SYSTEMATIC REVIEW

Comparison of Closed vs Open Suction in Prevention of Ventilator-associated Pneumonia: A Systematic Review and Meta-analysis

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Abstract

Introduction: Ventilator-associated events (VAEs) are one of the main sources of concern in critically ill patients due to the high frequency and mortality. We conducted this analysis to compare the effects of open endotracheal suctioning system with closed one on the incidences of VAEs in adult patients receiving mechanical ventilation (MV).

Materials and methods: A comprehensive literature search was performed in PubMed, Scopus, Cochrane Library, and hand searching bibliographies of retrieved articles. The search was confined to randomized controlled trials with human adults comparing closed tracheal suction systems (CTSS) vs open tracheal suction systems (OTSS) in prevention of ventilator-associated pneumonia (VAP). Full-text articles were used in order to extract the data. Data extraction was only started after completing the quality assessment.

Results: The search resulted in 59 publications. Among them, 10 were identified as eligible for meta-analysis. There was a significant increase in incidence of VAP when using OTSS compared to CTSS, so that OCSS increased the incidence of VAP by 57% (OR 1.57, 95% CI 1.063–2.32, $p = 0.02$).

Discussion: Our results showed that using CTSS can significantly decrease VAP development compared to OTSS. This conclusion does not yet mean the routine use of CTSS as a standard VAP prevention measure for all patients since individual patient's disease and cost are other factors that should be in mind when determining the choice of the suctioning system. High-quality trials with a larger sample size are highly recommended.

Keywords: Closed, Prevention, Suction, Ventilator-associated pneumonia.

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Highlights

Ten clinical trials were identified in this systematic review and meta-analysis regarding comparison of CTSS vs OTSS. All the included studies had high or unknown risk of bias regarding blinding of participants and outcomes. This meta-analysis has shown that using CTSS can significantly decrease VAP development compared to OTSS.

Introduction

Ventilator-associated pneumonia is one of the most serious and common infections in critically ill patients under MV. Its incidence differs between almost 5 and 50% in mechanically ventilated patients.[1–4] As VAP increases the morbidity [intensive care unit (ICU) length of stay, duration of MV, and hospital stay] and mortality, its prevention seems an essential step in the management of mechanically ventilated patients.[5–7] Based on VAP prevention bundle, suctioning has an important role in the pathogenesis of VAP.[8] Endotracheal suctioning is routinely performed in mechanically ventilated patients to clear secretions. Currently, there are two different types of suctioning systems. Closed tracheal suction systems which employ multiuse suctioning catheters and let endotracheal suctioning without disconnecting of patient from the ventilator resulting in decreased contamination, maintenance of positive pressure ventilation, and oxygenation.[9–11] It seems that during OTSS, the ventilator is disconnected which together with the negative vacuum pressure and fewer physiologic disturbances during suctioning like increased heart rate and mean arterial pressure, and decreased arterial deoxygenation lead to intense loss of lung volume and subsequent hypoxemia. Previous systematic reviews could not reach such a strong evidence regarding the priority of each intervention on VAP because of underreporting, low quality of the included trials (low sample size of trials and a potential for publication bias), and incomplete data sets of included studies.[12–17] Based on the lack of data in this field, we performed a systematic

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review and meta-analysis to reevaluate the efficacy of CTSS use compared to OTSS use in prevention of VAP in mechanically ventilated adult patients.

Materials and Methods

A comprehensive literature search was performed in PubMed, Scopus, Cochrane Library, and hand searching bibliographies of retrieved articles. ProQuest was searched to achieve additional grey literature. For the Cochrane Library, the Database of Systematic Reviews, the database of abstracts of reviews of effects (DARE), and the Cochrane central register of controlled trials (CENTRAL) were searched. The following keywords were used: VAP, "ventilator associated pneumonia", "ventilator associated events", "open suction", and "closed suction". The search was confined to randomized controlled trials (RCTs) with human adults that were published after 2000 and in English language. The latest search was performed in June 2020.

Our primary research question was to make a comparison of CTSS vs OTSS in prevention of VAP. For this reason, we searched for clinical trials investigating the onset of VAP in OTSS and CTSS. We used a broad inclusion strategy to achieve the maximum sensitivity. The inclusion criteria were as the following: (1) Clinical studies published up to June 2020; (2) Articles with available data about onset of VAP in CTSS and/or OTSS. Final inclusion of the studies was determined by two reviewers who were independently making the final decision on inclusion of the studies. For studies reported in more than one publication, data abstraction was performed using all publications; however, we included just one report in our study. The studies meeting the following criteria were excluded: (1) Review articles, case reports, and conference abstracts; (2) The animal studies; (3) Original articles not containing data on onset of VAP in CTSS and/or OTSS; (4) Articles that were inaccessible after two times of mailing for paper request from the corresponding author; (5) Articles with unclear data description; (6) Duplicate reports; (7) Not randomized articles; (8) Articles before year 2000. Furthermore, the randomization procedure was critically appraised. To prevent manipulation of the allocation process, the method of assigning the patients to either CTSS or OTSS should be adequately concealed for both patient and clinician (healthcare worker). This method was judged by two reviewers without masking of author or source, using four ratings for quality of allocation concealment: (A) Adequate concealment of the allocation; (B) Uncertainty about adequate concealment of allocation; (C) Allocation definitely not adequately concealed; (D) Allocation concealment not used. Discrepancies in ratings were resolved through discussion between reviewers. No additional information was sought from the original authors. Reporting quality assessment of included articles was performed according to the consolidated standards of reporting trials (CONSORT). The CONSORT statement is used worldwide to improve the reporting of RCTs.[18] We considered studies with 10 points or more as studies with moderate to good study quality. However, all the selected studies were included in the systematic review, regardless of their score. Additionally, Cochrane Risk of Bias 2 (RoB2) tool in RevMan 5.3 was used to assess the final included studies. Three authors assessed the quality of each article independently. In the times of disagreement, the final decision was made consulting with two other authors. Data extraction was only started after completing the reporting quality and risk of bias assessment. Full text articles were used in order to extract the data. Two authors independently performed the data extraction from text and tables. The authors of the original studies were contacted in case of lacking essential data in the text.

Data Analysis

From each study, data were extracted on the outcomes measured. The synthesis of data was performed using random effect models. To assess heterogeneity of treatment effects across the studies, I^2 statistic was computed in Review Manager (version 5.3). I^2 is derived from Cochrane's Q statistic. It measures the extent of inconsistency among the studies' results, and the outcome is interpreted as the percentage of total variation across studies that is due to heterogeneity rather than chance.[19] A value of 0% indicates that all variability in effect estimates is due to chance and that none is due to heterogeneity. Larger values show that most of the variability is due to heterogeneity rather than chance.

Results

The search resulted in 59 publications. Forty articles were excluded at first screening based on their titles and abstracts because they met the exclusion criteria such as irrelevant purposes, unclear indicators, review articles, case reports, conference abstracts, and animal models. Full texts of the remaining 19 potentially related studies were obtained. Five studies were excluded because of not meeting the inclusion criteria and the remaining 14 studies, after removing four articles due to not being randomized, 10 were included for this systematic review and meta-analysis. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart of the study is shown in Flowchart 1. Study characteristics and results of the nine studies that are included in the systematic review are summarized in Table 1. Risk of bias assessment of included studies based on the Cochrane RoB2 tool in RevMan 5.3 for RCTs are summarized in Figure 1. All the included articles had risk of bias regarding not being blind both for participants and outcomes.

Heterogeneity was tested by the heterogeneity statistic Q and quantified using I^2. Results showed almost a high heterogeneity among the studies ($I^2 = 49\%$, $p = 0.04$). Therefore, the use of random effect model in this study was correct and appropriate. That is, the studies used have been extracted from different communities. This can be observed and inferred due to the different OR values for studies in the first part of the output. The Forest plot of the study for incidence of VAP is presented in Figure 2. It shows that the incidence of VAP in CSS is significantly lower than OSS (OR: 1.57, CI 95%; 1.06–2.32, $p = 0.02$). The funnel plot is presented in Figure 3. The funnel plot can be used to check for the presence or absence of publication bias. Asymmetry will indicate the existence of diffusion biases. The symmetry of this graph indicates no diffusion bias. However, it seems that the study of Rabitsch et al. behaves relatively differently from other studies.[20] Sensitivity analysis showed that, after excluding the study by Rabitsch et al., the result from meta-analysis changed from (OR: 1.57, CI 95%; 1.06–2.32, $p = 0.02$) to (OR: 1.49, CI 95%; 1.03–2.16, $p = 0.04$), which is presented in Figure 4.

Discussion

The results of this meta-analysis showed that OTSS was associated with a significant increase (57%) in VAP frequency compared with CTSS. Previous studies have shown that CTSS tends to decrease the

Flowchart 1: Flow diagram of the study

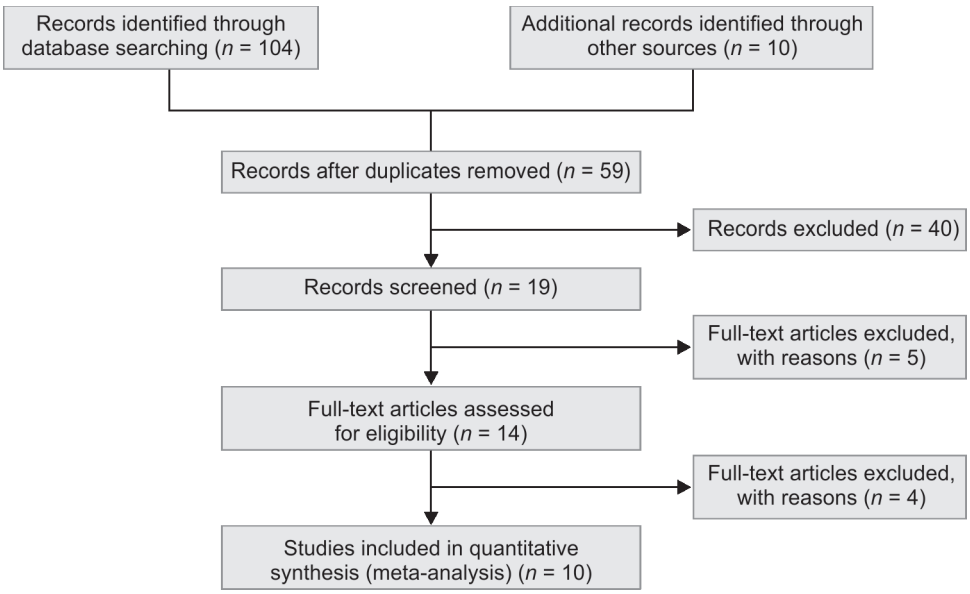

Table 1: Study characteristics and results of the included studies in the systematic review

				Sample size		*CSS*		*OSS*			
	Author	*Year*	*Study type*	*CSS*	*OSS*	*VAP*	*No VAP*	*VAP*	*No VAP*	*p-value*	*Conclusion*
1	Alipour et al.[23]	2016	Clinical trial (prospective randomized)	43	43	7	36	17	26	0.016	The incidence of VAP was significantly lower in closed method compared to the open method
2	Ardehali et al.[24]	2020	Clinical trial (prospective randomized)	60	60	10	50	22	38	0.637	There was not any significant difference between groups regarding incidence of VAP
3	Hamishekar et al.[25]	2014	Clinical trial (prospective randomized)	50	50	6	44	10	40	0.27	There was not any significant difference between groups regarding incidence of VAP
4	Combes et al.[26]	2000	Prospective randomized study	50	54	4	46	9	45	0.07	Closed suction nonsignificantly reduced incidence of VAP without any adverse effect
5	Topeli et al.[27]	2004	Prospective, randomized, controlled trial	41	37	13	28	9	28	0.47	There was no difference between the groups in terms of the frequency of development of VAP, mortality in the MICU, length of MICU stay and duration of MV
6	Rabitsch et al.[20]	2004	Prospective randomized study	12	12	0	12	5	7	0.037	CSS reduced the incidence of VAP when compared with OSS
7	David et al.[28]	2011	Open-labelled randomized controlled trial	100	100	18	82	29	71	0.07	Using the clinical criteria, the incidence of VAP was higher with OES than with CES. When tested for superiority, CES was associated with a trend to a reduced incidence of VAP (odds ratio, 1.86; 95% CI, 0.91–3.83; $p = 0.067$). The number needed to treat with CES to prevent 1 VAP was 9 (95% CI, −0.7 to 22.7)
8	Lorente et al.[29]	2005	Clinical trial (prospective randomized)	210	233	43	167	42	191	0.62	There was not any significant difference between groups regarding incidence of VAP

(Contd...)

Table 1: *(Contd...)*

				Sample size		CSS		OSS			
	Author	*Year*	*Study type*	*CSS*	*OSS*	*VAP*	*No VAP*	*VAP*	*No VAP*	*p-value*	*Conclusion*
9	Lorente et al.[30]	2006	Clinical trial (prospective randomized)	236	221	33	203	31	190	0.99	There was not any significant difference between groups regarding incidence of VAP
10	Zeitoun et al.[31]	2003	Prospective randomized study	23	24	7	16	11	13	0.278	Use of a closed suction system did not decrease the incidence of nosocomial pneumonia when compared with the open system

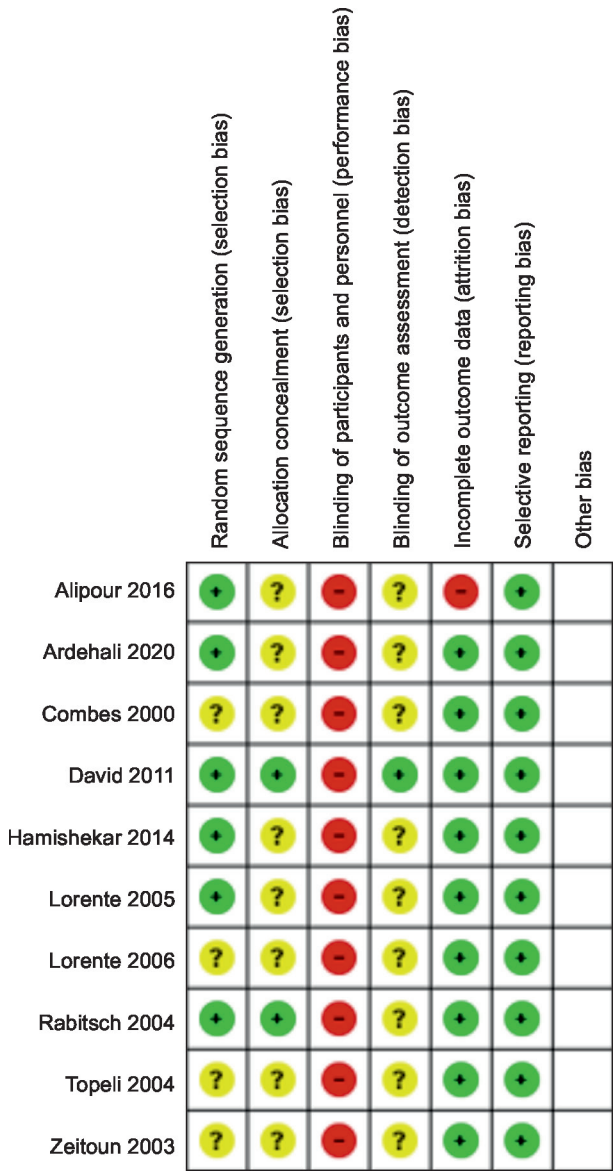

Fig. 1: Risk of bias in the included studies

development of VAP, but the insignificant results of some studies can be due to less statistical power, the different method for VAP definition, heterogeneity of samples, small trial sizes, and wide confidential interval.

In this study, all the included studies had high or unknown risk of bias regarding blinding of participants and outcomes. However, it was accepted, while the nature of these studies was not compatible with blinding since the setting of the studies was technically impossible to be blinded while the difference between CTSS and OTSS was completely obvious on the first sight.

Bacterial transfer from naso-oropharynx and gut to the lower respiratory tract in mechanically ventilated patients via endotracheal tube cuff or by direct cross contamination during nursing intervention results in VAP development.[21] It seems that CTSS as compared with OTSS prevents cross transmission of bacteria in intubated patients on MV, but previous systematic review and meta-analysis could not show a significant reduction of VAP by using CTSS.[13–17,22] The reason for these insignificant results in the previous meta-analysis can be due to different included studies. First of all, the previously published meta-analyses were mostly conducted before 2010 and therefore have included articles before 2000, which have not been included in present meta-analysis.[11,14,16,17] There was only one meta-analysis published after 2010, which had included some articles in languages other than English that are not included in the present meta-analysis. On the other hand, our meta-analysis includes the newest published articles regarding the onset of VAP in CTSS vs OTSS, which were not included in previous meta-analyses.[12] In addition, heterogeneity of the patients in included studies can contribute to the different results of the previous meta-analysis in comparison to the present study as the patients from included studies were from various kinds of ICUs such as surgical, medical, neurosurgical, and trauma and the included studies in previous meta-analyses and the current meta-analysis are different. On the other hand, there was a high possibility for false-positive respiratory tract infections among patients with CTSS in some of the trials since in these trials, the specimens for microbiological testing were not taken by a new and sterile system which increases the risk of tracheal secrete contamination from reused catheters and bias for subsequent diagnosis of pneumonia. Regarding the trials included in our systematic review and meta-analysis, they have shown different results on reduction of VAP; three of them showed a significant reduction and the other seven did not show a significant reduction of VAP.[23–31] In addition, duration of hospital or ICU stay, duration of MV, and mortality rate were other outcomes assessed in these trials which had no difference between CTSS and OTSS. In the previous guidelines, the priority for the use of either CTSS or OTSS for VAP prevention was considered as an unresolved issue. Some guidelines have favored CTSS over OTSS use for cost and safety considerations, without of a favorable evidence supporting CTSS use for the prevention of VAP.[32–35] One of the problems in

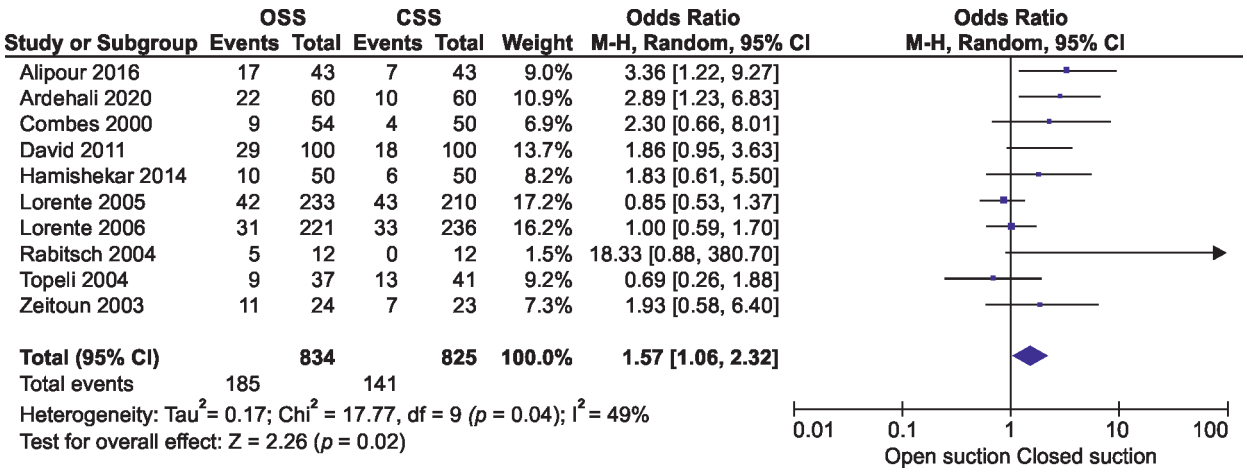

Fig. 2: Forest plot showing the results of the studies

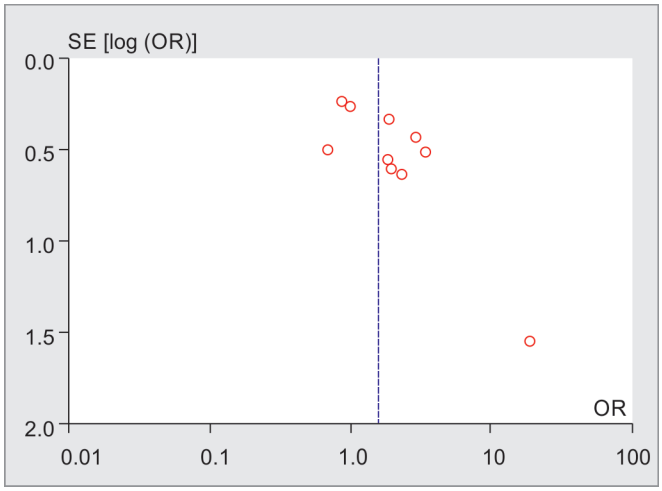

Fig. 3: Funnel plot of the study

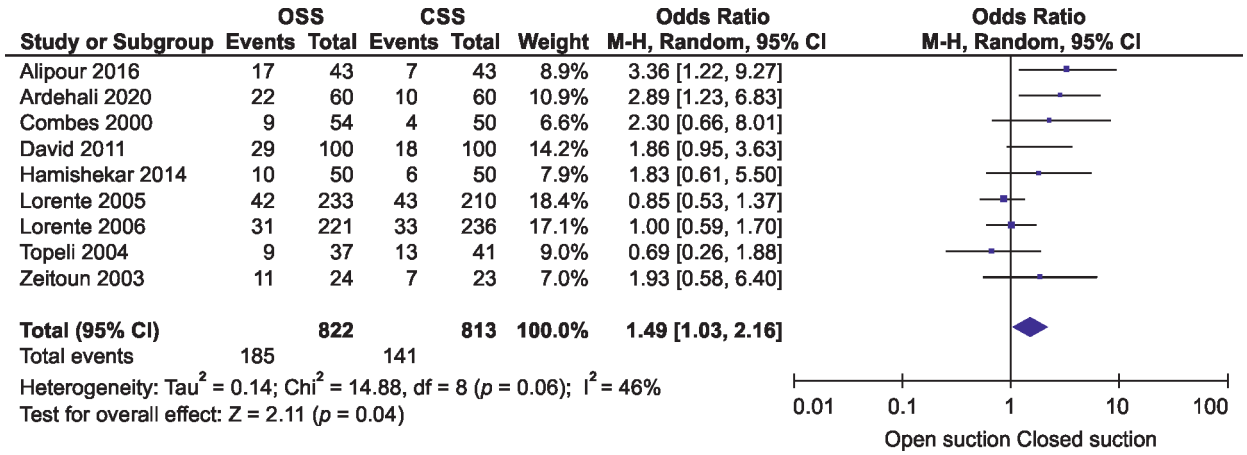

Fig. 4: Forest plot showing the results of the sensitivity analysis

performed trials was the inconsistency regarding the optimal time of CTSS exchange. As it differ from 24 to 168 hours in different studies, meta-regression analysis showed no relation between VAP development and CTSS exchange. Although most companies have recommended routine exchange of closed suction, most studies were underpowered, so there is no strong evidence to support this recommendation.[36,37]

This study has some limitations. First, patients' demographic data, study protocols including prophylactic antibiotics, oral care, time of CTSS exchange, and the risk of VAP were not uniform across

the trials. Second, we did not include non-English language trials in this meta-analysis, which can reduce the generalizability of our results. Third, nearly half of our trials lacked information on sequence generation, allocation concealment, and blinding of outcome assessors which to some extent was due to the special design nature of the studies. Finally, most of the trials had small sample size which could lead to lower power of the included studies. Thus, although the results from the current study are reliable based on their exact methodology and high overall power, future trials with larger sample size and possible solutions for blinding of participants and outcomes are needed for reaching to nonbiased results.

Conclusion

Our results showed that using CTSS can significantly decrease VAP development compared to OTSS. This conclusion does not yet mean the routine use of CTSS as a standard VAP prevention measure for all patients since individual patient's disease and cost are other factors which should be in mind when determining the choice of the suctioning system. High-quality trials with a larger sample size is highly recommended.

Authors' Contribution

AM had full access to all data in the study and took responsibility for the integrity of data and the accuracy of the data analysis. SS designed the study and analyzed the results. SR, SHS, and SJ interpreted the data and wrote the paper. AM, KS, SS, and SR performed the systematic search and checked papers methodology and bias. SJ and SHS advised on the conception and design of the study. All authors vouched for the respective data and analysis, approved the final version, and agreed to publish the manuscript.

Availability of Data and Materials: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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