. Respir Care 2014;59(12):1905-1911.
14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
15. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction - GRADE evidence profiles and summary of findings tables. J Clin Epidemiol 2011;64(4):383-394.
16. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928.
17. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919.
18. McGuinness LA, Higgins JPT. Risk-of-bias VISualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods 2021;12(1):55-61.
19. Swartz K, Noonan DM, Edwards-Beckett J. A national survey of endotracheal suctioning techniques in the pediatric population. Heart Lung 1996;25(1):52-60.
20. Sole ML, Byers JF, Ludy JE, Zhang Y, Banta CM, Brummel K. A multisite survey of suctioning techniques and airway management practices. Am J Crit Care 2003;12(3):220-230; quiz 231-232.
21. Rose L, Redl L. Survey of cuff management practices in intensive care units in Australia and New Zealand. Am J Crit Care 2008;17(5):428-435.
22. Whiffler K, Andrew WK, Thomas RG. The hazardous cuffed endotracheal tube–aspiration and extubation. S Afr Med J 1982;61(7):240-241.
23. Cho JD, Park SS. Continuous positive airway pressure improves the immediate post-extubation airway patency. Korean J Anesthesiol 2009;57(4):450-454.
24. Lai H-C, Pao S-I, Huang Y-S, Chan S-M, Lin B-F, Wu Z-F. The relationship between postoperative pneumonia and endotracheal suctioning under general anesthesia in ophthalmic surgery: a retrospective study. Asian J Anesthesiol 2018;56(1):33-38.
25. Coutinho WM, Vieira PJC, Kutchak FM, Dias AS, Rieder MM, Forgiarini LA, Jr. Comparison of mechanical insufflation-exsufflation and endotracheal suctioning in mechanically ventilated patients: effects on respiratory mechanics, hemodynamics, and volume of secretions. Indian J Crit Care Med 2018;22(7):485-490.
26. Abdel-Ghaffar HS, Youseff HA, Abdelal FA, Osman MA, Sayed JA, Riad MAF, Abdel-Rady MM. Post-extubation continuous positive airway pressure improves oxygenation after pediatric laparoscopic surgery: a randomized controlled trial. Acta Anaesthesiol Scand 2019;63(5):620-629.
27. Liu S, Ye Z, Zou H, Mei C, Hu Z, Xu W. Comparison of positive and negative pressure extubation after mechanical ventilation in intensive care unit patients. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue 2022;34(3):265-268.
28. Keller UM. Aspiration and hypoxia after extubation. Anaesthesist 1987;36(1):39-45.
29. Guglielminotti J, Constant I, Murat I. Evaluation of routine tracheal extubation in children: inflating or suctioning technique? Br J Anaesth 1998;81(5):692-695.
30. L'Hermite J, Wira O, Castelli C, de La Coussaye J-E, Ripart J, Cuvillon P. Tracheal extubation with suction vs. positive pressure during emergence from general anaesthesia in adults: a randomised controlled trial. Anaesth Crit Care Pain Med 2018;37(2):147-153.
31. Andreu MF, Dotta ME, Bezzi MG, Borello S, Cardoso GP, Dib PC, et al. Safety of positive pressure extubation technique. Respir Care 2019;64(8):899-907.
32. Farhadi R, Nakhshab M, Hojjati A, Khademloo M. Positive versus negative pressure during removal of endotracheal-tube on prevention of post-extubation atelectasis in ventilated neonates: a randomized controlled trial. Ann Med Surg (Lond) 2022;76:103573.
33. Yousefshahi F, Barkhordari K, Movafegh A, Tavakoli V, Paknejad O, Bina P, et al. A new method for extubation: comparison between conventional and new methods. J Tehran Heart Cent 2012;7(3):121-127.
34. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol 2010;24(2):157-169.
35. Kivastik J. Paediatric reference values for spirometry. Clin Physiol 1998;18(6):489-497.
36. D'Silva DF, McCulloch TJ, Lim JS, Smith SS, Carayannis D. Extubation of patients with COVID-19. Br J Anaesth 2020;125(1):e192-e195.
37. Juang J, Cordoba M, Xiao M, Ciaramella A, Goldfarb J, Bayter JE, Macias AA. Post-anesthesia care unit desaturation in adult deep extubation patients. BMC Res Notes 2021;14(1):149.
38. American Thoracic Society, Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med 2005;171(4):388-416.