IOSR Journal of Nursing and Health Science (IOSR-JNHS)
e-ISSN: 2320–1959.p- ISSN: 2320–1940 Volume 8, Issue 4 Ser. VII. (July-Aug .2019), PP 74-80
www.iosrjournals.org

The Effect of Open Versus Closed Tracheal Suctioning System on the Physiological outcomes of Mechanically Ventilated Patients

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Abstract:
Background: *Tracheal suctioning (TS) is one of the most important procedures implemented formechanically ventilated patientto maintain airway patency. Recently, there are two types of suctioning system which are open and closed suctioning system. The current study was carried outto identify the effect of open versus closed tracheal suctioning system on the physiological outcomes of mechanically ventilated patients.*
Methods: *A quasi experimental design was carried out on a purposive sample of 74 patients admitted in the intensive care units at king fahad general hospital and king abdulaziz hospital. The samples were divided to closed suctioning system (group A)and open suctioning system (group B). Patient`s physiological outcomes evaluation sheet was utilized for data collectionbefore,during, immediately after TS, 5 minutes after TS, and 10 minutes after TS.*
Results*: There were significant differences between the studied groups in relation to systolic blood pressure, oxygen saturation, respiratory rate, mean arterial pressure, and central venous pressure during the TS ($p<0.05$). Also there were significant differences between the studied groups in relation to oxygen saturation, respiratory rate, and mean arterial pressure immediately after the TS ($p<0.05$), while 5 minutes after TS the significant was in oxygen saturation and central venous pressure ($p<0.05$).And in 10 minutes after TS the significant was in central venous pressure and PetCo2($p<0.05$).*
Conclusions: *The finding of the study illustrate that closed suctioning system caused fewer alteration in patient`s physiological outcomes than open suctioning system.*
Recommendation: *the researcher recommend using of the CSS at all ICUs communities, and perform similar study to be replicated with a larger sample size.*
Key words: *Tracheal suctioning, open suctioning system, closed suctioning system, physiological outcomes, mechanically ventilated patient.*

Date of Submission: 03-08-2019 Date of Acceptance: 19-08-2019

I. Introduction

Tracheal suctioning (TS) is a procedure implemented to remove secretion from the patient airway by insertion of suction catheter (SC) through the artificial airway such as endotracheal tube(ETT) or tracheostomy tube (TT) [1] .It is essential and frequently procedure implemented for critically ill patient required mechanical ventilation(MV) to maintainairway patency by removing pulmonary secretion, thereby enhancing effective respiration, maintain ventilation, and avoid secretion accumulation[2]. TS is necessary procedure for ventilated patient, but it may cause serious consequences such as alteration of cardiorespiratory parameters, hypoxemia, cardiac arrhythmia and infection[3] [4].Therefore, monitory of physiological outcomes during and after the TS procedure is important to minimize the associated complication[5].

Tracheal suctioning can be performed by either an open or closed suctioning system. During open suctioning system (OSS) the patient is disconnected from MV and the airway is suctioned by sterilizedsingle used SC connected to the vacuum system, then the patient re-connected to ventilator[5]. Disconnecting the patient frome the MV result in dropping of airway pressure as will losing the lung volume. However, there is another suction system known as closed suctioning system (CSS). It is multiuse SCconnected to the MV circuit which allows the SC enters into artificial airway through one-way valve without disconnecting the patient from the ventilator during the TS. Thus, maintain the positive end-expiratory pressure (PEEP) and the lung volume [6].

Several researchers compared the effect of both suctioning systems on physiologicoutcomes, oxygenation and ventilation alteration, and incident ofventilator associated pneumonia (VAP). Some of studies have shown that there were no differences between OSS and CSS, in regard of VAP incident rate, physiological changes, costs, and effectiveness of secretion removal[7] [8] [9] . In contrast, other researchers believethat CSS in compare to OSS has positive physiological outcomes consequences and reduce the incident rate of infection[6] [8]

[10].The researchers explained their results as OSS is associated with interruption of patient`s ventilation, which can predispose to physiologic disturbances due to decay of intrathoracic pressure, like hypoxemia, altered mean arterial pressure, and heart rate [11].

The previous related literature review is insufficient and conflicting regarding the two tracheal suctioningsystems.In addition, CSS has been newly implemented in some of the Saudi Arabian healthcare settings.Therefore, the current study was conducted to evaluate the effect of open versus closed tracheal suctioning system on the physiological outcomes of mechanically ventilated patients .

1.1. Research Hypothesis

A closed suctioning system has fewer physiological disturbances on physiological outcomes stability more than an open suctioning system for mechanically ventilated patients.

2. Material and Methods

2.1 Design: A quasi-experiment design with repeated measurements was used in thisstudy.

2.2Setting: The study was conducted in Intensive Care Units at King Fahad General Hospital (KFGH) and King Abdul-Aziz Hospital (KAAH).The ICU in KAAH consists of 20 bed capacity, dedicated for all medical and surgical patients who are admitted either as emergency or electives cases. The main indication for ICU admissionwere respiratory, cardiovascular, neurologic, non-operative trauma, postoperative trauma, and postoperative non-trauma.

On another hand, the ICU in KFGH consist of twoof intensive care unit. They are Surgical Intensive Care Unit (SICU) with 10-bed capacity and exclusive for critically ill surgical, trauma and neuroscience patients who have undergone a variety of general and specialty surgical procedures. Including all gastrointestinal procedures, head, neck, and orthopedic surgery and renal transplantation, as well as all other surgical specialties. Then, medical intensive care unit (MICU) with 15-bed capacities, generally occupied with patients from the emergency room and general ward, with a variety of medical diagnoses such as sepsis, pulmonary disease, oncology, renal failure, infectious diseases, and multiple organ dysfunction

2.3Subjects: A purposive sample of 74 patients who fulfills inclusion criteria were included in the study, based on the power analysis Epi-Info program with the confidence level of 95% and the marginal error of 5%.

2.4 Inclusion criteria: Patient in this study were selected based on the following criteria: (a) aged between 18 and 65 years old, (b) male or female patients, and (c) mechanically ventilated patients, (d) hemodynamically stable patient, and (e) required tracheal suctioning system.

2.5 Exclusion Criteria: Patients who were subjected to nursing interventions, resuscitation, or ventilator changes before a TS procedure with less than 15 minutes.

2.6Study tool: One tool was developed by the researchers to conduct the recent study"Patient`s physiological parameters evaluation sheet" based on a previous conducted studies and relevant literatures [12] [13] [14] . It was used to assesspatient's baseline characteristics and physiological outcomes. It consists of two parts:

Part 1: Baseline characteristics assessment sheet,It divided in to three sections which are **(a)** Demographic and clinical characteristics section(like age, sex, unit, use of sedation, and diagnosis) **(b)** ventilator parameters section (asduration of MV, ventilator mode, fraction of inspired oxygen (FiO_2), Positive end expiratory pressure (PEEP), positive inspiratory pressure (PIP), flow rate, expiratory time (Te), inspiratory time (Ti) andinspiratory: expiratory ratio (I: E)**(c)** suction characteristics section which include size of the SC, type and size of airway, frequency of suctioning, and duration of oxygen reconnection.

Part 2: physiological outcomes follow up sheet, It was developed to monitor the patient's physiological outcomes before, during, and three times after the suctioning procedure (immediately after, 5 minutes, and 10 minutes after TS). Physiological outcomes consist of cardiovascular outcomes (HR, BP, CVP, and MAP) and respiratory outcomes (SpO_2, RR and $PetCO_2$). heart rate (HR), systolic blood pressure (SBP), preductal oxygen saturation (SpO2). mean airway pressure (MAP), central venues pressure (CVP), diastolic blood pressure (DBP),: end-tidal carbon dioxide pressure (PetCo2) .

2.7Validity and Reliability

The data collection tool was revised by a jury of five academic experts in the medical surgical nursing and emergency and critical care nursing at the faculty of Nursing in king Abdulaziz university, and two expert clinician nurses from KFGH to check tool validity . The validity, clarity of items, and completeness were tested by the expert jury.Feedback of jury considered and required modifications of the tool was done. Their suggestion was to categorize the B/P reading. The reliability of the developed tool was tested using internal consistency methods (Alpha Cronbach test) by using SPSS version 20. The Alpha Cronbach test result was a=0.714, which indicates an accepted reliability of the tool. A pilot study was conducted to test the feasibility and applicability of the developed tool.

2.8Methods for data collection

Approval for conducting this study was obtained from the ethical committee of postgraduate studies at KAU and the ethical committee of the Ministry of Health. Informed consent was obtained prior participation from all patients or their substitute decision maker (if unconscious patient), after explaining the potential benefits and hazards from participation. The anonymity, privacy, confidentiality, and the right to refuse to participate in the study were assured.

The data was collected in four monthsfrom September to December 2018 during the morning duty by using an observational flow chart.Suctioning procedure was performed by the researcher to minimize the variations in suctioning technique, based on American association of respiratory clinical practice guideline.care (AARC, 2010). Firstly, demographic information was collected from the subjects' chart before initiating of the TS.

Primarily,Patients were randomly divided into two groups, group Areceived CSS, while group Breceived OSS. For both groups the clinical indication for TS was assessed initially, the head of the patient was positioned at 30 degree, than the appropriate size of SC was selected. Physiological parameters were measured before, during, and after TS (immediately after, 5 minutes after, and 10 minute after TS) through a cardiomonitor beside the patient`s bed.Hyper-oxygenationwith 100% oxygen was delivered for 60 seconds before and after the suctioning event for both group.

Forthe group A, the CSS was remained connected to MV circuit through the adapter, patients were heperoxygenatedthru MV. The SC was inserted in to the artificial airway through Y-piece connector and advanced until resistant was encountered, then withdrawn for 1-2 cm. Negative pressure was applied on 120 mmHg while SC was gently rotated and withdrawn. Patients were hyper-oxygenated and monitored.

For the group B, ETT or TT was disconnected from the MV the SC was passed down in the artificial airway until resistance was metthan withdrawn for 1-2 cm.The suction pressure was applied on 120 mmHg, and the SC was withdrawn while rotating slightly. The patient was then immediately reconnected to the MV circuit. The suction was done 1-3 times and from 5-10 seconds depending on patient need in both groups. The patient was excluded if required repetitive suctioning more than three times.

II. Result

Table 1 shows the distribution of studied patients according to baseline characteristics. Regarding the ages, it was observed that the mean age of CSS groups was 37.6±2.1 while the mean age of the OSS group was (42.4±1.629). Also, the male gender was the majority of OSS and CSS groups (67.6%, 59.5% respectively). Moreover, most of the participants in CSS group were admitted to SICU (62.2%), while in OSS group they were admitted to MICU (54%). In relation to sedation, the findingillustrate that 64.9% of OSS group were under sedation, compared to CSS group who were 59.5%. Concerning the diagnosis, the majority of patients in OSS and CSS groups were neurological disorder cases (35.1%, 45.9% consequently). Additionally, it was observed that there weren`t significant differences between OSS and CSS regarding patients baseline characteristics.

Table 2 demonstrates comparison between suction characteristic among OSS and CSS group. It was observed that the majority of both groups (73%) had ETT while only 27% of patients had TT. 56% of inserted ETT size were 8 mm for CSS patients compared to 46% for OSS. Also size 8 mm TT was inserted for 70% of patients who had TT among two groups.Additionally, SC size 12 was the most common size used for patients in CSS (40.9%), while size 14 for OSS patients (54.1%). Also, approximately half of the patients in OSS group (54.1%) required 10 second to be reconnect to oxygen compared to CSS group who were connected to MV along the TS procedure. Moreover,half of patients in OSS (51.4%) need suctioning catheter pass only one time, compared to (89%) of patient with CSS.

Table 3 Illustrate a comparison between mean physiological outcomes (HR, SBP,DBP,SpO_2, RR, MAP, CVP, and $PetCo_2$) among OSS and CSS group at five different times of suctioning (before, during, immediately after, 5 minutes after, and 10 minute after TS).

The mean of HR in OSS group during, immediately, 5 minutes after TS, and 10 minutes after TS (93.2±12.2, 97.9±12.8, 93.1±12.5, 87.4±12.2 respectively) was significantly higher than CSS group (87.6±12.4, 90.1±11.7, 86.2±11.8, 81.2±11.7 respectively). Also, the mean of SpO2 in OSS group during five time assessment was lower (96.6±5.37, 88.7±4.54, 86.5±4.71, 91.7±3.15, 97.8±4.16corresponding) compared to CSS group (95.6±4.85, 94.2±4.04, 94.1±3.67, 95.2±3.42, 98.7±3.47 corresponding).

Moreover, the mean RR in OSS group was higher during and immediately after TS (21.1±38, 21.9±3.03 respectively) compared to CSS group (18.5±1.81, 18.8±2.12 corresponding). In regard MAP, the mean among OSS group was lower (88.19±2.23, 77.62±2.06, 78.54±2.33, 81.03±2.22, 83.43±2.31 respectively) compared to CSS (88.97±2.61, 82.84±2.69, 82.7±3.2.62, 82.92±2.58, 90.05±2.61 corresponding). The mean CVP among both group showed no significant differences.

The table demonstrate that there were no significant statistical variance between all physiological outcomes among OSS group & CSS group before TS. Moreover, the tables illustrate that there were significant statistical variance in HR,SPO2, RR, MAP, and CVP between OSS group and CSS group during the TS (P= 0.06, 0.05, 0.05, 0.03, 0.05 correspondingly).On other hand, there were significant statistical difference in SPO_2, RR, and MAP among two groups immediately after TS (P= 0.05, 0.05, 0.04 respectively).

Moreover, the table show that there were significant statistical difference between SPO2 & CVP between the two groups immediately after 5 minutes after TS (P= 0.05, 0.05 consequently). Additionally, there was significant statistical difference in CVP and PetCo2 between the two groups immediately after 10 minutes after TS (P=0.05, 0.05 correspondingly). At time, the results illustrate no significant statistical difference between two studied groups in relation to the other physiological parameters during different time interval.

III. Discussion

Tracheal suctioning is essentially performed procedure in mechanically ventilated patients. Based on reviewing the related literature the researcher observed that until now there are no concrete evidences of one system being better than the other(open vs closed TS). Therefore, the study was performed to evaluate the different effect of OSS and CSS on physiological outcomes stability of the mechanically ventilated patient.

As regard baseline characteristics of studied sample,the results revealed that around half of the OSS group was between 40 to 49 years old. While CSS group were between 30 to 39 years. Also, the majority of the studied patients were males, post-surgical cases and they were under sedation. Also, most of the patients in CSS were presented in SICU where most patients in OSS were in MICUwith no statistical significant differences between two groups in regard the baseline characteristics.

In relation to suction characteristics, the present study illustrates that there was no significant difference between the two groupsconcerning the size of the SC and tracheal tube type. The majority of the patients in OSS groupshad SC size 14 fr, while most patients of CSS had SC size 12 fr.

Concerning the comparison between OSS and CSS in relation to the mean physiological outcomes among both groups, the study found that TS through CSS can better preserve the stability of physiological outcomes in comparison with the conventional OSS. It was observed that there were significant differences between the studied groups in relation to SpO_2, RR, MAP, and CVP during the TS in different time interval. Also there were significant differences between the studied groups in relation to SpO_2, RR, and MAP immediately after the TS, while in 5 minutes after TS the significantdifferences was in SpO_2 and CVP, and in 10 minutes after TS the significantdifferences was in CVP and $PetCo_2$.

The mean HR in current study was increased during TS in OSS more than in CSS groups (93.2 ± 12.2, 87.6 ± 12.4 respectively) and returned to the base status after 10 minutes in CSS compared to OSS which sustained above before TS value (87.4±12.2, 81.2±11.7) with no significant differences between OSS and CSS groups during the five consecutive measurements. This finding was inconsistent with the finding of study conducted by Elsaman (2017)[15] , which show that both suctioning systems have similar effect of HR. Moreover, the current finding was constant with Afshari et al. (2014)[10] who emphasized that significant decrees were observed in HR and SpO_2 among OSS and CSS groups.The increase in HR seems to be due to the blockage of the tracheal tube by the SC which cause hypoxia and then bradycardia, or airway irritation by suctioning tube movement, or accompanied anxiety pain and stress which are caused by TS procedure itself.[16]

Regards SpO_2, the results show a significant differences between OSS and CSS groups in the four consecutive measurements of TS (during, immediately after, 5 minute after, and 10 minutes after TS). The mean SpO2 in OSS group significantly decreased during the TS compared to CSS (88.7±4.54, 94.2±4.04) and remained decreased 5 minutes after TS. Our finding was similar to these studies indicating better oxygen saturation with CSS. As during TS with CSS MV is continuous and this would maintain PEEP with minimal changes in FiO2, which a voiding lung volume loss [12] [17] [18] .

Moreover, the finding showed a significant difference between OSS and CSS in regard MAP. Mean MAP in OSS group significantly increased during, immediately after, and 5 minutes after TS(77.62±2.06, 78.54±2.33, 81.03±2.22 respectively) compared with CSS (82.84±2.69, 82.73±2.62, 82.92±2.58 respectively), however, MAP was similar to the initial value by 10 minutes after TS. SBP in CSS group increased significantly during and immediately after the TS, but the magnitude of increases was lower than observed in the OSS group. On the other hand, the current study shows that the mean RR in the OSS during and immediately after TS is significantly higher than the mean of RR in the CSS.The results of the current study could be attributed to the issue that the all patients are on MV, and the ventilator is the responsible for controlling of breathing for patients in intensive care unit, thus making the respiration more rapid or slower.

The present study results are consistent with the results of Taheri et al. (2012) [19]which showed that there was a significant difference between mean RR and arterial blood oxygen saturation before, during and after the closed and open suctioning. The results of this study are contradictory with a study carried out by Afshari et al. (2014) [10]who emphasized that no significant differences were observed between the two suctioning systems in term of SBP, DBP, and MAP in the five consecutive.

Additionally, the current result showed a significant differences among CSS and OSS groups regarding $PetCo_2$ in 10 minutes after TS. The mean of PetCo2 showed slightly changes during the different time interval of TS. And this may be a due to the short time of TS. This finding is consistent with study conducted by Vianna, et al. (2017)[20] to compare the effect of two different level of hyper-oxygenation on gas exchange during open endotracheal suctioning. They found increment of $PetCo_2$ level after TS with OSS in the two groups regardless of hyper-oxygenation duration.

4.1 Limitation

This study had some limitations that should be considered during interpreting the findings which are,the sample size was collected from two hospital setting in Saudi Arabia. Therefore, the result of this study is not representative of all ICUs in Saudi Arabia`s hospital**.** Moreover, all patients received 100% oxygenation before and afterTS which might mask the actual impact of suctioning with either suction system on oxygenation and ventilation.

4.2 Conclusion

CSS demonstrated substantial physiological benefits over OSS in the mechanically ventilated patients. The important basic physiological outcomes, $Sp0_2$ and HR, were significantly more stable during the use of CSS compared to OSS, as the OSS required an interruption of pressure support. Thus, the hypothesis was accepted, and the researcher recommend using of the CSS at all ICUs communities.

4.3 Recommendation

Closed suctioning system preserves better physiological outcomes stability than OSS in mechanically ventilated patient. Hence the researcher recommended using of the CSS at all ICUs communities. Moreover, similar study can be replicated with a larger sample size in order to generalize the study`s results.

Table 1: Distribution of patients according to baseline Characteristics

Baseline Characteristics	OSS		CSS		Chi-Squ	P. value
	No	%	No	%		
Age (year)						
20-29	2	5.40	2	5.40	7.938	0.284
30-39	13	35.1	19	51.3		
40-49	15	40.5	12	32.4		
50-60	7	18.9	4	10.8		
Mean±SD	42.4 ±1.629		37.6 ± 2.11			
Gender						
Male	25	67.6	22	59.5	0.520	0.315
Female	12	32.4	15	40.5		
Unit						
SICU	17	45.9	23	62.2	0.500	0.480
MICU	20	54.1	14	37.8		
Diagnosis						
Respiratory	8	21.6	9	24.3	7.678	0.689
Cardiac	5	13.5	10	28		
Metabolic	5	12.15	3	8.1		
Infection	1	2.7	2	5.4		
Trauma	1	2.7	0	0		
Neurology	17	45.9	13	35.1		
Sedation						
Yes	24	64.9	22	59.5	17.987	0.081
No	13	35.1	15	40.5		

OSS: open suctioning system, CSS: closed suctioning system. SICU: surgical intensive care unit, MICU: medical intensive care unit

Table 2: Distribution of closed suctioning system & open suctioning system groups

Variables	OSS		CSS		Chi-Squ	P. value
	N	%	N	%		
Suction catheter size						
10	5	13.5	9	24	3.921	0.392
12	12	32.4	15	40.9		
14	20	54.1	13	35		
ETT	27	73	27	73	0.05	0.603
TT	10	27	10	27		
ETT size						
6	2	4	0	0	4.769	0.216
7	8	31	3	11		
8	12	46	15	56		
9	5	19	9	33		
TT size						
8	7	70	7	70	3.251	0.192
9	3	30	3	30		
Patient reconnection to oxygen						
<10 sec	17	45.9	37	100	24.002	0.08
10 sec	20	54.1	0	0		
Frequency of suctioning						
1 times	19	51.4	33	89	12.678	0.190
2-3 times	18	48.6	4	11		

CSS: closed suctioning system, OSS: open suctioning system, ETT: endotracheal suctioning system, TT: tracheal suctioning system.

Table 3: Mean differences of physiological outcomes between open suctioning system and closed suctioning system groups through out suctioning time .

variable	T1			T2			T3			T4			T5		
Groups	OSS	CSS	test	OSS	CSS	test	OSS	CSS	test	OSS	CSS	test	OSS	CSS	test
Mean±SD	Mean (SD)	Mean (SD)	P	mean (SD)	mean (SD)	P	mean (SD)	Mean (SD)	P	mean (SD)	mean (SD)	P	Mean (SD)	Mean (SD)	P
HR	79.8	80.4	0.06	93.2	87.6	3.81	97.9	90.1	7.41	93.1	86.2	5.86	87.4	81.2	5.02
	11.2	12.1	0.81	12.2	12.4	0.06	12.8	11.7	0.09	12.5	11.8	0.08	12.2	11.7	0.08
SBP	110	114	1.12	115	117	0.32	117	116	0.06	115	114	0.06	114	112	0.42
	14.6	14.2	0.29	14.1	14.6	0.58	14.6	13.6	0.81	13.2	13.8	0.81	13	13.6	0.52
DBP	74.1	76.3	1.09	78.1	77.8	0.03	79.2	77.6	0.53	78.8	76.4	1.66	78.8	75.2	3.3
	9.17	9.31	0.31	8.79	9.31	0.87	10.2	8.94	0.47	10.1	8.64	0.23	8.88	8.41	0.07
SPO2	96.6	95.6	0.67	88.7	94.2	30.2	86.5	94.1	60.7	91.7	95.2	20.1	97.8	98.7	992
	5.37	4.85	0.42	4.54	4.04	0.05	4.71	3.67	0.05	3.15	3.42	0.05	4.16	3.47	0.32
RR	18.2	18.4	0.02	21.1	18.5	15.6	21.9	18.8	26.6	19.7	19.2	0.42	19.3	19.1	0.06
	1.82	1.69	0.89	3.38	1.8	0.05	3.03	2.12	0.05	1.84	3.92	0.52	2.37	3.93	0.81
MAP	88.19	88.97	1.93	77.62	82.84	4.76	78.54	82.73	4.26	81.03	82.92	2.55	83.43	90.05	1.18
	2.23	2.61	0.17	2.06	2.69	0.03	2.33	2.62	0.04	2.22	2.58	0.12	2.31	2.61	0.28
CVP	7.16	7.84	2.41	7.16	7.84	2.41	7.16	7.84	2.41	7.16	7.84	2.41	7.16	7.84	2.41
	1.79	1.95	0.06	1.79	1.95	0.05	1.79	1.95	0.13	1.79	1.95	0.05	1.79	1.95	0.05
PetCO2	39.3	38.3	2.53	39.1	38.3	1.66	38.2	38.3	0.02	38.2	38.3	0.06	37.8	34	31.5
	3.61	1.77	0.12	3.54	1.77	0.20	3.68	1.77	0.91	3.6	1.77	0.81	13.6	2.05	0.06

P is significant if < **0.05**, **T1**: before tracheal suctioning, **T2**: during TS, **T3**: immediately after tracheal suctioning, **T4**: 5min after tracheal suctioning, **T5**: 10 min after tracheal suctioning, **HR**: heart rate, **SBP**: blood pressure, **SpO_2**: preductal oxygen saturation. **MAP**: mean airway pressure, **CVP**: central venues pressure, **DBP**: diastolic blood pressure, **$PetCo_2$**: end-tidal carbon dioxide pressure.

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