Comparison of a Closed with an Open Endotracheal Suction: Costs and the Incidence of Ventilator-associated Pneumonia

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비용, 인공환기관련폐렴 발생 빈도에 있어서의 개방 기관내 흡인술에 대한 폐쇄 흡인술의 비교

정재우[1], 최은희[2], 김진희[2], 서효경[2], 최지연[2], 최재철[1], 신종욱[1], 박인원[1], 최병휘[1], 김재열[1]

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연구배경: 폐쇄관을 이용한 기관내 흡인은 임상적으로 중한 환자에게 생리적인 이점이 있지만, 병원성 균주에 의한 기관지 내의 집락화가 증가될 수 있다는 보고가 있다. 비용증가는 폐쇄흡인의 또 다른 제한점이다. 본 연구는 폐쇄흡인 및 개방흡인에 따른 병원균주의 집락화와 인공환기관련폐렴의 빈도와 가격효율성을 비교해보고자 시행되었다.
방 법: 각각 한 달의 간격을 사이에 두고 내과계 중환자실에 입원한 환자들을 대상으로 다중사용 개방흡인, 단일사용 개방흡인, 다중사용 폐쇄흡인을 순차적으로 시행하였다. 비용, MRSA의 기관지내 집락화, 인공환기폐렴의 발생률을 분석하였다.
결 과: 106명의 환자가 연구 대상으로 포함이 되었고, 이 중 20명의 환자가 다중사용 개방흡인을, 42명이 단일사용 개방흡인을, 44명이 다중사용 폐쇄흡인술을 시행받았다. MRSA의 집락화와 인공환기관련폐렴의 빈도는 세 군간에 의미있는 차이를 보이지 않았다. 입원 일당 소모되는 비용은 다중사용 개방흡인이 $10.58, 단일사용 개방흡인이 $28.27, 다중사용 폐쇄흡인의 경우 $23.76인 것으로 나타났다.
결 론: 다중사용 폐쇄흡인을 매 48시간마다 교환하는 경우 MRSA 집락화와 인공환기폐렴 발생 빈도는 비슷하였고, 기관내 흡인술에 있어서 비용면에서도 효율적인 방법임을 알 수 있었다. *(Tuberc Respir Dis 2008;65:198-206)*

Key Words: Closed suction, Cost, MRSA, Open suction, Ventilator-associated pneumonia

Introduction

The removal of airway secretion is critical in the management of mechanically ventilated patients because these patients breathe solely through an artificial airway. Therefore, endotracheal suctioning is the most frequently performed nursing and physiotherapy procedure in the ICU. Although the benefits of patent airways by endotracheal suctioning are evident, it has complications. Endotracheal suctioning has been associated with arterial oxygen desaturation[1,2], decrease in systemic venous oxygenation[3,4], cardiac arrhythmia[5] and even sudden death[6].

Currently, two types of suction catheter systems are used. The conventional suction technique involves the use of a sterile, single-use open suction catheter. Open-system suctioning requires the patient to be disconnected completely from the ventilator circuit; therefore, oxygen, humidity and PEEP are not delivered during suctioning. Because the desired PEEP is not maintained in the patient's lungs, small airways and alveoli may collapse. Unstable patients may immediately deteriorate due to hypoxemia[7].

Another method of endotracheal suctioning is using a multiple-use closed suction system. Closed suction consists of a suction catheter enclosed within a flexible plastic film sleeve. Because the catheter remains attached to the ven-

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tilatory circuit, it eliminates the need to disconnect the circuit for endotracheal suctioning. The benefits of closed suction over open suction include the maintenance of positive pressure ventilation during suctioning, less desaturation, and a reduced risk of disseminating contaminated bronchial secretions[8,9]. In addition, many critical care nurses consider closed suction to be easier to use, less time-consuming and better tolerated by the patient[10]. In some reports, closed suction was associated with lower incidence rate of ventilator-associated pneumonia (VAP)[11] and even with the high probability for survival[12].

Although, closed suction appears to be a safe and an effective method of endotracheal suctioning, disadvantages also exist. Because suction catheters are contaminated after the initial pass through an endotracheal tube, repeated insertion of closed suction catheter may increase the risk for colonization of endotracheal tube by pathogens. Another problem is the high cost of closed suction catheter. The cost-burden of disposable, single-use, suction catheters are quite high because at least several hundreds of them are used and discarded in a day in single MICU. To save cost, many ICUs, including ours, use the open suction catheter repeatedly (usually it is changed 3 times a day per patient). Although the tip of the suction catheter is dipped into sterile saline while it is not used, it cannot be considered to be clean enough. In this situation, the use of multiple-use, closed suction catheter can be the most cost-effective and the most sanitized way of endotracheal suctioning.

In the present study, we hypothesized that closed suction does not increase the risk for colonization of tracheobronchial tree by pathogens or the development of ventilator-associated pneumonia compared to single-use, open suction. Authors also analyzed the cost-effectiveness of the closed suctioning.

Materials and Methods

1. Patients

After Institutional Review Board approval, the study was conducted prospectively at the medical ICU of ChungAng University Hospital, Seoul, Republic of Korea from April 1st to September 14th, 2006. Patients on mechanical ventilation via artificial airways were included in the study, after informed consent had been provided by their families.

2. Methods of endotracheal suctioning

For patients treated with open suctioning, a sterile suction catheter (Suction Catheter, Insung Medical co., LTD, Korea) was passed through the endotracheal tube until resistance was encountered. A suction pressure of 80 to 100 cm H_2O was applied while withdrawing the catheter from the airway. The pass of suction catheter was limited to <15 sec. Patients were suctioned at least every 3 hours and on an "as needed" basis determined by nursing personnel.

Before starting this study, nursing staffs in the MICU completed education program for closed suction catheter (Trach Care Closed Suction System, Ballard Medical Products, Midvale, UT, USA). It was composed of video and oral presentation for the closed suction system with bed-side practice. For patients receiving closed suctioning, the catheter (inside the sheath) advanced into the endotracheal tube until mild resistance was met. The catheter was then withdrawn using intermittent suction pressure of 80 to 100 cm H_2O and each pass was limited to <15 sec. The catheter was then irrigated through the irrigation port with sterile saline while applying suction. Patients were suctioned at least every 3h and on an "as needed" basis determined by nursing personnel. Catheters were changed every 48 hr.

3. Protocol

The study consisted of three separated, one month periods. Each month of study was separated by one or one and half month of wash out period. Three ways of endotracheal suctioning; multiple-use, open suction catheter-suction catheter was changed 3 times a day (from April 1st to April 30th), single-use, open suction catheter (from June 1st to June 30th) and multiple-use, closed suction catheter (from September 15th to October 14th) were consecutively applied. During each study month, colonization of endotracheal tube by methicillin resistant *Staphylococcus aereus* (MRSA), VAP incidence rate and the cost of each method were analyzed.

4. Colonization of tracheobronchial tree by MRSA

During the stay in the MICU, endotracheal aspirate was obtained as determined by attending physicians for the clinical assessment of each patient. Specimens were taken to a microbiology lab for Gram staining and culture for pathogens. MRSA was considered to be a colonizer when it was isolated from a patient without any sign of pulmonary infection.

5. Ventilator-associated pneumonia (VAP)

The diagnosis of VAP was defined according to previously published criteria[13,14], when patients on mechanical ventilation for more than 48 hrs developed a new and persistent infiltrate on chest X-ray accompanied by at least two of the following clinical features: a) purulent endotracheal secretions as determined by Gram stain, b) fever $>38.3^{o}C$ without extrapulmonary infectious source, and c) peripheral leukocytosis of greater than $10,000/mm^3$ or peripheral leucopenia less than $4,000/mm^3$. Surveillance for the development of VAP was performed by an infection-control nurse on a daily basis. Chest X-ray reading was done by an independent radiologist. The diagnosis of VAP was finally defined by a pulmonologist.

6. Costs for endotracheal suctioning

Patients' costs for each method of suctioning were compared. The cost of the open suction method was determined by the cost of disposable catheters per procedure and multiplied by the average number of suctioning procedures per patient per day. The cost of the closed suction method was determined by the cost of the closed suction system per patient per day. The cost for sterile saline which was consumed for flushing or lubrication of airway was also counted.

7. Statistical analysis

Physiologic data were examined, using mean±SD. The homogeneity among three groups (multiple-use, open suction, single-use, open suction and multiple-use, closed suction group) in regards to demographic data was evaluated with t-test and Mann-Whitney test. The difference in the colonization by MRSA and the VAP incidence rate were also analyzed by χ^2 test. Significance level was determined at $p<.05$.

Results

1. Patients

During separated 3 months of study period, 475 patients were admitted in the ICU. Three-hundred sixty one patients were excluded because they did not take mechanical ventilation. Eight patients stayed in the MICU less than 48 hrs and excluded from the analysis. By this, one-hundred and six patients were studied. Twenty patients were treated with multiple-use, open suction, while 42 and 44 patients were cared with single-use open catheter and multiple-use, closed catheter, respectively (Figure 1). A demographic profile of the patients is shown in Table 1. Three groups were similar in age, sex, duration of ICU stay, APACHE III score, duration of ventilator care and total frequency of bacteriologic examination of endotracheal suction during enrolled period. The patient's underlying disease is shown in Table 2.

2. Colonization of bacteria in the endotracheal tube

The most common cultured bacteria is *Pseudomonas aeuruginosa* and the second is MRSA in total enrolled patients (Table 3). There was no significant difference among three groups. But second common bacteria is MRSA in multiple-use, open suction group, *Stenotrophomonas maltophilia* in single-use, open suction group, *Acinetobacter baumanii* in multiple-use, closed suction group (Table 3).

3. Colonization of MRSA in the endotracheal tube

During the time of enrollment (one month for each group), MRSA colonized 7 patients in multiple-use, open suction group, 2 patients in single-use, open suction group and 4 patients in multiple-use, closed suction group. Seventy-nine patients discharged from multiple-use, open suction group during the study period and 88 patients from single-use, open suction group and 81 from multiple-use, closed group. The duration of stay

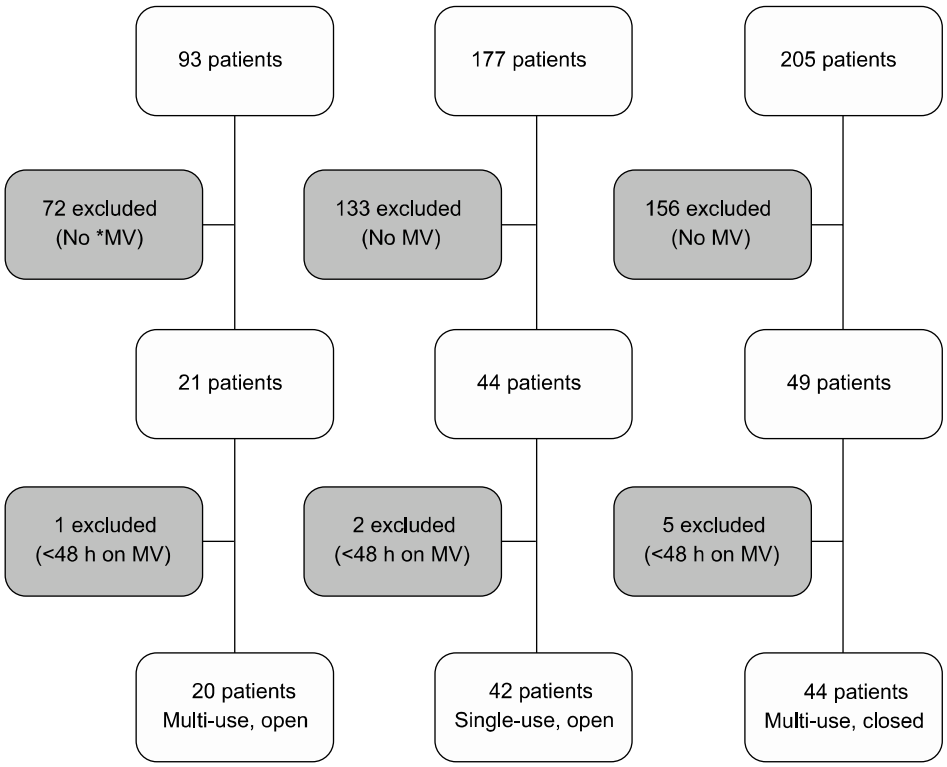

Figure 1. Enrollment of patients for multiple-use, open suction, single-use, open suction and multiple-use, closed suction method. MV: mechanical ventilation.

Table 1. Demographic profile of patients

	MUOS	SUOS	MUCS	p
Number	20	42	44	
Age	69.2±12.7	71.1±11.3	63.0±16.1	.277
Male:Female	16:4	26:16	25:19	.199
APACHE III	64.8±31.1	58.1±23.1	55.9±20.7	.372
ICU stay (days)	29.2±53.3	26.2±51.0	32.7±70.8	.497
Days of ventilator care	21.8±54.3	20.3±42.2	25.7±58.8	.424
Total frequency of bacteriologic exam of suction	3.63±4.24	3.61±6.32	3.33±5.60	.355

MUOS: multiple-use, open suction group; SUOS: single-use, open suction group; MUCS: multiple-use, closed suction group.

Table 2. The underlying disease of patients

Underlying disease	Number
Cerebral infarction or hemorrhage	20
Pneumonia	20
Congestive heart failure or myocardiac ischemia	15
Chronic or acute renal failure	13
Malignancy	12
COPD or asthma	8
Drug intoxication	6
Sepsis	5
Liver cirrhosis	4
Idiopathic pulmonary fibrosis	3
Hemothorax	2
Neuromuscular disease	2

for each group was 588 days, 593 days and 556 days, respectively. The ratio of colonization by MRSA (colonization rate*100/number of discharged patient) was 8.86 for multiple-use, open suction group, 2.27 for single-use, open suction group and 4.94 for multiple-use, closed suction group. The density of colonization (colonization rate*1,000/days of ICU stay) was 11.90, 3.37 and 7.19, respectively (Figure 2). There was not a statistically significant difference among three groups as far as MRSA colonization was concerned. The duration of MRSA colonization occurring after mechanical ventilator applying are 4.43, 5, 6 days respectively.

Table 3. The culture of endotracheal suction

	MUOS	SUOS	MUCS	Total
Pseudomonas aeuruginosa	8	8	7	23
MRSA	7	2	4	13
Stenotrophomonas maltophilia	5	5	3	13
Acinetobacter baumanii	1	3	6	10
Klebsiella pneumoniae	2	3	2	7
MSSA		3	3	6
E.coli	2	4		6
Serrtia marcescens	2	2	2	6
Acinetobacter calcoaceticus	2	3		5
Streptococcus pneumoniae	1	2		3
Enterobacter aerogenes		1	1	2
Proteus mirabilis				1
Acinetobacter lwoffii				1
Total	30	37	29	96

MUOS: multiple-use, open suction group; SUOS: single-use, open suction group; MUCS: multiple-use, closed suction group; MRSA: methicillin resistant Staphylococcus aureus; MSSA: methicillin sensitive Staphylococcus aureus.

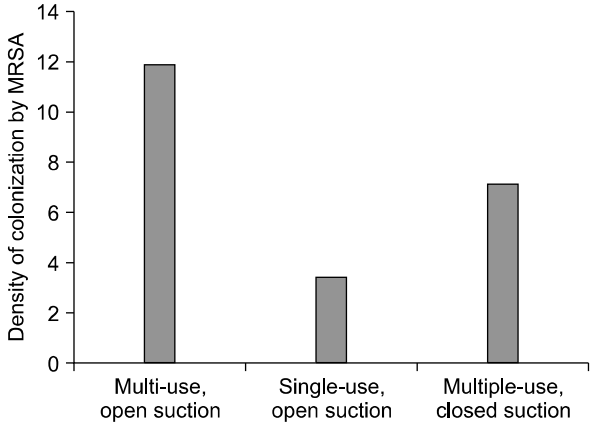

Figure 2. Density of colonization by MRSA. MRSA colonized 7 patients in multiple-use, open suction group, 2 patients in single-use, open suction group and 4 patients in multiple-use, closed suction group. Seventy-nine patients discharged from multiple-use, open suction group during the study period and 88 from single-use, open suction group and 81 from multiple-use, closed suction group. The duration of ICU stay was 588 days, 593 days and 556 days, respectively. The density of colonization = colonization rate × 10,000/days of ICU stay.

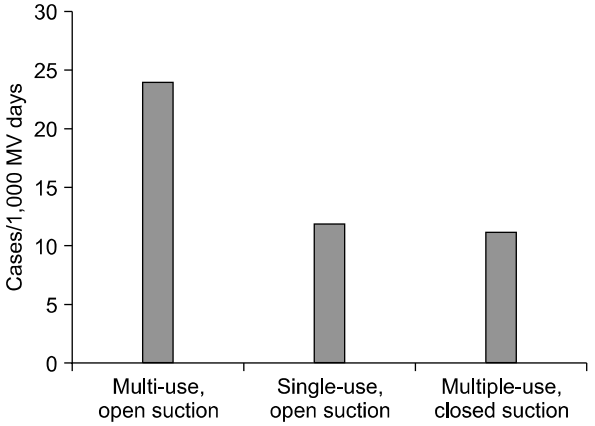

Figure 3. The incidence rate of VAP per 1,000 days of mechanical ventilation for multiple-use, open suction, single-use, open suction and multiple-use, closed suction method. VAP developed 4 cases in multiple-use, open suction group, 2 cases in single-use, open suction group and 2 cases in multiple-use, closed suction group. The duration of mechanical ventilation was 168 days, 172 days and 187 days, respectively.

4. Incidence rate of ventilator associated pneumonia (VAP)

During the study period (one month for each group), VAP developed 4 cases in multiple-use, open suction group, 2 cases in single-use, open suction group and 2 cases in multiple-use, closed suction group. The duration of mechanical ventilation was 168, 172 and 187 days for each group. When we consider the duration of mechanical ventilation, the incidence of VAP was 23.81, 11.63 and 10.70 cases per 1,000 days of mechanical ventilation, respectively (Figure 3). Although VAP

incidence seemed to be higher in control group compared to other two groups, it was not statistically significant ($p>.05$). The bacteria of VAP is MRSA in 4 cases, Pseudomonas aeruginosa in 5 cases, Acinetobacter baumanii in 1 case and Klebsiella pneumoniae in 1 case. There was overlapped infections. The mean duration of VAP occurrence is 58.4 hours after ventilator apply.

5. Cost for endotracheal suctioning

The cost for open suction catheter was $0.61 per each. The cost of suctioning per patient per day in multiple-use, open suction (catheters changed 3 times) and single-use, open suction (average of 32 suctioning procedures) was $1.83 and $19.52. The cost of the closed suction catheter was $40.3. Because it was used for 48 hours, the cost is $20.2 per day.

During open-catheter suctioning process, to wash out the mucus plug, the lumen of suction catheter is flushed with normal saline. Usually one ample of 20 ml normal saline is consumed during this process ($0.19 per each ample). To wash out the rubber tube distal to a suction catheter, three bottles of 1 liter normal saline ($0.89 per each bottle) was used per patient per day for both open suction groups ($2.67/patient/day, respectively). For closed suction group, 4 bottles of 1 liter normal saline ($3.56/patient/day) were use to flush a catheter and a rubber tube (20 ml ample of normal saline is unnecessary for closed suctioning). Therefore, the total daily cost for suctioning was $10.58 for multiple-use, open suction group, $28.27 for single-use, open suction group and $23.76 for multiple-use, closed suction group, respectively (Table 4).

Table 4. Cost for endobronchial suction

	MUOS	SUOS	MUCS
Cost of catheters per day	$1.83	$19.52	$20.2
Cost of saline per day	$8.75	$8.75	$3.56
Total cost per day	$10.58	$28.27	$23.76

MUOS: multiple-use, open suction group; SUOS: single-use, open suction group; MUCS: multiple-use, closed suction group.

Discussion

There are numerous complications associated with an endotracheal suction procedure. Although the closed-suction system does not eliminate all risks and hazards, it does minimize many of them. Closed-suction systems allow patients to maintain same ventilation, PEEP, and oxygenation during suctioning[15]. It is more comfortable both to nursing staffs and patients[10]. In addition, closed suction are cost-effective for patients requiring ventilation for one day or longer[16].

However, as many other techniques, the closed suction system is not without potential problems. It is possible that closed suction has the potential for an increase in bacterial populations inside the suction catheter. Insertion of multi-use, contaminated catheter can inoculated a large number of microorganisms into the trachea each time the patient is suctioned. By this way, closed suctioning may increase the incidence of ventilator associated pneumonia. In addition, the cost-effectiveness of closed suction system may be different depending on the situation of medical insurance system in each country. In the present study, authors tried to evaluate the safety and the cost-effectiveness of closed suction system.

Of 106 patients included in this study, twenty patients received endotracheal suctioning by multiple-use, open suction catheter (suction catheter was changed 3 times a day), 42 by single-use, open suction catheter and 44 by multiple-use, closed suction catheter. Each way of suctioning was consecutively applied for one month period and one or one and half month of wash out period was interposed between each method. Lorente et al argued that closed tracheal suction system, when it was used for more than 24 hr, does not increase VAP[17]. Therefore, we decided to change the close suction catheter every 48 hrs. In the present study, There was no significant difference in regards to age, male to female ratio, APACHE III score, duration of ICU stay and duration of ventilator care and frequency of endotracheal suction during enrolled period among three groups (Table 1).

Colonization of the tracheobronchial tree is commonly listed as a risk factor for nosocomial pneumonia[14,18]. As for multiple-use, closed suctioning, concern has always been expressed whether repeated insertions may increase the chance of colonization of endotracheal tube by potentially virulent organisms. There has been controversy on this issue. Some reported that closed suctioning is associate with a significant increase in colonization compared with open suctioning[12,19]. The reason for the increased colonization rate was explained by more frequent suctioning in the closed-suction system due to ease of the procedure. On the other hand, Cordero et al reported that closed suction group showed less colonization by Gram-negative bacilli compared to open suction group[10]. In the present study, the ratio of colonization by MRSA (colonization rate*100/number of discharged patient) was 8.86 for multiple-use, open suction group, 2.27 for single-use, open suction group and 4.94 for multiple-use, closed suction group. Although MRSA colonization seems to be higher in multiple-use, open suction group, it was not significant statistically ($p < .05$). In the previous studies, closed-suction catheter has usually been used for 24 h and then discarded. Interestingly, results from our study indicate that closed-suction catheter can be used for as long as 48 h without increasing the risk of colonization of endotracheal tube by MRSA.

During the study period, VAP developed 4 cases in multiple-use, open suction group (20%), 2 cases in single-use, open suction group (4.8%) and 2 cases in multiple-use, closed suction group (4.5%). All diagnostic methods taken into account, the incidence of VAP ranges from 9 to 50% in different studies[20,21]. The incidence of VAP in single-use, open catheter and multiple-use, closed catheter groups seems to be lower than that previously reported. It may be due to a short duration of observation period (one month for each group) in our study. Although, the occurrence of VAP seems to be higher in multiple-use, open suction group, it did not meet the level of statistical significance. Our results are consistent with those findings of other researchers who reported that suctioning performed by closed-suction system does not increase the incidence of nosocomial pneumonia[10,12,22]. Even though, Combes et al argued that the incidence rate of VAP was lower for closed-suction system than open-suctioning, there was no follow up studies supporting their data[11]. In the current situation, closed system can be considered to be as safe as open-suctioning, as far as VAP is concerned.

Results from this study indicate that overall cost for closed suction system was slightly lower per patient per day based on an average of 32 suctioning procedures per day. Very small difference it may look ($4.51/patient/day), closed suction can save as much as $20,083 annually when we consider an average of 12.2 patients on mechanical ventilation per day in our MICU. Although cost-effectiveness of closed suction system have been evaluated in other countries[10,16,23], our study would be the first which verified this issue in the Republic of Korea (Table 4). But many hospitals in the republic of Korea actually use multiple-use open suction system, therefore closed suctioning system is practically expensive method.

Based on results of this study, multiple-use, closed suctioning has the similar incidence of colonization of MRSA and occurrence of VAP and is a cost-efficient way of endotracheal suction.

The limitations of this study are 1) the patients were of small number, 2) this study is sequential design, therefore three groups were not studied at the same time, 3) although the manufacturer recommends that the closed catheter is used during 24 hr, we extended the use of the catheters for 48 hr, 4) physicians ascertaining the outcomes of VAP and MRSA colonization were not blinded, 5) endotracheal suctioning for knowing the colonization was not done regular time and frequency.

Summary

Background: Tracheobronchial suctioning using the closed suctioning system has physiological benefits for critically ill patients. Despite these benefits, there are concerns about increased colonization of tracheobronchial tree by pathogenic organisms. The cost is another

hinder to the introduction of closed suction system. The aim of this study was to evaluate the incidence of colonization and ventilator associated pneumonia and the cost-effectiveness of closed suction compared with open suction.

Methods: During separated one month period, patients admitted MICU were cared by multiple-use, open suction, single-use, open suction and multiple-use, closed suction method, consecutively. Costs, colonization of tracheobronchial tree by MRSA and the incidence of ventilator-associated pneumonia (VAP) were analyzed.

Results: One-hundred and six patients were enrolled. Twenty patients were treated with multiple-use, open suction, while 42 and 44 patients were cared with single-use, open catheter and multiple-use, closed catheter, respectively. Colonization by MRSA and the incidence of VAP were not different among three ways of suctioning. The overall costs per patient per day for suctioning were $10.58 for multiple-use, open suction, $28.27 for single-use, open suction and $23.76 for multiple-use, closed suction.

Conclusion: Multiple-use, closed suctioning, when suction catheters were changed every 48 hrs, has the similar incidence of colonization of MRSA and occurrence of VAP and is a cost-efficient way of endotracheal suction.

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