Impact of Subglottic Saline Irrigation on Reducing Bacterial Contamination for Oral Surgery Patients

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This study investigated the effectiveness of subglottic irrigation (SI) with 100 mL of saline on reducing bacterial contamination in the subglottic space during oral surgery procedures without the use of throat packs. Subglottic lavage and irrigation were performed through the suction lumen located on specialized endotracheal tubes (ETTs) with capabilities of permitting evacuation from the subglottic space. Fifty-three patients who were scheduled for oral surgery procedures under general anesthesia while intubated with specialized ETTs at Kyushu Dental University Hospital were enrolled in this study. Subglottic irrigation was performed, and the sample fluid was collected through the ETT suction lumen for smear and culture bacterial examinations after 3 points in time: immediately after intubation, after completing the surgical procedure, and again after SI. Oral surgery without a throat pack significantly increased bacterial contamination in the subglottic lavage ($p < .001$), and SI decreased bacterial contamination ($p < .001$) similarly to levels found after tracheal intubation. Subglottic irrigation with 100 mL of saline was effective in reducing bacterial load in the subglottic space to levels similarly noted immediately after intubation for patients undergoing intraoral surgical procedures without the use of a throat pack.

Key Words: Subglottic irrigation; Bacterial contamination; Endotracheal tube with suction lumen.

Cuffed endotracheal tubes (ETTs) are designed to provide a tracheal seal, permit positive-pressure ventilation, and prevent the passage of fluids and other debris that may be present in the pharynx into the lungs, which could otherwise increase the risk of postoperative pneumonia (POP) following anesthesia.[1] Although the use of a cuffed ETT may not completely prevent the aspiration of fluids that have accumulated in the subglottic space, small volumes of fluids leaking around the cuff and into the lower airways are not usually a serious problem in otherwise healthy patients. However, during many intraoral surgical procedure (SXs), contamination of the subglottic space resulting from the influx of oral bacterium, surgical bleeding, dental and biological debris, oral and nasal secretions, and especially surgical irrigation fluids may be more problematic, particularly if a throat pack is not used. In these circumstances, not only is a larger volume of accumulated fluids more likely to fill the subglottic space, increasing the risk of aspiration, but those fluids may also help translocate serious pathogens with the potential for causing aspiration or POP, especially in at-risk elderly or medically compromised patients. Common causative pathogens of aspiration pneumonia have been reported as gram-positive bacteria such as *Staphylococcus aureus*, including methicillin-resistant *S aureus* (MRSA) and *Streptococcus pneumoniae*, and gram-negative bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, *Serratia*, *Proteus mirabilis*, *Hemophilus influenzae*, and *Pseudomonas aeruginosa*.[2] Although intravenous antibiotics remain widely used for reducing bacterial load during surgery[3] and proper timing of antimicrobial prophylaxis is certainly critical to reducing the risk of surgical site infections,[4] there is considerable concern regarding the overuse of antibiotics in health care settings, including dental settings.[5,6] This has prompted the evaluation of other potential options for minimizing bacterial infection risks.

Although the subglottic space is usually enclosed by the tracheal cuff during tracheal intubation (TI), ETTs with a subglottic suction lumen have been developed recently that permit intermittent or continuous drainage of the subglottic space (Figure 1). These specially

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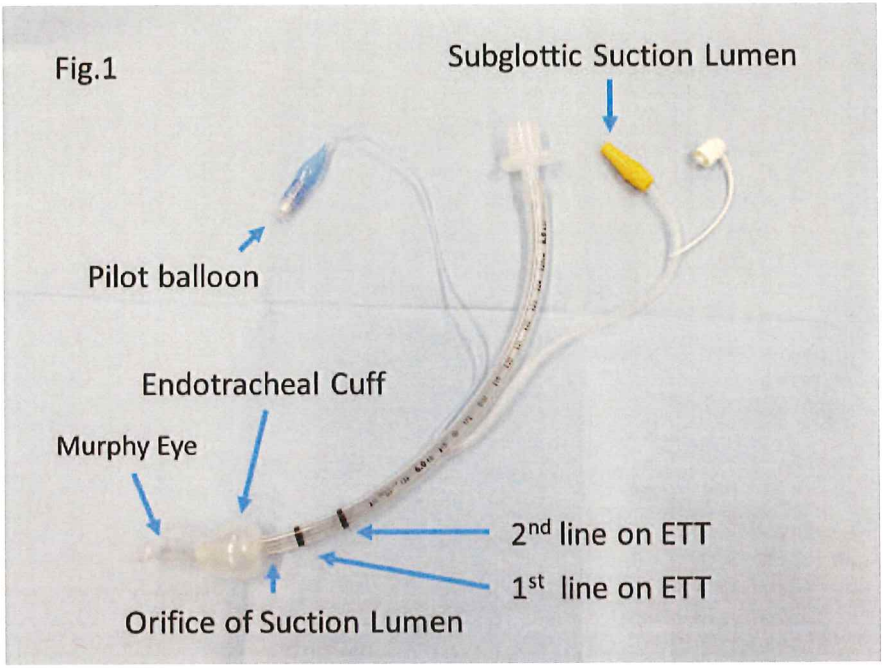

Figure 1. Specialized endotracheal tube with the suction lumen that enables collection of the lavage fluid for bacterial examination and for performing saline irrigation in the subglottic space (TaperGuard Evac Tracheal Tube, Covidien).

designed ETTs have been shown to be effective for managing intubation-related secretions and reducing the incidence of ventilator-associated pneumonia for critically ill patients in the intensive care unit.[7–10] Moreover, the ETT suction lumen also can be used to facilitate irrigation of the subglottic space, permitting delivery of a relatively large volume of irrigation fluid that can be easily and completely evacuated from the oropharyngeal space under visualization with a video laryngoscope (VLS). The use of saline irrigation may be beneficial in reducing the bacterial load of the contaminated subglottic space, which may ultimately reduce the need for additional antibiotics.

In this study, the efficacy of saline irrigation on reducing bacterial contamination of the subglottic space was investigated in intubated patients undergoing oral surgery procedures without the use of throat packs (TPs). The suction lumen on the specially designed ETTs used in this study enabled irrigation of the subglottic space with saline and collection of the lavage fluid for bacterial examination.

METHODS

This study was approved by the Kyushu Dental University Institutional Review Board (initial approval number 16-19, revised approved number 18-19, and approval number 19-13 for extension of the study period), and all participants signed an informed consent agreement prior to the start of the clinical study. Fifty-three patients who were scheduled to undergo TI for oral surgery procedures at Kyushu Dental University Hospital were enrolled in this study. The types of oral surgery procedures performed included the extraction of an impacted tooth (33 patients), excision of a cyst (5 patients), removal of rigid fixation plates (5 patients), osteotomy including 2 cases of a LeFort 1 osteotomy (5 patients), tumor resection (3 patients), resection of a bony sequestrum (3 patients), and other including duplicated surgery (4 patients). No TPs were used throughout the study. Preoperative examination was performed to exclude patients with any obvious oral and/or nasal infections. All patients included in the study presented appropriately nil per os on the day of surgery.

Intraoperative monitors, including electrocardiogram, pulse oximetry, and noninvasive blood pressure cuff, were placed once the patients were appropriately positioned on the operating table. Ringer's acetate solution with 1% glucose was infused intravenously at rate of 60–120 mL/hour for fluid maintenance. General anesthesia was induced with a propofol bolus (1.5–2 mg/kg) and continuous infusion of remifentanil (0.3–0.5 μg/kg/min). Rocuronium (0.6 mg/kg) was administered to facilitate muscle relaxation for TI while the patient was

mask ventilated with oxygen (4 L/min) and sevoflurane (2%). Nasal pretreatment was performed for patients planning to receive nasal intubation using tampons soaked in an approximately 2 mL of 0.118% tramazoline hydrochloride. A specially designed ETT with a suction lumen (TaperGuard Evac Tracheal Tube, Covidien, Dublin, Ireland; Figure 1) was used to intubate orally or nasally all patients after confirming the absence of fluids in the laryngopharynx using VLS (McGRATH MAC, Medtronic, Dublin, Ireland). Patients who were nasally intubated received the same style but smaller size ETT. Positioning of the ETT was confirmed to set the second line mark of the ETTs (9.3–10.5 mm from the tip of the tube for 6.0–7.5 I.D., respectively) at the position of vocal cords using VLS. The tracheal cuff was inflated with air until the cuff pressure reached 20 mm Hg, as confirmed by a cuff pressure gauge (Cuff Manometer, VBM, Noblesville, Ind). Following intubation, anesthesia was maintained with sevoflurane (1.5–2.0%), oxygen/air (FiO_2 50%), and a continuous infusion of remifentanil (0.1–0.2 μg/kg/min). Patients typically remained in a supine or slightly head-down position during the perioperative period.

Before the start of the SX, the oral cavity was disinfected with a povidone iodine solution 50 times diluted with distilled water, and any residual antiseptic solution in the oral cavity was completely evacuated. Cefazolin sodium (1 g) was administered intravenously before starting surgery and subsequently repeated every 3 hours during surgery in all patients as part of the standard practice for antibiotic prophylaxis.[11]

Sample Collection and Subglottic Lavage

Collection of subglottic fluid for bacterial examination was performed in the same manner throughout the study. Any residual fluid noted within the oral cavity and/or larynx, but not within the trachea, was suctioned during inspection with VLS. Correct positioning of the ETT was also confirmed. Using a sterile 5-mL syringe primed with 2 mL of sterile saline attached to the suction lumen, gentle suction was applied to confirm the existence of fluids in the subglottic space prior to saline injection. The saline (2 mL) was then slowly injected through the suction lumen and left in the subglottic space for 1 minute. The lavage was then collected through the same ETT suction lumen with a new sterile 5-mL syringe. The volume of the collected lavage was measured and transferred into a special container for bacterial examination. All collected lavage samples were refrigerated until transfer for bacterial smear and culture examinations (SRL Inc, Tokyo, Japan).

The 3 distinct time points for collecting the subglottic fluid were as follows:

1. After TI
2. After the SX
3. After subglottic irrigation (SI)

Subglottic irrigation was performed with 100 mL of sterile saline infused using an IV circuit connected to the suction lumen on the ETT. Any irrigation fluids draining superiorly from the glottic opening were completely evacuated using suction while visualizing with a VLS. Remaining irrigation fluids in the subglottic space were gently aspirated through suction lumen after SI.

Bacterial Examination

Bacterial counts in the smear examinations were done after Gram staining by microscopic inspection for the detection of cocci, bacilli, fungus, epithelium, and others and evaluated in the following 5 classifications per inspected field: (–) not detected, (<1) less than 1, (1+) 1, (2+) 2–10, and (3+) more than 11.

Bacterial culture tests were also done using blood agar, bromothymol blue, and chocolate medium for the detection of species of *Streptococcus*, *Staphylococcus*, *Pseudomonas*, *Neisseria*, *Serratia*, *Corynebacterium*, and others and evaluated in the following 5 classifications per culture: (–) not detected, (<1) less than one-third, (1+) one-third, (2+) two-thirds, and (3+) fully filled. *P aeruginosa*, *S aureus*, and MRSA were specifically confirmed to be present in the collected lavage as target bacteria by using the selected culture medium, respectively.

Statistical and Power Analysis

Statistical analysis was performed using SPSS version 25 (IBM, Tokyo, Japan). An a priori power analysis was performed based on the data from a preliminary study ($n = 24$) done to evaluate the effects of oral surgery on bacterial contamination. Using the data from that pilot study, G*Power (statistical software, version 3.1.9.4) calculated a total sample size of 31 subjects assuming a nonparametric statistical test for bacterial analysis, 2 tails, effect size 0.625 (mean difference 0.792 and SD difference 1.067) calculated by the data of the preliminary study, α error .05, and power .95. Statistical significance was reported when the probability value was less than .05.

Table 1. Patient Profiles ($N = 52$)*

Gender, male/female	17/35
Age, y	36.7 ± 18.5
Height, cm	160.4 ± 8.7
Weight, kg	55.6 ± 10.1
Surgical time, min	95.0 ± 69.2
Nasal TI (R/L)/oral TI (R/M/L)	41(22/18)/12(8/2/2)
Depth of ETT (nasal/oral), cm	28.0 ± 0.9/22.3 ± 1.2
Count of ETT (I.D. 6.0/6.5/7.0/7.5) mm	4/27/17/4
Inflation volume of cuff (nasal/oral), mL	3.7 ± 1.8/4.4 ± 1.5

* ETT depth was measured from the nares for nasal TI or from the incisors for oral TI. Values presented as number or mean ± SD. ETT indicates endotracheal tube; L, left; M, median of mandible; R, right; TI, tracheal intubation.

Values for age, height, weight, surgical time, air volume in cuff, and the length from the tip of the ETT from the incisor or external naris and other parametric values are presented as mean ± SD. Values of collected lavage volume were statistically tested using paired repeated-measures 1-way layout variance analysis and multiple comparisons with Bonferroni correction.

The proportion of positively detected materials among the 4 groups divided by the substantivity of Gram stain and bacterial form of cocci or bacilli was tested using Pearson's chi-square test.

The distribution of the bacterial classification was assessed among the 3 groups (after TI, after SX, and after SI) by nonparametric paired 2-way analysis of variance using Friedman ranking. Statistically significant differences between the 2 groups with paired samples out of the 3 groups was also assessed using Wilcoxon's signed rank test.

The relationship between bacterial counts in smear and culture examinations was confirmed using the Kendall and Spearman rank correlation coefficient. The relationship between bacterial counts in the smear examination and the duration of surgery was also assessed in the same manner.

RESULTS

Lavage samples after SI for bacterial examination were obtained successfully from the subglottic space in all cases. However, 1 patient was excluded from the analysis because of possible contamination from excess collected lavage (2.6 mL) speculated to be drawn from fluid in the oral cavity after TI. Finally, the collected lavage samples from 52 patients were analyzed for bacterial examination. The data from the profile of the subjects are presented in Table 1.

Subglottic contents were not taken through the suction lumen after TI in all cases. Collected lavage from the subglottic space was 1.8 ± 0.2 mL (recovery rate 90%) after TI, increasing to 2.2 ± 0.8 mL after SX compared with after TI (110%, $p < .001$), and returning to 1.8 ± 0.3 mL after SI compared with after TI (90%, $p \geq .05$).

Gram-positive cocci were detected in 16 of 52 patients after TI. The bacterial counts differed between the 3 sampling times, with a noted increase in bacterial counts after SX compared with both after TI and after SI ($p < .001$). Figure 2 demonstrates that bacterial count of gram-positive cocci increased after SX when compared with after TI ($p < .001$) and then decreased significantly after SI when compared with after SX ($p < .001$). The bacterial counts after TI and after SI were similar with no statistically significant difference noted. There was no association between surgical time and gram-positive cocci counts (slope = –0.001, $r^2 = -.0136$, nonsignificant).

α-Streptococcus was the most frequently detected bacterium in the bacterial culture examinations. Table 2 presents the counts of other detected species in subglottic lavage samples from the smear and the culture examinations. While *S aureus*, MRSA, and *P aeruginosa* were all specifically targeted for culture examination, *Pseudomonas aureus* was not detected in any of the collected lavage samples in this study, and most of the positive cases for *S aureus* and MRSA were detected in the patients who were nasally intubated (Table 2). The bacterial count of both of *Neisseria* and *Corynebacterium* differed among the 3 sampling points ($p < .02$ and $p < .05$, respectively), but the effect of surgery or SI on bacterial count was not significant for either species.

The correlation between classifications of bacterial amounts in smear and culture examinations was confirmed using Kendall ($r = .737$, $p < .001$) and Spearman ($r = .811$, $p < .001$) rank correlation coefficients. The intercept of linear regression was 1.2, and the slope was 0.57.

Figure 3 presents a picture of the collected lavage samples in their respective containers along with the correction color chart. Collected lavage samples were frequently contaminated with blood and mucus from the oral and/or nasal cavity during surgery, which is clear by the dark red color of the middle container (after SX).

DISCUSSION

Contamination of the subglottic space from the oral cavity often occurs during intraoral SXs without TPs. Bacterial counts of the collected fluid from the

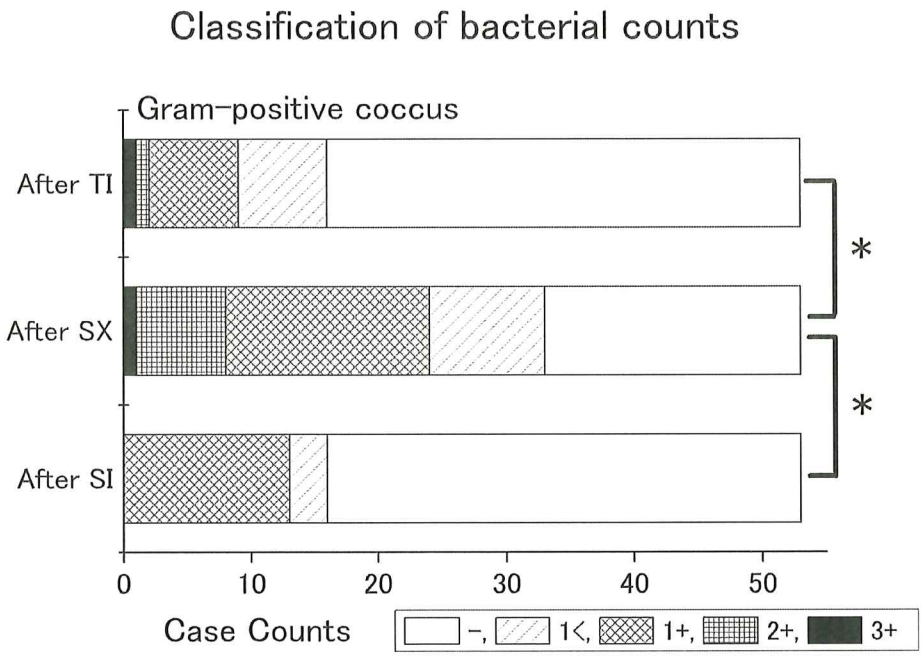

Figure 2. Classification of bacterial counts of gram-positive coccus by smear examination at 3 collecting points. Gram-positive coccus counts increased after the SX (*$p < .001$ vs after TI), significantly decreased after SI (*$p < .001$ vs after SX), and normalized following SI (nonsignificant vs after TI). SI indicates subglottic irrigation with 100 mL of saline; SX, surgical procedure; TI, tracheal intubation.

Table 2. Detected Bacterial Species in Subglottic Lavage*

Bacterial Species	*After TI*	*After SX*	*After SI*
Staphylococcus aureus†	8 (6)	10 (9)	4 (4)
MRSA†	4 (4)	4 (4)	2 (2)
Pseudomonas aeruginosa†	0 (0)	0 (0)	0 (0)
α-streptococcus	38 (28)	42 (32)	41 (31)
γ-streptococcus	5 (3)	11 (10)	8 (8)
Staphylococcus aureus β lactamase	8 (8)	8 (8)	6 (6)
Neisseria	15 (11)	24 (18)	24 (18)
Corynebacterium	7 (6)	11 (10)	2 (2)
Haemophilus influenza	3 (3)	2 (2)	2 (2)
Serratia	0 (0)	1 (0)	2 (1)
Escherichia coli	1 (1)	1 (1)	1 (1)
Klebsiella pneumoniae	1 (1)	1 (1)	1 (1)
Klebsiella oxytoca	1 (1)	0 (0)	1 (1)
Streptococcus constellaus	0 (0)	1 (1)	1 (1)
Streptococcus agalactiae	1 (1)	1 (1)	0 (0)
Streptococcus anginosus	0 (0)	1 (1)	0 (0)
Staphylococcus epidermidis	1 (1)	0 (0)	0 (0)
Candida albicans	0 (0)	1 (0)	0 (0)
Enterobacter aerogenes	0 (0)	0 (0)	1 (0)

* MRSA indicates methicillin-resistant *Staphylococcus aureus*; SI, subglottic irrigation; SX, surgical procedure; TI, tracheal intubation. Initial numbers indicate the total positive-case counts and numbers in parentheses indicate nasally intubated patients.

† Target species of bacterial examination.

subglottic space increased after conclusion of the SXs when compared with the samples taken after TI. When SI was carried out after surgery with 100 mL of saline using the subglottic suction lumen on an ETT, the bacterial counts decreased to approximately the same level as after TI. Although the use of TPs during surgery and endotracheal suction during extubation is popular and potentially useful for reducing potential bacterial contamination of the lung fields, SI with saline may also be a useful strategy for reducing bacterial contamination in the subglottic space before extubation.

Regarding the minor irregularities in obtained volumes of the lavage, there were usually no fluids noted in the subglottic space upon aspiration immediately after TI. This is likely because the oral cavity and pharynx were suctioned prior to placement of the ETT, and therefore, the subglottic space was empty. Also, the injected saline lavage was likely not fully recovered because of the small residual fluid volume possibly located between the cuff and the orifice of the suction lumen on the ETT. The larger collected volume noted with the second samples (after XS) was obtained after surgery but before SI and aspiration. The increased volume of lavage fluids collected from the subglottic space after SX was likely contaminated by blood and secretions, as evident by the changing darker red color (Figure 3). This was likely due to the influx of oral or

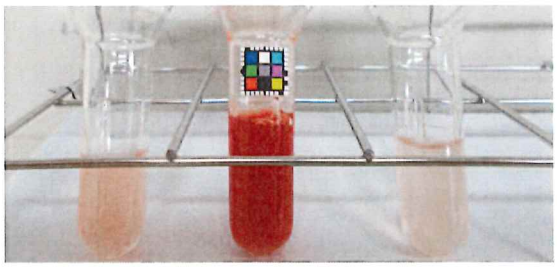

Figure 3. Collected lavage from the subglottic space with the correction color chart. SI indicates subglottic irrigation with 100 mL of saline; SX, surgical procedure, TI, tracheal intubation.

nasal hemorrhage into the subglottic space. Therefore, it can be concluded that oral surgery directly affected contamination of the subglottic space, and SI could decrease bacterial counts following a 1-minute irrigation with saline.

α-*Streptococcus* was the most frequently detected bacteria in culture examinations of the collected lavage from the subglottic space. Reported normal bacterial flora in the oral and nasal cavity[12,13] was also detected in subglottic lavage samples (Table 2). These results supported the translocation of bacteria from the oral and nasal cavity to the subglottic space.

Although *P aeruginosa* was not detected in the subglottic samples in this study, it is considered one of the indigenous bacteria in the nasal cavity and could become a problematic pathogen for immunocompromised patients. The number of samples in this study was too small to detect the incidence of *P aeruginosa*. *S aureus* and MRSA, which are also important pathogens in hospital-acquired infections, were detected in 8 and 4 patients after TI, respectively. It is also remarkable that most of the cases with these detected pathogens were among those who were nasally intubated, even immediately after TI, as evident in this study (Table 2). Although oral care has been recommended for prevention of ventilator-associated pneumonia,[14] these results could suggest that nasal care prior to nasal intubation may also be important for reducing the translocation of pathogens from the nasal cavity to the subglottic space.

Results of both smear and culture examinations were semiquantitative, and quantitative results using a polymerase chain reaction method might be needed for a more precise evaluation of the impact of SI. Collection of the lavage samples using the suction lumen used a process similar to collecting bronchoalveolar lavage for qualitative examinations. Species of subglottic bacterium in the smear and culture examination were very similar to previous reports on oral microbial flora.[12,13] Gram-positive cocci were the species most commonly detected using smear examinations in this study. Therefore, the effects on bacterial counts following SI were tested using the results of gram-positive cocci on the distribution of bacterial counts among the collected lavage samples. Results revealed increased bacterial counts after the conclusion of the oral SX and a reduction in bacterial counts after using SI, which returned to levels approximating those after TI (Figure 2). In addition, there was no significant relationship between surgical time and bacterial counts. Therefore, SI may be of value and should possibly be considered for reducing bacterial counts even if the surgical time is short.

Although prevention of aspiration pneumonia requires a reduction in the influx of subglottic pooled contents, endotracheal suction is likely unable to evacuate any contents within the subglottic space while the ETT cuff is inflated and might be insufficient for clearing the residual subglottic contents upon decompression of the cuff for extubation. Endotracheal suction may also cause harmful stimulation, which could precipitate an asthmatic attack and/or myocardial ischemia.[15] Furthermore, endotracheal suction with a small tube was reported as a cause of bacterial translocation in an incident of POP.[16] However, this study did not assess the differences between SI and other options, such as endotracheal suction, in terms of effectiveness on reducing bacterial influx. Although the results of this study could not determine the effectiveness of SI on reducing the incidence of POP, use of an ETT with a suction lumen capable of aspirating the pooled subglottic contents and performing SI before decompression of the tracheal cuff when extubating the ETT may be useful.

Antibiotics that might affect bacterial counts were given intravenously just before surgery and repeated every 3 hours during surgery in all cases.[11] This study focused on the bacterial load of the subglottic mucosal surface, which is unlikely to be directly affected by such antibiotics. Furthermore, SI was completed within a few minutes, and the concentration of any accumulated antibiotics in the mucosa is unlikely to have changed in such a short period. Overall, the use of antibiotics is unlikely to have greatly affected the evaluation of the effects of SI on bacterial counts.

Generally speaking, the antibacterial spectrum and the sterilizing power of antiseptic solutions (such as povidone-iodine) are much broader and stronger than most commonly used antibiotics. However, the strength of toxicity and potential tissue damage resulting from the use of antiseptic solutions tends to be considerably higher than found with antibiotics. This relatively simple method of SI with saline could potentially reduce the

overuse of perioperative antibiotics in health care settings, including dental settings,[5,6] because SI with saline reduced bacterial contamination in the subglottic space after oral surgery in this study.

Use of an ETT with a suction lumen might cause excessive compression of the external nares and inferior concha by the suction tube branched at the middle of the ETT. A smaller-size ETT than usually selected is recommended to help avoid soft-tissue damage by compression via the suction tube. In this study, a thin sponge was also placed between the upper part of the external naris and the ETT to reduce the compression of the naris. No tissue damage, such as erosion and/or ulceration of the naris, occurred in this study.

Limitations of this study included the absence of a zero-time control group with TI but no oral surgery due to ethical considerations. In addition, the lack of a control group who received surgery with a TP prevented evaluation between those groups who did and did not receive a TP. Furthermore, this study was unable to conclude whether SI was more effective for reducing bacterial counts than subglottic suction alone. The effects of SI on the incidence of POP were also not clarified by this study. Additional large-scale clinical studies would likely be needed to assess the effects of SI on the incidence of POP with high-risk oral surgery patients because of the extremely low incidence of POP in low-risk oral surgery patients.

CONCLUSION

This study demonstrated an increase in bacterial load within the subglottic space for patients receiving intraoral SXs without the use of a TP. Furthermore, the use of SI performed after surgery with 100 mL of saline using the subglottic suction lumen on an ETT led to a decrease in bacterial counts to the same level noted immediately following intubation. Subglottic suction and/or SI might be useful strategies for the reduction of subglottic bacterial contamination during oral surgery procedures. Further studies are likely warranted to assess the clinical relevance and risk/benefit of SI, especially for potentially reducing the incidence of POP for at-risk patients.

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