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Original Article

Which Suction Method is Preferable for Patients After Cardiac Surgery: Open or Closed Endotracheal Suction System?

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ABSTRACT

Background: There are 2 different methods of suctioning the airway: the open tracheal suction system (OTSS) and the closed tracheal suction system (CTSS). The aim of this study was to compare the efficacy of the OTSS and the CTSS in maintaining the stability of hemodynamic and oxygen parameters in patients after cardiac surgery.

Methods: This randomized controlled clinical trial was conducted on 60 patients who were under mechanical ventilation after cardiac surgery. The study population was randomly divided into the OTSS and CTSS groups. All the patients were at least 18 years old and hemodynamically stable. Hemodynamic parameters such as systolic and diastolic blood pressures were measured. Oxygen parameters such as the saturation percentage of arterial blood oxygen (SpO_2) and the oxygen pressure of arterial blood (PaO_2) were measured before, immediately, and also 3 and 5 minutes after suction. All the parameters were compared between the 2 groups.

Results: The mean heart rate, the mean systolic blood pressure, and the mean arterial blood pressure showed a higher increase in the OTSS group ($P<0.05$), whereas the mean PaO_2 and SpO_2 were higher in the CTSS group ($P<0.05$).

Conclusions: The CTSS caused fewer disturbances in the hemodynamic and oxygen parameters in comparison with the OTSS in our study population. Therefore, disturbances in the aforementioned parameters can be avoided by using the CTSS in patients undergoing cardiac surgery. ***(Iranian heart Journal 2018; 19(3): 51- 59)***

KEYWORDS: Airway management, Suction, Cardiac surgical procedures, Hemodynamics

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Cardiovascular disease is the main cause of mortality all over the world. Aging, obesity, and an increase in the prevalence of hypertension and diabetes mellitus are the main reasons for the high rates of cardiovascular disease. [1] In the Iranian population, coronary artery disease is the leading cause of mortality and morbidity, and the cost of treatment and medical care is high. [2]
There are currently 2 strategies to approach patients suffering from ischemic heart disease: coronary artery bypass grafting (CABG) and percutaneous coronary intervention. [3, 4] The selection of the appropriate method is based on the patient's angiographic features and clinical condition, as well as the treating physician's discretion. [5, 6] Cardiac surgery may be indicated in patients with valvular diseases, congenital heart disease, or heart transplantation. [7] These patients need general anesthesia and mechanical ventilation during surgery. [8] The suctioning of the airway secretions is extremely important for intubated patients in that it enhances the quality of respiration, improves oxygenation, and prevents the airway obstruction by the secretions. Another advantage of suctioning is that it can protect the respiratory tract against infections. [9-15] In the intensive care unit (ICU), airway suctioning is possible via 2 methods: the open tracheal suction system (OTSS) and the closed tracheal suction system (CTSS). In the OTSS, ventilation should be discontinued during suctioning, while the CTSS obviates the need to disconnect the patient from the ventilator and ventilation can be continued during suctioning. [16] The OTSS is applied frequently, but it may cause such complications as increased chances of atelectasis, decreased respiratory volumes and oxygenation, and ultimately hypoxemia. [17] The CTSS appears to be more suitable for patients inasmuch as it can reduce the incidence of nosocomial pneumonia, [18] the rate of aspiration and hypoxemia, [19] and the incidence of contamination with the patient's respiratory secretions. [20]
Several studies have shown the superiority of the CTSS over the OTSS. [17-20] Nonetheless, these results should be interpreted in light of the unavoidable differences in the underlying conditions of different patients in different hospitals. Accordingly, we conducted the present study in Rajaie Cardiovascular, Medical, and Research Center on a sample of Iranian patients who undergo cardiac surgery so as to compare the efficacy of the CTSS and the OTSS. Before the study, the OTSS was the preferred method of suctioning among patients after cardiac surgery in our hospital and an important purpose of this study was to demonstrate the benefits of the CTSS in order to generalize its use.

METHODS

The present randomized controlled clinical trial was conducted on 60 patients admitted to the Cardiac Surgery Ward of Rajaie Cardiovascular, Medical, and Research Center—a cardiovascular tertiary care hospital in Tehran, Iran—between October and December 2016. The study protocol was approved by the institutional ethics committee. After providing the patients with thorough explanations about the study, informed written consent for participation was obtained from them. The inclusion criteria comprised a minimum age of 18 years, elective cardiac surgery (including CABG and heart valve surgery), stable hemodynamics, a peripheral capillary oxygen saturation (SpO_2) level of more than 80%, the absence of any severe lung disease, and the absence of any serious arrhythmias.
Via balanced block randomization techniques, the patients were randomly assigned to 2 groups of the OTSS and the CTSS. The study was open-label. The data collected prior to surgery encompassed the demographic characteristics, chronic underlying diseases,

and the prescribed drugs. All the patients were admitted to the ICU after cardiac surgery and underwent mechanical ventilation.

The study endpoints were classified into 2 groups: the hemodynamic parameters and the oxygen parameters. The hemodynamic parameters were comprised of the heart rate, blood pressure, and the mean arterial blood pressure. The mean arterial blood pressure was measured invasively with a Spacelabs transducer and a bedside Spacelabs ELO monitor from the left radial artery line. The oxygen parameters consisted of SpO_2, the oxygen pressure of arterial blood (PaO_2), the partial pressure of carbon dioxide ($PaCO_2$), the acidity of arterial blood (pH), the alveolar–arterial oxygen gradient ($AaDO_2$), and the ratio of the arterial blood pressure to the percentage of inspired oxygen. These parameters (except for pH) were considered the primary endpoints of the study.

A Techno Medica GASTAT-603ie was used to analyze the levels of SpO_2, PaO_2, $PaCO_2$, and pH. $AaDO_2$ and the ratio of the arterial blood pressure to the percentage of inspired oxygen were calculated and recorded according to the related formulae. The data on the hemodynamic and oxygen parameters were collected 1 hour after surgery in the ICU. The parameters were recorded before, immediately after, and 3 and 5 minutes following the 2 methods of airway suctioning.

The data were described as means ± standard deviations for the interval variables with normal distributions and counts (%) for the categorical variables. The fitness of the distribution of the interval variables to a normal distribution was assessed with the one-sample Kolmogorov–Smirnov test. The associations between the suctioning type and the other variables were determined with the Student *t*-test for the interval variables and the Pearson χ^2 test or the Fisher exact test, as needed, for the nominal variables. Repeated-measure analysis of variance (ANOVA) models were used for the assessment of the variations in the interval variables over time. A *P* value equal to or less than 0.05 was considered statistically significant. The statistical analyses were carried out with the IBM SPSS Statistics, version 19, for Windows (IBM Inc, Armonk, NY).

RESULTS

The study population was comprised of 60 patients: 23 (38.8%) women and 37 (61.7%) men at a mean age of 54±15.8 years (19–83 y). The participants' baseline characteristics were compared between the 2 study groups, and the results are presented in Table 1. There were no significant differences in terms of the basic data between the CTSS and the OTSS groups (*P*>0.05).

The information about the surgical procedures and medication usage is presented in Table 2, which shows the similarity between the 2 study groups (all *Ps*>0.05).

Table 1. Comparisons of the baseline data before surgery between the 2 groups

	Open Suction (n=30)	Closed Suction (n=30)	*P*
age	50 ± 16.2	58± 14.5	0.207
Sex (F/M)	12/18	11/19	0.791
BMI (kg/m^2)	25.8± 5	25.7±3.6	0.46
Smoking	4 (13.3%)	5 (16.7%)	0.718
Hyperlipidemia	8 (26.7%)	11 (36.7%)	0.405
Hypertension	10 (33.3%)	14 (46.7%)	0.292
Diabetes mellitus	8 (26.7%)	3 (10%)	0.095
Hemoglobin (g/dL)	10.11 ± 0.89	10.1 ± 1.24	0.138
LVEF (%)	46.2± 7.39	46.5 ± 7.44	0.828

BMI, Body mass index; LVEF, Left ventricular ejection fraction

Table 2. Comparisons of the surgery data between the 2 study groups

	Open Suction (n=30)	Closed Suction (n=30)	*P*
Type of Surgery			
CABG	13 (43.3%)	19 (63.3%)	0.121
Heart valve surgery	17 (56.7%)	13 (43.3%)	0.302
Other surgeries	5 (16.7%)	1 (3.3%)	0.085
Serum transfusion (mL)	1850 ± 570	1730 ± 480	0.920
Pump time (min)	102.5 ± 39.5	87.5 ± 29.1	0.226
Drugs			
Inotropic agent use	9 (30%)	12 (40%)	0.417
Inotrope Dose			0.487
Low dose	8(26.7%)	12 (40%)	
High dose	1(3.3%)	0	
Epinephrine	9 (30%)	7 (23.3%)	0.559
Norepinephrine	1 (3.3%)	2 (6.7%)	0.0554
Milrinone	2 (6.7%)	3 (10%)	0.642
Low-dose nitroglycerin	18 (60%)	19 (63.3%)	0.196

CABG, Coronary artery bypass grafting

The results of the study outcomes are presented in Table 3, 4. The findings were as follows:

Systolic blood pressure: Systolic blood pressure rose after airway suctioning and then dropped gradually. The maximum systolic blood pressure was detected just after suctioning in the 2 groups. Significant differences were detected in all the post-suctioning stages in the OTSS group in comparison with the CTSS group (Table 3). The *P* values for both the main effect of time and the interaction between time and groups were less than 0.001, which means that the CTSS maintained systolic blood pressure lower and with less variability over time than the OTSS.

Table 3. Comparisons of blood pressure and the heart rate between the 2 study groups

	Open Suction (n=30)	Closed Suction (n=30)	*P*
Systolic Blood Pressure (mm Hg)			
Baseline	111 ± 13.7	115 ± 11.2	0.232
Just after suction	134 ± 12.4	118 ± 10.5	<0.001
3 min after suction	127 ± 15	116 ± 9.6	0.001
5 min after suction	120 ± 13.9	113 ± 10.3	0.021
Diastolic Blood Pressure (mm Hg)			
Baseline	65 ± 11.8	64 ± 8.6	0.690
Just after suction	79 ± 10.8	66 ± 8.2	<0.001
3 min after suction	75 ± 12	64 ± 7.8	<0.001
5 min after suction	70 ± 11.5	63 ± 8	0.004
Mean Arterial Pressure (mm Hg)			
Baseline	95 ± 12.4	98 ± 9.6	0.378
Just after suction	115 ± 11.7	101 ± 9	<0.001
3 min after suction	109 ± 13.6	99 ± 8.1	0.001
5 min after suction	103 ± 12.9	96 ± 8.7	0.015
Heart Rate (beat/ min)			
Baseline	89 ± 13.1	91 ± 17.3	0.604
Just after suction	111 ± 12.4	93 ± 17.1	<0.001
3 min after suction	104 ± 13.9	92 ± 17.1	0.005
5 min after suction	96 ± 15.3	90 ± 17.4	0.166

Diastolic blood pressure: Diastolic blood pressure increased following airway suctioning and subsequently decreased gradually. Again, significant changes were detected after suctioning (Table 3). Similar to systolic blood pressure, there was a significant interaction insofar as diastolic blood pressure was more stable with the CTSS than with the OTSS.

Mean arterial blood pressure: The mean arterial pressure rose after suctioning and then decreased steadily. The changes were significant in all the stages following suctioning, and they were higher in the OTSS group (Table 3).

Heart rate: The heart rate initially rose after airway suctioning before it exhibited a gradual fall. The maximum heart rate was detected just after suctioning in the 2 groups. The rise was significant in the OTSS group by comparison with the CTSS group, just after airway suctioning (Table 3). The *P* values for both the main effect of time and the interaction between time and groups were less than 0.001, which suggests the considerable superiority of the CTSS over the OTSS.

PaO_2: The pressure of oxygen declined after airway suctioning but subsequently rose gradually. The reduction was significant just after suctioning, and the pressure of oxygen declined more in the OTSS group than in the CTSS group (Table 4). The repeated-measure ANOVA revealed the significant main effect of time and the interaction between time and groups ($P<0.001$).

PaCO2: There was a significant change in the 2 groups following airway suctioning but not 5 minutes after suctioning (Table 4). There was an interaction between time and groups, which denotes different changing patterns in the study groups ($P=0.006$).

Oxygen saturation: After airway suctioning, oxygen saturation declined more in the OTSS group than in the CTSS group (Table 4).

Table 4. Comparisons of the oxygen parameters between the 2 study groups

	Open Suction (n=30)	Closed Suction (n=30)	*P*
Partial Pressure of O_2 (mm Hg)			
Baseline	218 ± 62	212 ± 57.2	0.697
Just after suction	179 ± 63.5	170 ± 50.4	0.540
3 min after suction	121 ± 41.7	166 ± 61.8	0.001
5 min after suction	141 ± 56.4	172 ± 57	0.037
Partial Pressure of Carbon Dioxide (mm Hg)			
Baseline	30 ± 5.6	31 ± 5.1	0.531
Just after suction	34 ± 4.9	35 ± 5.8	0.665
3 min after suction	37 ± 6.2	34 ± 5.9	0.096
5 min after suction	35 ± 4.9	34 ± 5.8	0.521
pH (mol/L)			
Baseline	7 ± 0.1	7 ± 0.1	0.474
Just after suction	7 ± 0.1	7 ± 0.1	0.456
3 min after suction	7 ± 0.1	7 ± 0.1	0.983
5 min after suction	7 ± 0.1	7 ± 0.1	.767
Alveolar–Arterial O_2 Gradient (mm Hg)			
Baseline	102 ± 59.9	107 ± 53.6	0.737
Just after suction	135 ± 62.4	143 ± 49.7	0.567
3 min after suction	190 ± 41.5	148 ± 59.6	0.002
5 min after suction	172 ± 55.8	142 ± 55.4	0.041
PaO_2/FiO_2 ratio (mm Hg)			
Baseline	435 ± 124.1	423 ± 114.5	0.697
Just after suction	357 ± 127.1	339 ± 100.8	0.540
3 min after suction	241 ± 83.4	332 ± 123.7	0.001
5 min after suction	281 ± 112.7	344 ± 114	0.037
O_2 Saturation (%)			
Baseline	100 ± 0.7	100 ± 0.8	0.606
Just after suction	99 ± 1.3	99 ± 1.8	0.412
3 min after suction	88 ± 3.3	98 ± 1.6	<0.001
5 min after suction	93 ± 2.8	98 ± 1.1	<0.001

pH: pH did not have any significant changes in the 2 groups after suctioning. The *P* value for interaction was not significant.

$AaDO_2$: The increase of this index was higher in the OTSS group just after airway suctioning. As is shown in Table 4, the pattern of the changes of the gradient in the OTSS was different from that of the CTSS ($P<0.001$ for interaction).

PaO_2/FiO_2 ratio: There was a decrease in this ratio just after airway suctioning, with the change being more pronounced and significant in the OTSS group (Table 4). Similar to the previous index, the changing pattern was different between the OTSS and the CTSS ($P<0.001$ for interaction).

DISCUSSION

Based on the results of the present study, the post-cardiac surgery use of the CTSS—in comparison with the OTSS—conferred stabilization in the hemodynamic and oxygen parameters. It, therefore, appears that the CTSS it is safer and more suitable for patients after cardiac surgery.

In the current study, the mean heart rate initially rose after airway suctioning and then declined in the OTSS and CTSS groups, but the changes were less pronounced in the CTSS group and were significant just after the suctioning of the airway ($P=0.04$). Several studies have reported similar results. Bourgault et al [21] reported an increase in the heart rate in their study population, with the change being significant with the OTSS in comparison with the CTSS ($P<0.05$). Lee and coworkers [22] also found a rise in the heart rate with the OTSS, which was significant just after airway suctioning ($P<0.05$). Valderas and colleagues [23] reported no significant differences between the CTSS and the OTSS.

Our patients' systolic blood pressure increased during airway suctioning and then decreased afterward, and the changes were significant in all the post-suctioning stages ($P<0.05$). Furthermore, there was more stability in this regard with the CTSS than with the OTSS. This finding was in line with the results reported by Nazmieh et al [24] and Zolfaghari and coworkers. [25]

We found no significant difference with respect to diastolic blood pressure between the OTSS and CTSS groups. Zolfaghari et al [25] demonstrated a significant difference in diastolic blood pressure in that the rise was more significant in their OTSS group than in their CTSS group ($P<0.05$).

In the present study, the mean arterial pressure initially increased and then gradually decreased in both OTSS and CTSS groups, but the changes were less remarkable in the latter group and were significant in all the post-suctioning stages ($P<0.05$). Zolfaghari and colleagues [25] showed similar results, whereas Mohammadpour et al [26] found no significant difference between the OTSS and CTSS groups. Nazmieh and coworkers [24] reported a rise in the mean arterial rate in their CTSS group a minute after airway suctioning.

In both of our study groups, PaO_2 decreased after the suctioning of the airway and then had a gradual increase; the reduction, however, constituted statistical significance in the OTSS group ($P=0.018$). Accordingly, the OTSS may have a higher efficacy in decreasing the pressure of oxygen. This finding is concordant with the result reported in a study by Lasocki et al.[27]

According to our results, the change in $PaCO_2$ was not significant in any stages after airway suctioning in both groups ($P>0.05$). Nazmieh et al [24] reported that $PaCO_2$ decreased significantly with the CTSS in comparison with the OTSS.

Oxygen saturation decreased after the suctioning of the airway in both of our study groups. The reduction was significant in all the stages ($P<0.05$), and it was more stable in the

OTSS group. Seyed Mazhari et al [24] and Nazmieh and colleagues [28] reported similar results.

In our study, the change in pH was not significant in any stages after airway suctioning (P<0.05), which chimes in with the result reported by Özden et al. [29]

The $AaDO_2$ gradient initially rose after airway suctioning and then dropped gradually in both of our study groups. The increase was higher in the OTSS group, and the changes were significant just after the suctioning of the airway (P=0.039). This result is similar to that reported in a study by Copnell et al. [30]

According to our findings, the PaO_2/FiO_2 ratio decreased after airway suctioning and increased gradually afterward. The reduction was more pronounced in the OTSS group, with the change constituting statistical significance (P=0.018). In contrast, in the study by Copnell et al, [30] no difference was observed between the 2 groups.

We found that the changes in the hemodynamic and oxygen parameters were less pronounced in the CTSS group. Given the importance of the stabilization of patients following cardiac surgery, the CTSS appears to be more suitable in this group of patients inasmuch as these parameters are subjected to fewer disturbances with this method.

First and foremost among the limitations of the present study is that while with the OTSS it was possible to suction the trachea and the mouth simultaneously, suctioning the mouth was not possible with the CTSS. Another drawback of note is that our nurses had more experience with the OTSS than with the CTSS and they generally preferred the former. Given that the CTSS is especially useful in unstable patients or those who are suffering from oxygenation problems (eg, hypoxemia), we would recommend that new training programs be devised for nurses in the ICU, as well as for medical students, with an emphasis on the use of the CTSS.

CONCLUSIONS

In the immediate post-cardiac surgery period, it is of vital importance that the patient be stabilized and hypoxia be prevented. In light of the results of the present study, it appears that the CTSS causes fewer disturbances in the hemodynamic and oxygen parameters than the OTSS.

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