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Effectiveness of Suctioning Methods on Cardiorespiratory Parameters among Critically ill Children Undergoing Mechanical Ventilation

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Abstract: **Suctioning of secretions from endotracheal tube is one of the basic procedures performed daily for mechanically ventilated patients at pediatric intensive care unit. Two methods for suctioning are used and known as an open and closed suction. This study was aimed to investigate effectiveness of suctioning methods on cardiorespiratory parameters among critically ill children undergoing mechanical ventilation. Research design: quasi-experimental was carried out to meet the aim of this study. Subjects: A purposive sample included 60 pediatric patients undergoing mechanical ventilation and divided randomly into two group. Setting: The study was done at pediatric intensive care in Aswan University Hospital. Tool: Pediatric assessment sheet was used for collecting data, which included two parts: Child' demographic data and an assessment sheet to monitor children' cardiorespiratory parameters as oxygen saturation, heart rate, systolic and diastolic blood pressure and respiratory rates. Results: There were highly statistical significant differences between the two methods of suctioning as regards the mean of respiratory rate, Oxygen saturation, among children before, during and after the closed and open suctioning methods, (P<0.001) while no statistical significant difference were found as regards the mean of heart rate, systolic and diastolic blood pressures. Conclusion: The use of the closed suction system leads to less disturbances in the cardiorespiratory parameters compared to open suction system among children under mechanical ventilation. Recommendation: Nurses should be encourage in all pediatric intensive care units and trained to implement closed suction system in their sitting.**

Keywords: **Suctioning methods, Cardiorespiratory Parameters, Critically Ill Children, and Pediatric Intensive Care Unit.**

1. INTRODUCTION

Endotracheal suctioning is one of the common procedures performed by nurses in intensive care units often to maintain of exchange gases, adequate oxygen, and alveolar ventilation in patients under mechanical ventilation **(Oh, et al., 2015).** As members of health care, nurses play an important role in the suction process and their experience in using the usual or new methods is essential for development of evidence-based practices (**Valizadeh, et al., 2014)**.

Suctioning is implementing several times by nurses as a routine care because children who are unable to cough, ineffective mucociliary movement function, impaired the function of irregular glottic and insufficient humidification **(Chegondi, et al., 2018).** Mechanical ventilation is used for some infants in neonatal intensive care unit (NICU) for several physiological and clinical reasons and is increasingly used as a life-saving tool in treating acute and chronic respiratory failure, especially in reversible cases. Effectively improves gas exchange while reducing dyspnea and inspiratory effort. However, it also impairs the spontaneous removal of airway secretions in critical patients, and coughing

is less effective or impossible **(Govoni, et al., 2012 & Schettino, 2014).** Endotracheal suction is necessary for children treated with Mechanical ventilation to remove secretions and prevent endotracheal tube and lower airways blockage **(Asgari, et al., 2013).**

Suctioning of the tracheal tube is an arduous and uncomfortable process that may cause complications such as vagal stimulation, increase respiratory rate, atelectasis, hypoxia, increase intracranial pressure, damage to the lining of the chip area, cardiac dysrhythmia, bleeding, and an increased risk of hospital-acquired infections. These physiological complications can also affect the central nervous system, leading to manifestations such as agitation, pain, hallucinations, aggression, delusions, anxiety, and intensity of disease **(Barr, et al., 2013 & Sole, et al., 2015).**

The open suction system and the closed suction system are standard methods for suctioning lung secretions. To remove the airway secretions of the patients, an open suction technique is performed by separating the ventilator circuit and inserting a sterile suction catheter. In a closed suction system, suction is done using a catheter in an enclosed casing attached to the inside of the trachea, by placing a catheter between the endotracheal tube and the Y segments of the ventilator circuit without separating the ventilator circuit **(Ozden, and Gorgulu, 2014 & Haghighat, and Yazdannik, 2015 & Kuriyama, et al., 2015).**

Significance of the study:

Suction tube is a device to remove secretions and keep the airways open and causes many complications. Early complications of the suctioning include changes in blood pressure, heart rate, breathing and oxygen saturation **(Alizadeh, 2008).** One of the measures to keep the airway open is to suction the endotracheal tube in patients under ventilation. This procedure can be accompanied with some complications. An appropriate suction method can be selected to prevent severe complications **(Afshari, et al., 2014).** Therefore; it is necessary to evaluate vital signs during endotracheal tube suctioning to control and prevent the most serious complications **(Phipps, et al., 2003).**

Aims of the study:

The present study aimed to investigate the effectiveness of suctioning methods on cardiorespiratory parameters among critically ill children undergoing mechanical ventilation.

Research Hypotheses:

1. There are differences on cardiorespiratory parameters of pediatric intensive care patients when an open or closed suction is performed.

2. The closed suction method is more effective on the cardiorespiratory parameters than open suction method among pediatric intensive care patients undergoing mechanical ventilation.

2. SUBJECTS AND METHODS

Research design:

Quasi-experimental research design was carried out to meet the aim of this study.

Setting:

This study was conducted at Pediatric Intensive Care Unit in Aswan University Hospital from the beginning of May 2018 until the end of October 2018.

Subjects:

A purposive sample included 60 pediatric patients undergoing mechanical ventilation taken from pediatric intensive care unit for six months.

The total sample was divided randomly into two groups (each group containing 30 infants) using simple random number table (the first infant was selected to perform the open suction method (group 1) and the second infant was selected for closed suction method (group 2) and so on.

All children who are undergoing mechanical ventilation and their parents accepted to participate in this study were included in the study.

Tool for data collection:

Pediatric assessment sheet (English form) was used to collect the data of this study (developed by the researcher), which included two parts as follows:

Part 1: Demographic data of children as gender, age, weigh, height, hospitalization reason, and duration of hospital stay**.**

Part 2: An assessment sheet to monitor the children' cardiorespiratory parameters as oxygen saturation, heart rate, systolic and diastolic blood pressure and respiratory rates.

Methods for data collection:

- Administrative approval was obtained from the responsible persons (directors of Aswan University Hospital and head of pediatric intensive care unit).

- Written approvals were taken from the parents of the hospitalized children after presenting ourselves to them and explaining the purpose of the study.

- At the pediatric intensive care unit, the researchers introduced themselves and informed the nurses about the nature of the study.

- **Pilot study:** pilot study was conducted on 10% of the sample size (6 children to test the applicability of the tool; and included in the study results because no modification were done after the pilot study.

- **Validity:** The validity of the tool was tested by measuring its contents validity index by 5 experts in both pediatric nursing and critical nursing field and it equaled 91% .

- **Reliability:** The reliability of the tool was calculated statistically by alpha crombach test (r=0.82).

- In 6 months duration we enrolled 60 children undergone mechanical ventilation, divided into 30 children for open suctioning methods (group 1) and 30 children for closed suctioning methods (group 2).

- The children' demographic data were collected from the children record.

- All children received oxygen by 100% for 2 minutes before suction and 2 minutes after the suction immediately.

- In the open suction group, the endotracheal tube was disconnected from the ventilator. A supply including a glove, ambo bag and a suitable size of the disposable suction catheter were passed down to the endotracheal tube and extended until resistance was met and 0.5 cm was withdrawn.

- Children in the close endotracheal suction system (CTSS) group were connected to an appropriate size close suction catheter which selected according to the manufacturer's recommendations for every size of endotracheal tube. It was placed between the endotracheal tube and the Y piece. The suction catheter was in the locked position and the water irrigation port was kept closed all the time. Then for suctioning, it was unlocked and inserted into the endotracheal tube via controlled by thumb valve.

Measurements:

- Cardio-respiratory parameters [the heart rate (beat/min), respiratory rate (c/min), systolic and diastolic blood pressure (mmHg), and oxygen saturation(%)] were done and recorded at five consecutive measurements [before suction (baseline), during the suction, immediately after suction (0 min), post suctioning 5th minute and post suctioning 15th minute] were Measured.

- Oxygen saturation, heart rate, and blood pressure were obtained using monitor while the respiratory rate was obtained from the mechanical ventilator.

- The mean of the heart rate, respiratory rate, systolic and diastolic blood pressure, and oxygen saturation in open and closed suctioning methods were compared with the two suctioning methods before, during, immediately, and 15th minute after suctioning.

Field of the study:

- The researchers collected the data during a period of six months from the beginning of May 2018 until the end of October 2018. This was done during the routine work of the hospital at morning. The assessment sheet requires about 15-20 minutes filling; about 1-3 children under mechanical ventilator were collected per week.

Ethical consideration:

Written consent was obtained from each parent to participate in the study. Participates have the ethical rights to agree or refuse to participate. The researchers informed them that the information obtained would be confidential and used for the study purposes only. The parents had the right to withdraw from the study at any time during the study without any effect on the care provided that for their neonates.

Statistical analysis:

Date entry and data analysis were done using SPSS version 19 (Statistical Package for Social Science). Data was presented as mean and standard deviation. Chi-square and Fisher Exact tests were used to compare qualitative variables. Mann-Whitney test was used to compare quantitative variables in case of non-parametric data. P-value was considered statistically significant at $P < 0.05$.

3. RESULTS

Table 1 showed the mean ±SD for the age of children in open and closed suction was 2.14 ± 2.48, 1.18 ± 1.69 years respectively. In open suction method, half of children (50.0%) were males and half were females (50.0%) while closed suction children 26.7% were males and 73.3% were females. As for the mean ±SD of children weight in open and closed suction methods was 8.65 ± 4.08 and 8.22 ± 3.88 respectively and the means ±SD of height was 78.92 ± 18.09 and 69.63 ± 16.15 respectively.

Table 2 illustrated the hospitalization reason for children undergoing mechanical ventilation in open and closed suctioning. This study revealed that about one third (33.3%) of children in open suction method had septic shock, followed by bronchopneumonia (20.0%) and 10.0% in the case of convulsion, while in closed suction, more than one third of children (36.6%) were bronchopneumonia followed by 16.7% heart failure and 13.3% convulsion.

With regard to the mean of duration of hospital stay and suctioning in open and closed suction methods the results **in table 3** revealed that the mean duration of hospital stay was 12.67 ± 14.81 and 5.10 ± 2.29 seconds, respectively (P <0.047*). Mean suction duration in open and closed suction methods was 15.83 ± 2.61 and 7.50 ± 2.50 seconds, respectively (P < 0.001**).

Table 4 illustrated that mean heart rate was lower during suction and immediately after suction in closed suction than in open suction (131.93 ± 25.24vs 145.03 ± 26.72 and128.23 ± 31.06vs144.40 ± 24.51respectively) but there were no significant differences observed between the two suction methods in all consecutive measurements.

Table 5 represented the mean ±SD of respiratory rate among studied children in open and closed suction, as shown in this table before suction there was no statistical significant differences between the two suction methods, but during suction, immediately after suction, 5-min after suction, and 15-min after suction there was highly statistically significant differences between the two suction methods (p=0.000**) with significance reduction of respiratory rate about 10 to 15 cycle/minutes between the two suction methods.

Table 6 revealed systolic blood pressure of children undergoing mechanical ventilation in open and closed suction. As shown in this table, no significant differences were observed between the two suction methods in terms of mean systolic blood pressure in the five consecutive measurements.

As regards the mean rates of diastolic blood pressure, the results **in table 7** revealed that the mean rates of diastolic blood pressure was lower in closed suction than in open suction and no statistically significant differences were observed between the two suction methods in terms of mean diastolic blood pressure before suction, immediately after suction, 5-min after suction, and 15-min after suction while there was a significant difference between the two suction methods during suction (P=0.050*).

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Table 8 showed that children in the closed suction group have a higher mean of Oxygen saturation than those in the open suction group in the five consecutive measurements particularly during suction and immediately after suction (94.03 ± 3.85vs 85.53 ± 8.94 and 97.67 ± 2.04vs 90.63 ± 9.76 respectively). There were highly statistical significant differences between the two suction methods during suction, immediately after suction and 5-min after suction and the P value was 0.000**.

Table 1: Percentage distribution of the children according to their characteristics in open and closed suction (n=60)

Personal data	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Age (years)	2.14 ± 2.48	1.18 ± 1.69	0.106
Sex:			
Male	15 (50.0%)	8 (26.7%)	0.063
Female	15 (50.0%)	22 (73.3%)	
Weight	8.65 ± 4.08	8.22 ± 3.88	0.841
Height	78.92 ± 18.09	69.63 ± 16.15	0.030*

* statistical significance differences, $\bar{x}$ ± SD (mean and stander deviation)

Table 2: Hospitalization reason for children undergoing mechanical ventilation in open and closed suction

Hospitalization reason	Open suction (n= 30)		Closed suction (n= 30)		P-value
	No.	%	No.	%	
Bronchopneumonia	7	23.3	11	36.6	1.107
Convulsion	3	10.0	4	13.3	1.000
Gastroenteritis	2	6.7	2	6.7	1.000
Heart failure	3	10.0	5	16.7	0.706
N. sepsis	0	0.0	2	6.7	0.492
Post arrested	2	6.7	0	0.0	0.492
RDI	2	6.7	3	10.0	1.000
Septic shock	10	33.3	3	10.0	0.028*

* statistical significance differences

Table 3: Mean and standard deviations of duration of suctioning and hospital stay among studied children in open and closed suction (n=60)

Clinical data	Open suction (n= 30)	Closed suction (n= 30)	P-value
Duration of hospital stay/days			0.047*
$\bar{x}$ ± SD	12.67 ± 14.81	5.10 ± 2.29	
Median (Range)	7 (1.0-60.0)	5.0 (2.0-9.0)	
Duration of suctioning/seconds			0.000**
Mean ± SD	15.83 ± 2.61	7.50 ± 2.50	
Median (Range)	15.0 (10.0-20.0)	7.0 (4.0-15.0)	

* statistical significance differences, ** highly statistical significance differences, $\bar{x}$ ± SD (mean and stander deviation)

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Table 4: Mean and standard deviations of heart rate among studied children in open and closed suction (n=60)

Heart rate	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Before suction	143.37 ± 27.34	131.93 ± 25.24	0.108
During suction	145.03 ± 26.72	137.97 ± 26.72	0.424
Immediately after suction	144.40 ± 24.51	128.23 ± 31.06	0.107
5-min after suction	138.63 ± 24.92	138.97 ± 25.05	0.982
15-min after suction	139.77 ± 26.25	134.17 ± 26.50	0.668

$\bar{x}$ ± SD (mean and stander deviation)

Table 5: Mean and standard deviations of respiratory rate among studied children in open and closed suction (n=60)

Respiratory rate	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Before suction	32.03 ± 12.14	31.15 ± 9.65	0.269
During suction	38.43 ± 11.42	23.07 ± 8.67	0.000**
Immediately after suction	37.03 ± 7.74	28.57 ± 10.30	0.001**
5-min after suction	39.47 ± 10.95	29.70 ± 12.09	0.003**
15-min after suction	39.87 ± 9.84	28.00 ± 11.29	0.000**

** highly statistical significance differences, $\bar{x}$ ± SD (mean and stander deviation)

Table 6: Mean and standard deviations of systolic blood pressure among studied children in open and closed suction (n=60)

Systolic blood pressure	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Before suction	130.93 ± 32.47	120.83 ± 24.17	0.304
During suction	126.27 ± 24.55	116.70 ± 31.71	0.105
Immediately after suction	125.33 ± 19.91	121.10 ± 33.21	0.375
5-min after suction	117.90 ± 22.43	112.60 ± 28.66	0.264
15-min after suction	116.10 ± 19.50	109.70 ± 23.88	0.297

$\bar{x}$ ± SD (mean and stander deviation)

Table 7: Mean and standard deviations of diastolic blood pressure among studied children in open and closed suction (n=60)

Diastolic blood pressure	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Before suction	76.20 ± 22.65	77.00 ± 22.56	0.847
During suction	82.97 ± 18.40	75.17 ± 28.56	0.050*
Immediately after suction	80.27 ± 19.14	71.03 ± 24.58	0.095
5-min after suction	76.07 ± 19.04	70.23 ± 26.54	0.166
15-min after suction	76.10 ± 16.57	67.30 ± 20.49	0.104

* statistical significance differences, $\bar{x}$ ± SD (mean and stander deviation)

Table 8: Mean and standard deviations of Oxygen saturation (%) among studied children in open and closed suction (n=60)

Oxygen saturation (%)	Open suction (n= 30)	Closed suction (n= 30)	P-value
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Before suction	89.10 ± 11.58	89.17 ± 9.59	0.876
During suction	85.53 ± 8.94	94.03 ± 3.85	0.000**
Immediately after suction	90.63 ± 9.76	97.67 ± 2.04	0.000**
5-min after suction	93.87 ± 10.50	98.27 ± 2.45	0.000**
15-min after suction	95.07 ± 10.18	97.50 ± 2.84	0.461

** highly statistical significance differences, $\bar{x}$ ± SD (mean and stander deviation)

4. DISCUSSION

Endotracheal suctioning is one of the most common procedures implemented at pediatric intensive care units. Open and closed suction are the two methods used for endotracheal suctioning, but none of them showed the superior suction method in the pediatric intensive care unit (**Evans et al., 2014)**. Endotracheal suctioning in children is accompanied by negative effects such as desaturation of arterial blood oxygen, irregular respiratory rate, bradycardia temporary increases in arterial blood pressure. Routine open of endotracheal suctioning method is associated with significantly lower heart rate and oxygen saturation **(Chegondi, et al., 2018).** *So* the current study was conducted to investigate effectiveness of suctioning methods on cardiorespiratory parameters among critically ill children undergoing mechanical ventilation**.**

This study was done on 60 children who were mechanically ventilated from May 2018 to October 2018 at pediatric intensive care unit in Aswan University Hospital. Children were randomized divided into two groups, group 1 with open tracheal suction system (OTSS) and group 2 with closed tracheal suction system (CTSS).

The present study revealed that there were no statistically significant differences between study and control group in relation to the characteristics of children. This confirms that these two groups were homogenous during the study.

This study showed the mean duration of hospital stay among studied children in open and closed suctioning; it was observed that, children in closed suctioning method had a shorter hospital stay than children in open suctioning method and there was no statistically significant difference between the two suction methods as regard the mean duration of hospital stay. This was coordinated with the study by **Elmansoury and Said (2017)** which entitled "Closed suction system versus open suction" and illustrated that group B with closed suction system had shorter length of stay than of patients in group A with an open suction system.

With regard to the mean duration of suctioning/seconds in our study, it was observed that, the mean duration of suction in closed suctioning was less than the mean duration of suction in open suctioning. **Morrow and Argent, (2008) & American Association for Respiratory Care (AARC), (2010)** also stated that**,** suction time should be as low as possible, some authors recommend 15 seconds and others less than 10 seconds. *From the researchers' point of view*, these results may be due to an open suction system is performed by disconnecting the child from ventilator and the suction catheter attached to the endotracheal tube while in closed suction (CS) system, the nurse connected the catheter to ventilator circuit and it becomes part of the mechanical ventilators device and stay in connect with the patient more than 24 hr. according to the manufacturer, the nurse does not require the catheter to be attached or disconnected or to prepare the equipment at each time of suction procedure, so that CS methods saving time.

The current study revealed that the mean of respiratory rates was lower in closed suctioning than in open suctioning during suction, immediately after suction, 5-min after suction, and 15-min after suction with highly statistical significant differences between the two suction methods. This finding was opposed to another study by **Cardoso et al., (2015)** which entitled "Randomized crossover trial of endotracheal tube suctioning systems use in newborns" and reported that, there was an increase in respiratory rate only with the use of open suction without significant differences. Also opposed to another study by **Taheri et al., (2012)** which stated that, respiratory rate after three minutes of suction showed a significant decrease in both steps in open method compared to closed method.

The results of the current study indicated that, the mean of Oxygen saturation was higher in the closed method compared with the open method with a highly statistically significant difference between the two methods during, immediately, and 5-min after suctioning. This was coordinated with a study conducted by **Taheri et al., (2012)** which entitled " The effect of open and closed endotracheal tube suctioning system on respiratory parameters of infants undergoing mechanical ventilation" and reported that, the arterial blood oxygen saturation ratio decreased significant in the open method compared to the closed method during suctioning and immediately after suction. Also was also agreed with **Pirr et al., (2013)** who carried study entitled " Closed versus open endotracheal suctioning in extremely low-birth-weight neonates" and mentioned that, the mean minimum SpO2 was significantly higher during closed suction compared to open suction and agreed with **Soares de Paula and Ceccon (2010**) who carried study entitled " Randomized comparative analysis between two tracheal suction systems in neonates" and stated that, there was statistically significant improvement in Oxygen saturation after procedure in both groups.

The results of the present study indicated that, there was a decrease in the mean of heart rate in the five consecutive measurements in closed suction compared to open suction without significant differences. This finding is consistent with the results of **Yazdannik et al., (2013)** who carried study entitled " Comparing two levels of closed system suction pressure in ICU patients" and stated that, there was no significant difference between the closed and open suction methods as regards heart rate**.** The study of **Hoellering et al., (2008)** also showed some changes in heart rate in open and closed suctioning. Others study by **Bourgault et al., (2006)** entitled " Effects of endotracheal tube suctioning on arterial oxygen tension and heart rate variability" also showed that heart rate in patients has increased significantly in the open suction method compared to closed technique. As agreed with **Asgari et al., (2013)** who carried study entitled " and reported that, pulse rate was significantly lower in the closed suction than the open one. *From the researchers' point of view*, these results may be related to, in the open suction method the suction tube disconnect from the ventilator and this lead to reduced oxygenation and hypoxia induced, Then, hypoxia stimulates the adrenergic nervous system, which controls the cardiovascular and hemodynamic responses as tachycardia, as a compensatory response to the lack of blood Oxygen saturation.

With regard to the mean systolic and diastolic blood pressure the current study showed that there was a decrease in systolic and diastolic blood pressure in closed suction method at the five consecutive measurements with no statistically significant differences between the two groups. This result correlates with **Jongerden et al., (2012)** who carried study entitled " Changes in heart rate, mean arterial pressure, and oxygen saturation after open and closed endotracheal suctioning" and revealed that systolic and diastolic blood pressures did not differ significantly after the two suction methods. As agreed with another study by **Afshari et al., (2014),** no statistically significant differences were observed between the two suction methods in terms of mean systolic blood pressure, diastolic blood pressure, and mean arterial pressure in the five consecutive measurements**.**

From the researchers' point of view, in a close endotracheal suction system, the catheter is a part of a ventilator circuit without the need to disconnect the ventilator and thus improve Oxygenation; significantly reduce signs of hypoxemia; subsequently the hemodynamic parameters as heart rate, systolic and diastolic blood pressure.

5. CONCLUSION

According to the findings of this study, the study concluded that:

The use of the closed suction system leads to less disturbances in the cardiorespiratory parameters, in particular, heart rate, respiratory rate, Oxygen saturation, systolic and diastolic blood pressures compared to open suction system in children undergoing mechanical ventilation because it does not deprive them of ventilation and oxygen support. Therefore, the close suction system is the best method of suction for critically ill children within the pediatric intensive care units.

There were highly statistically significant differences between the two methods of suction as regards the mean of respiratory rate, Oxygen saturation, in children before, during and after the closed and open suctioning methods, but no statistically significant difference as regards the mean of heart rate, systolic and diastolic blood pressures.

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6. RECOMMENDATIONS

Based on the results of the present study, the current study recommended that:

1- All health organizations should support the practice of closed suction as a high quality nursing care.

2- Nurses in all pediatric intensive care units should be encourage and trained them to implement closed suction system.

3- More scientific evidence is needed to evaluate the benefit of a closed suction system.

4- We recommend that the standard guidelines on a closed suction system be included in the current education of pediatric nurses and critical care.

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