

Effect of Different Endotracheal Suctioning Systems on Cardiorespiratory Parameters of Ventilated Patients

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Abstract

Introduction: We conducted this prospective randomised cross-over study to evaluate the effect of closed system (CS) versus open system (OS) endotracheal suctioning on heart rate (HR), mean arterial pressure (MAP), respiratory rate (RR), oxygen saturation (SpO₂) and electrocardiogram (ECG) rhythm of patients on mechanical ventilation. **Materials and Methods:** Fourteen adult patients were randomly allocated to receive either CS or OS suctioning in the first instance. For the subsequent suctioning, they were crossed over to the alternate suctioning system. The various cardiorespiratory parameters were recorded at BL1 (baseline 1), S1 (first suction pass), BL2 (baseline 2, i.e. immediately post first suction pass), S2 (second suction pass), T2 (2 minutes post suction) and T5 (5 minutes post suction). **Results:** Compared to CS, OS suctioning was found to result in higher HR at S1 ($P \leq 0.05$) and S2 ($P \leq 0.05$); higher MAP at BL2 ($P \leq 0.05$); lower SpO₂ at BL2 ($P \leq 0.01$) and S2 ($P \leq 0.01$). There was no significant difference in RR between the two suctioning systems. OS suctioning was also noted to result in a significantly higher incidence of arrhythmia ($P \leq 0.05$). **Conclusion:** Our study shows that OS suctioning results in more adverse changes in cardiorespiratory parameters compared to CS suctioning.

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Key words: Atelectasis, Closed system, Haemodynamic stability, Hypoxaemia, Open system

Introduction

Endotracheal suctioning is a routine procedure performed in the intensive care unit (ICU) to remove secretions from the tracheobronchial tree. This is to maintain patency and reduce the risk of pulmonary atelectasis in mechanically ventilated patients. Two systems are used, the open suction (OS) system and the closed suction (CS) system. The OS system requires disconnection from the ventilator during the suctioning process. This interruption of mechanical ventilation and oxygen delivery predisposes the patient to hypoxaemia and associated cardiorespiratory effects. The CS system does not require disconnection of the patient from the ventilator, thus permitting uninterrupted ventilation and thereby maintaining continuous oxygen supply and positive end expiratory pressure (PEEP) to patients. This study compares the cardiorespiratory effects of the two suctioning systems on ventilated ICU patients.

Prior to this study, a comprehensive literature search

yielded more than 30 articles in relation to endotracheal suctioning. Many of these studies were on the various effects of one of the two suctioning systems alone.¹⁻¹⁷ Some comparison studies were on infection control¹⁸⁻²⁰ and on cost.^{21,22} There were only 6 published studies²²⁻²⁷ comparing cardiorespiratory parameters during suctioning with the two systems. Most of these comparison studies were weak in standardisation of their protocols to reduce confounding variables which may affect their findings. In some studies, the research design and suction protocol were poorly described or defined and thus, the findings from the data were limited in generalisability and may not be transferable to other settings or groups. There were variances in the methods and time intervals of pre-oxygenation and suction pressure applied for the two systems.

We conducted this prospective randomised cross-over study to evaluate the effect of the two suctioning systems on heart rate (HR), mean arterial pressure (MAP),

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respiratory rate (RR), oxygen saturation (SpO₂) and electrocardiogram (ECG) rhythm of patients on mechanical ventilation.

Materials and Methods

The research design adopted was a prospective, randomised, cross-over clinical study. A “within-patient” comparison was utilised such that each subject acted as his/her “own control” to eliminate “between-patient” variation and to remove any “subject effect” from the comparison.

The research question was “Does the CS system endotracheal suctioning in ventilated ICU patients result in less adverse changes in HR, MAP, RR, SpO₂ and ECG rhythm as compared to the OS system endotracheal suctioning?”

The independent variables were CS and OS whereas the dependent variables were HR, MAP, RR, SpO₂ and ECG rhythm. The dependent variables were obtained from the parameter printouts from the bedside monitor, HP Component Monitoring System, Anaesthesia/Neonatal/Standard, HP Part No. 1046-9001F.

Approval for the study was obtained from the hospital research committee. All patients on mechanical ventilation in a Surgical Intensive Care Unit (SICU) of an acute care general hospital during the period 14 to 25 February 2000 were the subjects of this study. Prior to the suction procedure, an explanation was given and verbal consent obtained. Two patients opted out of the study.

Fourteen patients were recruited into the study. Their demographic data, main diagnosis, fraction of inspired oxygen (F_IO₂), PEEP levels, Glasgow Coma Scale (GCS), Ramsay sedation scores and APACHE II scores are recorded in Table I. All patients were intubated with oral endotracheal tubes, had invasive blood pressure monitoring via intra-

arterial cannula and were studied within 2 days of admission to the SICU. Exclusion criteria were raised intracranial pressure, treatment with neuromuscular blocking agents, mandatory closed suction system for reasons of infection control, GCS ≤8 and Ramsay sedation score ≥5. Study patients were randomly allocated to either OS or CS in the first instance. The alternate suctioning system was used for the subsequent suctioning between 2 to 4 hours after the first procedure.

A standardised protocol for endotracheal tube suctioning was employed (Fig.1). Cardiorespiratory parameters under study were obtained at B1, followed by 60 seconds of hyperoxygenation. The first suction pass was performed for 10 seconds during which printout at S1 was obtained at the fifth second. Printout was obtained immediately after completion of the first suction pass at BL2 followed by 30 seconds of hyperoxygenation. The second suction pass was performed for 10 seconds during which printout at S2 was obtained at the fifth second followed by 30 seconds of hyperoxygenation. Printouts were obtained 2 minutes (T2)

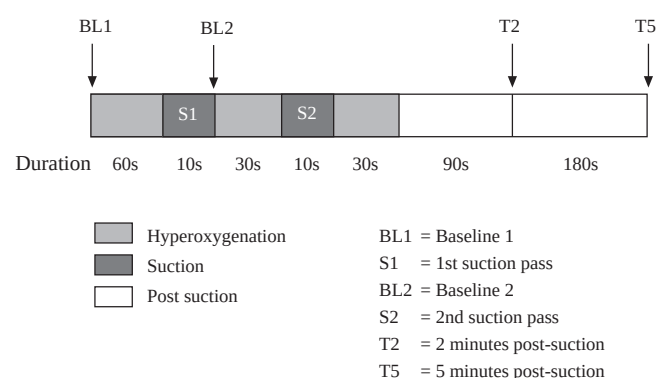


Fig. 1. Standardised protocol for endotracheal tube suctioning.

TABLE I: DEMOGRAPHIC DATA, MAIN DIAGNOSIS AND OTHER KEY PARAMETERS OF STUDY PATIENTS

S/No	Initials	Age	Gender	Main Diagnosis	FiO ₂ (%)	PEEP (cmH ₂ O)	GCS	Ramsay's sedation score	APACHE II
1	WHS	52	M	Liver cirrhosis	50	5	9	4	16
2	TTH	65	M	Intestinal obstruction	100	15	9	1	32
3	WCH	66	M	AMI	80	0	11	2	31
4	TAP	68	M	Liver abscess	40	5	11	2	18
5	LIS	76	M	Bleeding GIT	40	5	11	2	24
6	JAT	71	F	Goitre	40	5	11	2	17
7	JBT	71	F	Goitre	40	5	11	2	16
8	MAB	21	F	Liver laceration	50	5	11	2	9
9	LAH	81	F	Liver abscess	60	3	11	2	35
10	WWL	78	F	PGU	40	5	10	3	16
11	TGN	75	F	Bleeding GIT	50	5	11	2	16
12	TAS	86	F	Carcinoma stomach	40	5	11	2	24
13	HMT	61	F	Bleeding GIT	40	7	11	2	26
14	KTH	79	M	Pneumonia	80	5	11	2	17

PEEP: positive end expiratory pressure; GCS: Glasgow Coma Scale; AMI: acute myocardial infarction; GIT: gastrointestinal tract;

PGU: perforated gastric ulcer

and 5 minutes (T5) following completion of the second suction pass. To ensure reliability of data collected, the following were also standardised for both OS and CS: suction pressure of 120 mmHg, suction catheter size 12 FR, hyperoxygenation delivered via ventilator. The CS catheter used in this study was the DAR Hi-Care in-line suction catheter, 12 CH/FR, Ref No. 333/00312, Tyco Healthcare.

Statistical Analysis

The data were analysed using a commercial software programme (SPSS for windows, version 10.0, SPSS, Chicago, IL). Differences in HR, MAP, RR, and SpO₂ between the two suctioning systems were assessed using Wilcoxon signed ranks test. Variations in these cardiorespiratory parameters from BL1 were similarly

assessed. Fisher's exact test was used to assess the difference in incidence rate of dysrhythmia. A *P* value of ≤ 0.05 was considered statistically significant.

Results

Tables II to V show mean $\pm$ standard deviation of HR, MAP, SpO₂, and RR of study subjects during the suctioning procedure.

For CS suctioning, SpO₂ was significantly higher during S1 ($P \leq 0.05$) and at BL2 ($P \leq 0.05$) compared to BL1. SpO₂ was also significantly higher during S1 ($P \leq 0.01$) compared to BL1 in the case of OS suctioning. Between the two systems, SpO₂ was significantly better with CS at BL2 ($P \leq 0.01$) and during S2 ($P \leq 0.05$).

TABLE II: SPO₂ OF STUDY SUBJECTS DURING THE SUCTIONING PROCEDURE (MEAN $\pm$ SD)

	SpO ₂ (%)					
	BL1	S1	BL2	S2	T2	T5
OS	95.50 $\pm$ 4.70	97.00 $\pm$ 4.66**	95.36 $\pm$ 5.90##	95.79 $\pm$ 5.67#	94.86 $\pm$ 5.99	94.93 $\pm$ 5.34
CS	96.36 $\pm$ 3.27	98.29 $\pm$ 2.40*	98.07 $\pm$ 2.87*	97.00 $\pm$ 3.64	95.79 $\pm$ 3.87	95.50 $\pm$ 3.74

* $P \leq 0.05$ versus BL1; ** $P \leq 0.01$ versus BL1; # $P \leq 0.05$ OS versus CS; ## $P \leq 0.01$ OS versus CS

TABLE III: HEART RATE OF STUDY SUBJECTS DURING THE SUCTIONING PROCEDURE (MEAN $\pm$ SD)

	HR (breath/min)					
	BL1	S1	BL2	S2	T2	T5
OS	100.29 $\pm$ 22.05	102.29 $\pm$ 20.53#	101.00 $\pm$ 20.49	106.64 $\pm$ 30.86#	106.86 $\pm$ 29.87	105.07 $\pm$ 29.66
CS	100.00 $\pm$ 19.60	96.43 $\pm$ 20.40**	96.14 $\pm$ 20.00*	97.43 $\pm$ 19.79	100.43 $\pm$ 19.79	99.43 $\pm$ 21.51

* $P \leq 0.05$ versus BL1; ** $P < 0.01$ versus BL1; # $P \leq 0.05$ OS versus CS

TABLE IV: MEAN ARTERIAL PRESSURE OF STUDY SUBJECTS DURING THE SUCTIONING PROCEDURE (MEAN $\pm$ SD)

	MAP (mmHg)					
	BL1	S1	BL2	S2	T2	T5
OS	89.43 $\pm$ 19.54	92.79 $\pm$ 17.98	93.14 $\pm$ 21.03*#	95.71 $\pm$ 21.73**	89.43 $\pm$ 18.59	85.36 $\pm$ 16.75
CS	87.57 $\pm$ 18.03	91.21 $\pm$ 18.58*	84.64 $\pm$ 19.68	92.36 $\pm$ 21.44*	91.29 $\pm$ 19.35	86.86 $\pm$ 17.68

* $P \leq 0.05$ versus BL1; ** $P < 0.01$ versus BL1; # $P \leq 0.05$ OS versus CS

TABLE V: RESPIRATORY RATE OF STUDY SUBJECTS DURING THE SUCTIONING PROCEDURE (MEAN $\pm$ SD)

	RR (breath/min)					
	BL1	S1	BL2	S2	T2	T5
OS	20.21 $\pm$ 6.44	22.00 $\pm$ 9.98	23.21 $\pm$ 10.23	23.29 $\pm$ 10.62	22.14 $\pm$ 8.58	21.07 $\pm$ 7.49
CS	21.43 $\pm$ 7.61	20.14 $\pm$ 6.63	20.43 $\pm$ 7.45	22.43 $\pm$ 7.39	23.14 $\pm$ 8.50	23.43 $\pm$ 7.95

TABLE VI: INCIDENCE OF DYSRHYTHMIA DURING THE SUCTIONING PROCEDURE

	Dysrhythmia	No Dysrhythmia	Total
OS	5	8	13
CS	0	13	13
Total	5	21	26

Fisher's exact test, $P \leq 0.05$

For CS suctioning, HR was significantly lower during S1 ($P \leq 0.01$) and at BL2 ($P \leq 0.05$) compared to BL1. For OS suctioning, HR tended to rise during the procedure. This rise, however, did not achieve statistical significance. Between the two systems, HR was significantly higher with OS during S1 ($P \leq 0.05$) and S2 ($P \leq 0.05$).

For CS suctioning, MAP was significantly higher during S1 ($P \leq 0.05$) and S2 ($P \leq 0.05$) compared to BL1. For OS suctioning, MAP was also significantly higher at BL2 ($P \leq 0.05$) and during S2 ($P \leq 0.01$). Between the two systems, MAP was significantly higher with OS at BL2 ($P \leq 0.05$).

There was no significant change in RR compared to BL1, throughout the suctioning procedures for both systems. Neither was there any significant difference between the two systems in terms of RR.

One of the 14 patients had pre-existing cardiac dysrhythmia and was therefore excluded from this analysis.

Discussion

There have been various publications comparing cardiorespiratory parameters during tracheal tube suctioning with the OS and CS systems.²²⁻²⁷ Unfortunately, different preoxygenation methods involving manual bag ventilation result in inconsistent delivery of tidal volume and oxygen to the patient. Furthermore, different suction pressures and duration were used which further confounded the results of some of the studies. One study did not describe the study design or the suction protocol. This raises the question of reliability of data collected and the findings presented. Another study did not provide preoxygenation to study subjects. Knowing that suctioning exposes a patient to the risk of hypoxaemia, this may not be ethically acceptable. Furthermore, it is not routine practice to not provide preoxygenation as part of the endotracheal suctioning procedure.

Bearing in mind all the above points, we chose a prospective randomised “cross-over” design for our study. This design eliminates “between patient variation” which may exist if a “parallel group” study or “independent subject group” study is to be conducted. Each subject acts as his or her own control as the two suctioning systems are compared within subjects. This removes any “subject

effect” from the comparison, thereby providing a direct comparison of the two suctioning systems. According to Senn,²⁸ a “cross-over” study is preferred to a “parallel group” study as fewer patients have to be recruited to obtain the same number of observations and fewer observations have to be obtained to ensure the same precision in estimation. A minimum 2-hour “wash-out” period was employed after the first suction procedure to reduce “carry-over” effects in which the effect of the first suction system employed is believed to have adequately disappeared.

With both suctioning systems, there is an initial significant improvement in SpO₂ during S1. This improvement is probably a reflection of effective preoxygenation from a stable baseline state prior to first suctioning. This improvement is better sustained with CS compared to OS, resulting in better SpO₂ with CS at BL2 and S2. Loss of lung volume, and disruption of ventilation and oxygen supply contribute to hypoxaemia during endotracheal suctioning. Brochard et al²⁹ showed that disconnection of the patient from the ventilator followed by suctioning results in a significant loss of lung volume. CS suctioning does not require disconnection of the patient from the ventilator and allows a continuous supply of oxygen even while suctioning is in progress. We postulate that this reduces the degree of lung volume loss during CS and accounts for better preservation of SpO₂ compared to OS.

The recurrent laryngeal and superior laryngeal nerves, both branches of the vagus nerve, richly innervate the tracheal mucosa.³⁰ Tracheal suctioning results in vagal stimulation and this is the likely explanation for the observed decrease in HR during S1 and at BL2 for CS. The presence of an intact compensatory sympathetic function prevents severe bradycardia or even cardiac asystole.³¹ In the case of OS, there is no significant change in HR from BL1 at any point of time during suctioning. OS suctioning requires additional manipulation, i.e. disconnection and subsequent reconnection of the ventilator circuit to the patient's endotracheal tube. This invariably causes movement of the endotracheal tube and irritation to the trachea. Patients were noted to cough more during OS compared to CS. We postulate that this increased sympathetic stimulation overrides the vagal effect during OS suctioning. However, we cannot rule out a relative hypoxaemia as a contributory factor to this observation. Comparing the two systems, HR is significantly higher for OS during S1 and S2. Tachycardia results in increased myocardial oxygen demand and at the same time decreases myocardial oxygen supply due to reduced diastolic time. It is one major factor that contributes to myocardial ischaemia and is certainly an undesirable trait in the critically ill patient.

Wood¹⁴ explained that hyperinflation manoeuvres lead to a transient increase in intrathoracic pressure, augmented

left ventricular ejection fraction and elevated MAP. Our study did not involve any hyperinflation technique. Johnson et al²² attributed the rise in MAP to irritation of the trachea during suctioning and sympathetic response to this irritation. We postulate that this is the explanation for the rise in MAP we observed in both OS and CS suctioning. Additional manipulation with increased sympathetic stimulation during OS probably accounts for more persistent increase in MAP compared to CS. However, the magnitude of the difference in MAP is unlikely to be of much clinical significance.

Several authors^{22,24} have reported a significantly higher rate of cardiac dysrhythmias during OS suctioning compared to CS suctioning. Our results concur with these findings. We believe that two key factors contribute to this observation:

1. Additional tracheal tube manipulation leading to more tracheal irritation and more sympathetic stimulation with OS;
2. Relative hypoxaemia as a result of interruption to ventilation and oxygen supply with OS.

Our results suggest that CS suctioning offers a significant advantage over OS with regard to reducing the incidence of dysrhythmia during tracheal tube suctioning.

Conclusion

Our study highlights some advantages of CS suctioning compared to OS suctioning. CS suctioning was found to better maintain SpO₂ and result in less increase in HR and MAP. Very significantly, we experienced no cardiac dysrhythmia during CS suctioning compared to a 38.5% incidence of dysrhythmia with OS suctioning. These are issues that are of considerable importance in the management of critically ill patients who are unstable and usually intolerant of adverse cardiorespiratory changes during their stay in the ICU.

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