

**TWO LEVELS OF NEGATIVE PRESSURE IN OPEN
TRACHEAL SUCTIONING AND THEIR EFFECT ON
CARDIORESPIRATORY INDICES AND CARE OUTCOMES
AMONG ADULT PATIENTS IN CRITICAL CARE UNIT AT
MACHAKOS LEVEL FIVE HOSPITAL**

MARK LEWA NGUI

DOCTOR OF PHILOSOPHY IN NURSING

(Critical Care Nursing)

JOMO KENYATTA UNIVERSITY

OF

AGRICULTURE AND TECHNOLOGY

2026

**Two Levels of Negative Pressure in Open Tracheal Suctioning and
their Effect on Cardiorespiratory Indices and Care Outcomes
among Adult Patients in Critical Care Unit at Machakos Level Five
Hospital**

Mark Lewa Ngui

**A Thesis Submitted in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy in Nursing (Critical Care
Nursing) of the Jomo Kenyatta University of Agriculture and
Technology**

2026

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signed.....

Date.....

Mark Lewa Ngui

This thesis has been submitted for examination with our approval as University Supervisors:

Signed.....

Date.....

Dr. Elijah Githinji Mwangi, PhD
JKUAT, Kenya

Signed.....

Date.....

Dr. Albanus Kyalo Mutisya, PhD
JKUAT, Kenya

Signed.....

Date.....

Dr. Fatuma Aden Affey, PhD
Garissa University, Kenya

DEDICATION

This work is dedicated to my wife, Purity Mutheu, who has had to persevere with my prolonged absence from home and for ever being a source of encouragement and special support to me. It is also dedicated to my father, the late Samson Ngui Nzine and my mother, the late Alice Mbee Kaveke (Simba) for planting unwavering spirit of hard work and making it thrive and blossom. ‘Let them rest in peace’. This work is further dedicated to my children, Joy Museo, Ian Ngumbau and Luke Mumo for giving me the impetus to always aim higher.

ACKNOWLEDGEMENT

Special acknowledgement goes to the Jomo Kenyatta University of Agriculture and Technology for giving me a chance to pursue this doctoral programme in nursing and providing the administrative support required. I wish to acknowledge, in a special way, my supervisors: Dr. Elijah Githinji Mwangi, Dr. Albanus Kyalo Mutisya and Dr. Fatuma Aden Affey for their tireless professional support, guidance and supervision throughout the research process. I wish also to acknowledge my employer and sponsor, the Ministry of Defence, through the Directorate of Medical Services for permitting and enabling me pursue the PhD programme. Special appreciation goes to the leadership of the Machakos county and the Machakos Level Five Hospital staff and especially the Critical Care Unit multi-disciplinary team for their great assistance in data collection and collective effort in comprehensive patient care. If it were not for the limited space, their names deserved to have been put here. Thanks to all lecturers at JKUAT School of Nursing for special guidance and encouragement, my post graduate colleagues and peers, and to all those who in one way or the other contributed to completion of this work.

TABLE OF CONTENTS

DECLARATION.....	ii
DEDICATION.....	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES	xi
LIST OF FIGURES	xiv
LIST APPENDICES	xv
ABBREVIATIONS AND ACRONYMS	xvi
DEFINITION OF OPERATIONAL TERMS	xx
ABSTRACT	xxiv
CHAPTER ONE	1
INTRODUCTION.....	1
1.1 Background of the Study	1
1.2 Statement of the Problem	9
1.3 Justification	11
1.4 Objectives	13
1.5 Research Hypotheses.....	13
1.6 Scope	15

1.7 Study Limitations and Delimitations.....	15
CHAPTER TWO	16
LITERATURE REVIEW.....	16
2.1 Introduction	16
2.2 Important Concepts in Tracheal Tube Suctioning.....	16
2.2.1 Tracheal Bronchial Secretions	16
2.2.2 Tracheal Tube Suctioning	17
2.2.3 Tracheal Tube Suctioning Approaches.....	18
2.2.4 Tracheal Tube Suctioning and Airway Devices.....	19
2.2.5 Key Considerations During Tracheal Tube Suctioning	20
2.3 Suction Pressure and Effectiveness.....	21
2.4 Suction Pressure and Safety	23
2.4.1 Tracheal Tube Suction Pressure and Ventilator Associated Events	23
2.4.2 Tracheal Tube Suction Pressure and Bloody Tracheal Secretions.....	25
2.5 Suction Pressure and Cardinal Cardiorespiratory Indices.....	26
2.6 Suction Pressure and Patient Care Outcomes	29
2.7 The Theoretical Framework.....	31
2.7.1 General Systems Theory	32
2.7.2 Virginia Henderson’s Theory.....	33

2.8 Conceptual Framework	37
2.9 The Critique of the Existing Literature	39
2.10 The Summary	41
2.11 The Research Gaps	41
CHAPTER THREE	43
METHODOLOGY.....	43
3.1 Research Design.....	43
3.2 Study Site	44
3.3 Target Population	45
3.4 Sample Size.....	45
3.5 Sampling Techniques	48
3.6 Selection Criteria.....	48
3.6.1 Inclusion Criteria.....	48
3.6.2 Exclusion Criteria.....	49
3.7 Study Variables	49
3.7.1 Independent Variables.....	49
3.7.2 Dependent Variables	49
3.8 Study Instruments	50
3.9 Pretesting of the tools.....	52

3.10	Data Collection Procedures.....	52
3.10.1	General	52
3.10.2	Application of Data Collection Tools	52
3.10.3	Recruitment of Cases	53
3.11	Data Processing.....	55
3.12	Data Management	56
3.13	Ethical Consideration	57
3.13.1	Authority	57
3.13.2	Informed Consent.....	57
3.13.3	Potential Harm	58
3.13.4	Anonymity, Privacy and Confidentiality	59
3.14	Results Dissemination.....	59
CHAPTER FOUR		60
RESULTS		60
4.1	Introduction	60
4.2	Baseline Characteristics of Study Participants	60
4.2.1	Demographic Characteristics of Study Participants.....	60
4.2.2	Baseline Comparability of Experimental and Control Groups	61
4.2.3	Distribution of Study Participants by Diagnostic Category	62

4.2.4 Comparison of Diagnostic Categories between the Experimental and Control Suction Groups	63
4.3 Effectiveness and Safety of 180mmHg and 100mmHg Suction Pressures	64
4.4 Tracheal Tube Suctioning and Cardiorespiratory Indices	67
4.4.1 Effects of Tracheal Tube Suctioning on Cardiorespiratory Indices	67
4.4.2 Comparison of Cardiorespiratory Effects of Suctioning between Experimental and Control Suction Groups	80
4.5 Open Tracheal Tube Suctioning and Metric Patient Care Outcomes	88
4.5.1 Determination of Metric Patient Care Outcomes for Experimental and Control Groups	89
4.5.2 Comparison of Care Outcomes between the Experimental and Control Groups	90
CHAPTER FIVE.....	92
DISCUSSION, CONCLUSION, AND RECOMMENDATIONS.....	92
5.1 Introduction	92
5.2 Discussion	92
5.2.1 Effectiveness and Safety Between Experimental and Control Group Suction Pressures	92
5.2.2 Open Tracheal Tube Suctioning and Specific Cardiorespiratory Indices	94
5.2.3 Comparison of Patient Care Outcomes between Experimental and Control Groups	98

5.3 Conclusion.....	101
5.4 Recommendations	102
REFERENCES.....	105
APPENDICES	119

LIST OF TABLES

Table 1.1: Routine local Tracheal Tube Suction Pressures.....	6
Table 2.1: Key Considerations during Suctioning	20
Table 3.1: Statistical Parameters Used in Sample Size Calculation	46
Table 3.2: Determination of δ and σ Values	47
Table 3.3: Reliability Assessment of Data Collection Tool.....	51
Table 3.4: Reasons for Non-recruitment of the Excluded Patients	56
Table 3.5: Mid-term Comparison on Blood-tinged Secretions and Mortality	58
Table 4.1: Baseline Demographic Characteristics of Participants	60
Table 4.2: Comparability of the Experimental and Control Groups on Selected Extraneous Variables.....	61
Table 4.3: Disease Conditions of the Study Subjects	63
Table 4.4: Diagnostic Categories between the Experimental and Control Suction Groups	64
Table 4.5: Comparison of Effectiveness and Safety between 180mmHg and 100mmHg Negative Suction Pressures	65
Table 4.6: Comparison between groups on Bloody Tracheal Secretions and Ventilator-Associated Events	66
Table 4.7: Comparison of Mean and SD of HR/min in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	68

Table 4.8: Comparison of Mean and SD of SpO ₂ in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	70
Table 4.9: Comparison of Mean and SD of RR in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	72
Table 4.10: Comparison of Mean and SD of SBP in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	74
Table 4.11: Comparison of Mean and SD of DBP in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	76
Table 4.12: Comparison of Mean and SD of MAP in Repeated Measures ANOVA (and Friedman test) for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively	78
Table 4.13: Summarized Effects of Tracheal Tube Suctioning on Cardiorespiratory Indices within Groups	79
Table 4.14: Comparison of the Means and SD of HR at the Four Suction Time Points between Experimental and Control Groups using unpaired T-test	81
Table 4.15: Comparison of the Means and SD of SpO ₂ at the Four Suction Time Points between Experimental and Control Groups using Mann Whitney U test	82
Table 4.16: Comparison of the Means and SD of RR/min at the Four Suction Time Points between Experimental and Control Groups using Mann Whitney U test	83

Table 4.17: Comparison of Means and SD of SBP at the Four Suction Time Points between Experimental and Control Groups using unpaired T-test	84
Table 4.18: Comparison of Means and SD of DBP at the four Suction Time Points between Experimental and Control Groups using unpaired T-test	85
Table 4.19: Comparison of Means and SD of MAP at the Four Suction Time Points between Experimental and Control Groups using T-test/Mann Whitney U test	86
Table 4.20: Effect Size of the Change in HR, SpO ₂ & RR during Suctioning	87
Table 4.21: Effect Size of the Change in SBP, DBP and MAP during Suctioning ..	87
Table 4.22: Comparison of Percentage change in Cardiorespiratory Indices between 180mmHg and 100mmHg Negative Suction Pressures	88
Table 4.23: Descriptive Statistics of Selected Clinical Outcomes by Suction Pressure Group.....	89
Table 4.24: Comparison Between Experimental and Control Groups on Specific Outcomes of Care Metrics.....	91

LIST OF FIGURES

Figure 2.1: Application of General Systems Theory to Open Tracheal Tube Suctioning.....	33
Figure 2.2: Hierarchy of Virginia Henderson's Human Needs Superimposed into Abraham Maslow's Hierarchy of Needs	36
Figure 2.3: Conceptual Framework	38
Figure 3.1: Case Recruitment over Time	54
Figure 3.2: Participants CONSORT Flowchart Diagram	55
Figure 4.1: Effect of TT Suctioning on Heart Rate at Four Suction Time Points	68
Figure 4.2: Effects of TT Suctioning on SpO ₂ at Four Suction Time Points.....	69
Figure 4.3: Effects of TT Suctioning on Respiration Rate at Four Suction Time Points.....	71
Figure 4.4: Effects of TT Suctioning on Systolic Blood Pressure at Four Suction Time Points	73
Figure 4.5: Effects of TT Suctioning on Diastolic Blood Pressure at Four Suction Time Points	75
Figure 4.6: Effects of TT Suctioning on MAP at Four Suction Time Points	77

LIST APPENDICES

Appendix I: Patient Data Form 1a	119
Appendix II: Patient Data Form 1b (Continuation Form)	122
Appendix III: Patient Data Form 2.....	123
Appendix IV: Suction Procedure	125
Appendix V: Block Randomization Consort Diagram	128
Appendix VI: Consent Explanation Form	129
Appendix VII: Participants Consent Form	132
Appendix VIII: Fomu ya Ufafanuzi wa Makubaliano (Washirika)	134
Appendix XIV: Fomu ya Ukubali wa Mshirika	136
Appendix X: JKUAT ISERC Approval.....	138
Appendix XI: NACOSTI Research Permit.....	139
Appendix XII: Research Approval and Appointment of supervisors	140
Appendix XIII: Machakos County Research Authorization	141
Appendix XIV: Renewal of JKUAT ISERC Approval	142
Appendix XV: Renewal of NACOSTI Research Permit.....	143
Appendix XVI: Renewal of Machakos County Authorization.....	144
Appendix XVII: Research Budget.....	145
Appendix XVIII: Ventilator Associated Event Algorithm.....	146

ABBREVIATIONS AND ACRONYMS

AARC	American Association of Respiratory Care
ACV	Assist-Control Ventilation
ARDS	Acute Respiratory Distress Syndrome
ASV	Adaptive Support Ventilation
ATS	American Thoracic Society
BC	Before Christ
BP	Blood Pressure
CCU	Critical Care Unit
CDC	Centres for Disease Control
CI	Confidence Interval
CPAP	Continuous Positive Airway Pressure
CPG	Clinical Practice Guidelines
CPP	Cerebral Perfusion Pressure
CTSS	Closed Tracheal Suction System
DBP	Diastolic Blood Pressure
DCHS	Defence College of Health Sciences
DFMH	Defence Forces Memorial Hospital
DV	Dependent Variable
ETA	Endotracheal Airway

EtCO₂	End Tidal Carbon Dioxide
ETT	Endotracheal Tube
EV	Extraneous Variable
GIT	Gastrointestinal Tract
GST	General Systems Theory
H₂O	Water
HCAI	Health Care Associated Infections
HDU	High Dependency Unit
HR	Heart Rate
IBM	International Business Machines Corporation
ICU	Intensive Care Unit
IDSA	Infectious Disease Society of America
ISERC	Institutional Scientific & Ethics Review Committee
IV	Independent Variable
IVAC	Infection-related Ventilator Associated Complication
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KNH	Kenyatta National Hospital
KUTRRH	Kenyatta University Teaching, Referral and Research Hospital
MAP	Mean Arterial pressure

MITTS	Minimally Invasive Tracheal Tube Suctioning
MODS	Multiple Organ Dysfunction Syndrome
NACOSTI	National Commission for Science, Technology and Innovation
NCK	Nursing Council of Kenya
NPA	Nasopharyngeal Airway
OPA	Oropharyngeal Airway
OTSS	Open Tracheal Suction System
PEEP	Positive End Expiratory Pressure
PIP	Peak Inspiratory Pressure
PPE	Personal Protective Equipment
PrVAP	Probable Ventilator Associated Pneumonia
PSV	Pressure Support Ventilation
PsVAP	Possible Ventilator Associated Pneumonia
RR	Respiration Rate
RTTS	Routine Tracheal Tube Suctioning
SBP	Systemic Blood Pressure
SIMV	Synchronized Intermittent Mandatory Ventilation
SpO₂	Peripheral Oxygen Saturation
SPSS	Statistical Package for Social Sciences

TBS	Tracheal Bronchial Suctioning
TT	Tracheal Tube
TTS	Tracheal Tube Suctioning
VAC	Ventilator Associated Condition
VAE	Ventilator Associated Event
VA-LRTI	Ventilator Associated Lower Respiratory Tract Infection
VAP	Ventilator Associated Pneumonia
WBC	White Blood Cell

DEFINITION OF OPERATIONAL TERMS

Bloody tracheal secretions Coffee-ground material obtained during tracheal tube suctioning.

Cardiac indices These are measurements that are used to assess the function of the heart and the circulatory system. They included: Heart Rate (HR), which denotes the number of heart beats in one minute. Its reading was obtained from the cardiac monitor; and the Blood Pressure (BP), which encompasses Systolic, Diastolic and the Mean Arterial Pressure (MAP), and was measured in mmHg. Measurement was done with adult cuff tied on upper arm and the reading was obtained from the cardiac monitor.

Critical Care Outcomes These are clinical end-points emanating from summative interventions carried out on the patients in the critical care unit. Also referred to as Critical Care Outcome Metrics. They are: - length of mechanical ventilation, duration of tracheal tube, length of stay in ICU and mortality in ICU.

Duration of tracheal tube Was the total count in days a patient remained with a tracheal tube.

Intensive Care Unit (ICU) A department in the hospital equipped with life support equipment that deal with the management of critically ill patients with potential or actual life-threatening illnesses. It's synonymous to Critical Care Unit (CCU) and the two terms are used interchangeably.

Intra-suctioning time point Just after the second catheter pass. It's the time when cardiorespiratory measurements/readings were done.

KPa	Kilopascals refers to 1,000 newtons per square meter. Units in mmHg are converted to Kilopascals by multiplying by 0.13
Length of Stay in ICU	Is the number days that the study subjects remained admitted in the Intensive Care Unit. Calculated with precision of an hour as a fraction of a day.
Mechanical Ventilation Days (MVD):	Is the number of days exposure to ventilators by each and by all patient(s) in the selected population during the selected time period.
mmHg	Refers to millimeters of mercury. Are the Units for measuring pressure.
Mortality in ICU	Is the number of died mechanically ventilated patients divided by all patients who were mechanically ventilated in the Intensive Care Unit during the period of study expressed as a percentage.
Pa:	Pascal is the SI unit of pressure. It's a Newton per square meter.
Peak Inspiratory Pressure (PIP):	is the maximum ventilatory pressure involved in driving the set inspiration volume into the patient's lungs. The normal is from 20-40cmH ₂ O. It was measured and displayed on the mechanical ventilator.
Respiratory Indices	These included the Peripheral Oxygen Saturation (SpO ₂) and Respiration Rate (RR). SpO ₂ -is the percentage of oxygen carried on the hemoglobin molecule as measured via a pulse oximeter. The normal is 94% and above. Respiration Rate (RR) is defined as the number of patient

breaths made in one minute as read from the mechanical ventilator.

Suction catheter passes/entrance Is the number of times that a catheter was passed down to the respiratory airway via tracheal tube until tracheal secretions were cleared. Each catheter entrance lasted for 15 seconds.

Suction Effectiveness Is the number of catheters passes (entrances) performed to clear tracheal secretions during a tracheal suctioning session.

Suction Safety It is the absence of incidents of bloody tracheal secretions and Ventilator Associated Events.

Tracheal Suctioning Depth Suction catheter was passed down the tracheal tube until resistance was felt then withdrawn for about 1 cm before suctioning was begun.

Tracheal Tube Suctioning (TTS) Is the removal of pulmonary secretions by sucking them out via a suction catheter by selecting either 100mmHg or 180mmHg negative suction pressure. The appropriate suction pressure was set by occluding the main suction tube and then adjusting the pressure knob until the desired level was reached as indicated on the pressure gauge.

Ventilator Associated Events (VAE) Is the total number of clinical episodes encompassing:

- a) Ventilatory Associated Condition (VAC) -Associated with increment of FIO_2 by $\geq 20\%$ or PEEP to $\geq 3\text{cmH}_2\text{O}$ after 48hrs of stability.
- b) Infection-related Ventilator Associated Complication (IVAC): Associated with change in white blood cell count ($>12,000/\text{cm}^3$ or $<4,000/\text{cm}^3$) and/or

temperature ($>38^{\circ}\text{C}$ or $<36^{\circ}\text{C}$) and a new antimicrobial prescription started and sustained for at least four days and

- c) Possible Ventilator-associated Pneumonia (PsVAP): Associated with evidence for lower respiratory airway infection confirmed by positive microbiological culture.

VAE rate or VAE per 1,000 ventilator days: Was calculated as VAE cases divided by total mechanical ventilator days multiplied by 1000.

ABSTRACT

Tracheal Tube Suctioning is performed on intubated patients to clear secretions by sucking them out by means of negative pressure via a suction catheter. Disparities exist among practitioners on amount of suction pressure. Negative suction pressures ranging from 80-300mmHg have been tested. The Nursing Council of Kenya prescribes a suction pressure of 80-120mmHg. Suction levels beyond 200mmHg pose risks. ICU mortality in Kenya is 38.6% compared to world-wide level of 19.9%. This study was formulated to establish effect of open tracheal tube suctioning at 180mmHg and 100mmHg on cardiorespiratory indices and care outcomes among mechanically ventilated adult patients at Machakos level five county hospital. Ethical approval was granted by Jomo Kenyatta University Ethics Review Committee (JKU/ISERC/02316/0914) and permit issued by NACOSTI (P/23/28497). All ethical principles were upheld. A Randomized Controlled Trial, involving 76 mechanically ventilated adult patients was conducted with random allocation to 180mmHg and 100mmHg suction groups in 2024. Data was collected pertaining to cardiorespiratory indices at four suction-time points during open tracheal tube suctioning, on critical care outcome metrics, safety and effectiveness measures and suction catheter passes that cleared tracheal secretions. Independent t-test and Mann–Whitney U test were used for statistical comparison of quantitative indices; Chi-square test was used to determine homogeneity between the groups; and Repeated Measures Analysis of Variance and Friedman test were used to assess differences in the means within each group at Alpha level of 0.05. Results showed that the higher pressure was more effective in tracheal secretion clearance ($p < .001$) and both suction levels cause significant changes in cardiorespiratory indices ($p < .05$). There were significant differences ($p < .05$) between the two groups on diastolic and mean arterial blood pressure with the 100mmHg suction pressure causing bigger increment. There were no significant differences in metric patient care outcomes, Ventilator Associated Events and on incidences of bloody tracheal secretions ($p > .05$). The 180mmHg suction pressure did not therefore show additional harm compared 100mmHg suction level. Further research is recommended to establish the relationship between such suctioning and tracheal mucosal damage, intracranial pressure, pneumonia and for validation in a multi-center study.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Most patients in the Intensive Care Unit (ICU) require insertion of a tracheal tube to facilitate mechanical ventilation and allow removal of secretions that accumulate in the airways. According to Krüger et al. (2024) the mechanical inhibition of mucociliary activity owing to the physical presence of the tracheal tube together with depressed cough reflex that commonly manifests in critically ill patients are the very reasons for needing efficient Tracheal Tube Suctioning (TTS). This TTS, is the removal of such secretions through sucking them under negative pressure. A clear airway eases the work of breathing and leads to good oxygenation and ventilation. It's one of the main duties that critical care nurses perform frequently and autonomously (Chang et al., 2023; Sontakke et al., 2023).

Tracheal Tube Suctioning (TTS) is not without unwanted effects. Krüger et al. (2024) and Hixson et al. (2024) have reported that TTS is accompanied by complications such as hemodynamic instability, desaturation and hypoxia due to loss of lung volume and accompanying atelectasis, cardiac arrhythmias which may lead to cardiac and respiratory arrest, infections which include Ventilator-Associated Pneumonia (VAP) or Infection-related Ventilator Associated Complication (IVAC) often due to tracheal mucosal membrane damage; bleeding, pain, anxiety and increased intra-cranial pressure. They further indicated that the incidence and intensity of these manifestations depend on the amount of negative suction pressure used.

Historically, airway clearance is a known emergency lifesaving procedure. Description of tracheostomy and artificial airway creation were recorded in Egyptian and Hindu writings and later by the Hippocrates (460-370BC), who emphasized the necessity for maintaining patent airway (Benumof & Hagberg, 2023; Miller et al., 2020). Diphtheria pseudo-membranous disease stimulated more work on tracheal intubation during 1888-1891 period (Martin & Wunsch, 2023). In the late nineteenth and twentieth centuries tracheal suctioning has developed more along the advances in respiratory

medicine and ventilation support (Benumof & Hagberg, 2023). The 1952 Copenhagen poliomyelitis epidemic resulted into wide use of positive-pressure ventilation, marking a turning point in critical care medicine as prolonged endotracheal intubation demonstrated need for frequent airway clearance (Irwin & Rippe, 2023). Since the 1970s, research has progressively focused on optimizing safety and effectiveness, with investigations focusing on suction pressure, suction duration, suction frequency, and open versus closed suction systems (Chang et al., 2023; Krüger et al., 2024).

According to Waweru-Siika et al. (2020) Critical Care in Kenya dates back to 1950s during the 3rd Polio outbreak where rudimentary respiratory support was provided to patients at the then King Georges hospital (i.e. the current Kenyatta National Hospital). During that time, physicians took leadership in critical care units but along the way anaesthesiologists have gained predominance. Critical Care Nursing development in Kenya followed later on at around 1970 in form of on-the-job training with support from Japan nurses. Capacity for critical care in Kenya has grown to 537 ICU beds by 2020. Leading government facilities in ICU beds are Nairobi (99), Turkana (20), Mombasa (12), Kiambu (11), Kakamega (9), Machakos and several others (6), and other counties are below six beds (Barasa et al., 2020; Mwangi et al., 2023). More recently, the Kenya Ministry of Health (2023) through Kenya Harmonized Health Facility Assessment report has pointed out a tremendous increase in the number of ICU beds to a total of 1,353 (i.e. 899 adult beds, 196 paediatric & 258 neonatal beds nationally).

Effective Tracheal tube suctioning is fundamental to maintaining airway patency and adequate gas exchange in mechanically ventilated patients. Mechanically ventilated patients frequently have impaired cough reflexes, reduced mucociliary clearance, and increased production of respiratory secretions, all of which predispose them to secretion retention. Without effectively clearance of tracheal secretions, they accumulate within the tracheobronchial tree, resulting in partial or complete airway obstruction subsequently resulting into: increased airway resistance, ventilation-perfusion mismatch, impaired oxygenation, atelectasis and increased work of breathing (Blakeman et al., 2022; Klompas et al., 2022; Papazian et al., 2020;). Retained secretions also provide a good environment for bacterial colonization and

biofilm formation on endotracheal tubes, increasing the risk of ventilator-associated events (VAEs), ventilator-associated pneumonia (VAP), prolonged mechanical ventilation, longer intensive care unit (ICU) stay, higher healthcare costs, and increased mortality (Klompas et al., 2022; Papazian et al., 2020). Consequently, tracheal tube suctioning remains an essential nursing intervention for airway clearance; however, its effectiveness depends on selecting suction pressures that are sufficient to remove secretions while minimizing airway trauma and other suction-related complications (Blakeman et al., 2022; Maras et al., 2020).

The suction levels chosen presents potentially different outcomes on cardiorespiratory physiological indices (i.e. Heart Rate (HR) and Blood Pressure (BP); Respiration Rate (RR) and Peripheral Oxygen Saturation (SpO₂); safety and effectiveness.

Traditionally, the Open Tracheal Suction System (OTSS) has been the main stay in Tracheal Tube Suctioning, but the Closed Tracheal Suction System (CTSS) has been gaining usage in many hospitals and especially so with the outbreak of infectious respiratory diseases such a Covid 19 owing to their protection against spreading patients' bronchial secretions to the environment and decreasing the risk of aerosolization of tracheal secretions during suction-induced coughing. They are also associated with less likelihood for hypoxia due to loss of functional lung residue volume and atelectasis and are therefore preferred for patient sustained on high PEEP (>10cmH₂O), high FIO₂ (>80%), those with bloody secretions and those with high risk of infectious diseases. They have a comparable effectiveness with OTSS in secretion removal, frequency of suctioning but a higher likelihood for more hemodynamic stability under same negative suction pressures (Yılmaz & Özden, 2024). A lot of studies done comparing open and closed tracheal suction systems have not found a significant difference in terms of rates of Ventilator Associated Pneumonia, length of mechanical ventilation and ICU mortality (Ardehali et al., 2020). However, Sanaie et al. (2022) reported that OTSS is associated with 57% increase in VAP. Despite the observation that CTSS have advantages in selected conditions, OTSS still remain the predominant choice in many of the County level five hospitals in Kenya.

Despite tracheal tube suctioning being one of the most frequently performed interventions by nurses among mechanically ventilated patients, the most suitable negative suction pressure for adult open tracheal tube suctioning remains unknown. Current recommendations vary considerably ranging from 80 mmHg to below 200 mmHg, reflecting conflicting opinions among current guidelines, institutional protocols, and primary studies. Furthermore, the 2022 AARC Clinical Practice Guideline acknowledged that recommendations on suction pressure are based largely on low-quality evidence and expert opinion, highlighting the need for well-designed randomized controlled trials to evaluate the comparative safety and effectiveness of different suction pressures.

Critically ill mechanically ventilated patients require tracheobronchial toileting for better oxygenation and ventilation. This intervention should be carried out while minimizing the procedure-related physiological disturbances, airway mucosal trauma, and risk for infection. Critically ill patients are particularly more vulnerable to ventilator-associated respiratory infections, sepsis, multiple organ dysfunction syndrome, prolonged Intensive Care Unit stay and even death. The most significant cause of death in ICU is Multiple Organ Dysfunction Syndrome (MODS) often due to sepsis (Gourd & Nikitas, 2020) among other causes. In Kenya, ICU mortality rate is 38.6% (Linwa et al., 2023; Machakos Level Five Hospital, 2024; Njoki et al., 2024) compared to world-wide mortality rate of (19.9) % (Pisani et al., 2022) and relative to some other African countries like Egypt (24%) and Nigeria (34%) (Eya et al., 2022). However, some African countries like Cameroon are worse with an ICU mortality rate of 59.4% (Ashry et al., 2021). Factors contributing to this huge difference between world-wide rate and individual African countries' rates are largely unknown. Tracheal Tube Suctioning, being an invasive procedure is an important risk factor for development of pneumonia, subsequently resulting into sepsis and MODS among ICU patients (Li et al., 2024). The insertion and withdrawal of suction catheter brings contact with airway mucosa and may cause irritation, injury and bleeding. The extent of this damage is possibly influenced by not only the amount of the suction pressure but also the number of catheter passes used to clear the secretions. Therefore, a lower suction pressure though considered less likely to exert excessive negative pressure on the airway, may be counterproductive when it fails to adequately remove secretions

with only few catheters passes. Such repeated catheter passes increase the cumulative contact between the suction catheter and the airway mucosa and may end up increasing mucosal irritation, injury and bleeding. This disruption of airway mucosal barrier increases the likelihood for infections. Ideally, an appropriate suction pressure should be able to clear tracheal secretions with few catheters passes while remaining within a range that does not produce clinically significant cardiorespiratory disturbances or mucosal harm. In the recent publication of 2022, the AARC has recommended that open tracheal tube suction pressure be maintained below 200 mmHg with more research needed to validate this suggestion in terms of specific levels of pressure (Blakeman et al., 2022; Scott, 2020). This is the most global standard that provides upper boundary for tracheal tube suctioning. On the other hand, the Nursing Council of Kenya, the body that regulates nursing practice and education in the country, has prescribed a negative suction pressure of 80-120mmHg for adults (NCK, 2019). The chosen lower limit of 100mmHg in this study represents the average of the NCK prescribed suction pressure. Its therefore consisted with the national guideline while the higher suction level of 180mmHg is above the NCK recommendation but within the recommended AARC level for adult tracheal tube suctioning.

Anecdotal evidence in Kenya demonstrates great heterogeneity in choice of suction pressure for adult TTS. A spot check of routine negative suction pressures for several Kenyan health facilities is shown in Table 1.1 below:

Table 0.1: Routine local Tracheal Tube Suction Pressures

Serial	INSTITUTION	NEGATIVE SUCTION PRESSURE (adults)
1.	Kenyatta National Hospital (KNH)	120-150mmHg
2.	Kenyatta University Teaching, Referral and Research Hospital (KUTRRH)	80-120mmHg
3.	Defence Forces Memorial Hospital	80-150mmHg
4.	Aga Khan Hospital (using CTSS)	200-300mmHg
5.	The Karen Hospital (using CTSS)	200-300mmHg
6.	Machakos County Hospital	60-180 mmHg

CTSS: Closed Tracheal Suction System

Table 1.1 above shows the suction pressures adopted in some sampled hospitals in Kenya. The variability of the choices stands out clearly as shown on the table. Institutional guidelines are varied and out of tune with the NCK prescribed negative suction pressure for adults. Even though the data above points to use of higher suction pressure for CTSS, there is no evidence to show that there is a difference in suction pressures for the two approaches (Ramírez-Torres et al., 2024).

The drive for higher suction pressure appears to be due to perceived ineffectiveness of the NCK prescribed upper limit. This has created an important discrepancy between national guideline recommendation and the actual clinical practice. Moreover, there is insufficient local experimental evidence in Kenya, East Africa and Africa at large to show whether the higher suction pressures being used provides better secretion clearance without causing significant adverse effects. Studies done in Africa have only concentrated on endotracheal clearance knowledge and practice rather than suction pressure for airway clearance. There is no accessible published clinical trial dealing with testing of different suction pressures for tracheal airway clearance in Kenya and East Africa. Recent systematic reviews continue to demonstrate uncertainty regarding

the optimal negative pressure for open tracheal tube suctioning. In a systematic review and evidence-based clinical practice guideline, Blakeman et al. (2022) reported that studies comparing different suction pressures were scarce and unable to establish a pressure that was most suitable for secretion clearance and for maintenance of patient safety. The guideline therefore recommended maintaining adult suction pressure below 200 mmHg while using the lowest pressure capable of effectively removing secretions. This recommendation was classified as Level C evidence, reflecting reliance on limited research and expert consensus rather than strong randomized controlled trials.

Similarly, Sontakke et al. (2023), in a systematic review of airway clearance practices, identified considerable variation in the suction pressures used across studies and clinical settings. The review suggested that higher pressures may prove good for secretion removal but may also amplify physiological disturbances and cause airway injury, particularly when combined with large suction catheters, prolonged suction duration or deep catheter insertion. Consequently, the authors did not identify a definitive optimal suction pressure and emphasized the importance of individualizing suctioning according to secretion characteristics, artificial airway size and the patient's physiological response.

Maras et al. (2020) upon testing pressures of 80mmHg, 150mmHg and 250mmHg on cardiorespiratory indices and effectiveness in terms of secretion removal, reported that the suction pressure of 250mmHg was more effective than lower pressures and equally safe. This finding is not supported by other studies whose opinion about the matter is that negative suction pressures above 150mmHg are associated with higher likelihood for hypoxia, tracheal-mucosal injury and atelectasis (Sontakke et al., 2023).

Although high suction pressures (i.e. >200mmHg) have for a long time been associated with tracheobronchial mucosal injury, hypoxemia, hypoxia, bleeding and atelectasis, contemporary systematic evidence reviews found insufficient high-quality clinical evidence to determine the level of suction pressure at which these complications become clinically significant (Blakeman et al., 2022).

The choice of the most suitable suction pressure is a balance of its effectiveness in removing tracheal-bronchial secretions and potential harm. Low suction pressures in adults have been associated with ineffectiveness in secretion removal and more catheter entrances but more stable respiratory and hemodynamic indices (Rajakumari et al., 2020). However, they are likely to have higher incidences of lower respiratory system infections due to many suction catheters passes possibly causing more tracheal mucosal damage due to cumulative airway mucosal contact and inadequate secretion removal, creating a possibility of leakage downwards leading to Infection-related Ventilator Associated Complication (IVAC) or Ventilator Associated Pneumonia (VAP).

On the other hand, higher suction pressures have proved more effective in secretions removal through fewer catheter passes but cause more disturbance of cardiorespiratory indices. Patient cardiorespiratory instability increases with higher suction pressures (Maraş et al., 2020).

These discrepancies in opinions and recommendations point to lack of consensus and uniformity in determining the best optimal suction pressure for TTS, a situation that poses a dilemma among healthcare practitioners, resulting into great diversity in patient healthcare outcomes, costs, unpredictable healthcare quality and safety. In the absence of conclusive evidence identifying an optimal suction pressure based solely on cardiorespiratory responses, other equally important considerations include patient safety, clinical effectiveness and critical care outcomes. Consequently, the choice of suction pressure should also be informed by its association with ventilator-associated events, bloody tracheal secretions, duration of mechanical ventilation, duration of tracheal intubation, ICU length of stay, ICU mortality and the number of suction catheter passes required to achieve effective secretion clearance. This underscores the need for studies evaluating both the safety and effectiveness of different negative suction pressures in adult open tracheal tube suctioning.

The great diversity of opinion about choice of the most suitable suction pressure is again worsened by lack of knowledge on existing guidelines by the critical care nurses. The use of higher suction pressures among nurses is not unusual, nearly half of critical

care nurses have shown varied levels of adherence to open tracheal tube suctioning guidelines. Chen et al. (2021) observed an adherence of 51.6% to the recommendation of 80-120mmHg suction level. In a study by Pinto et al. (2020), only 46% of the critical care nurses had knowledge on existing guideline on suction pressure for tracheal suctioning. They further hypothesized that 20-30% of the critically ill patients are not receiving tracheal suction care based on current research recommendations. Alkubati et al. (2022) through their observational study carried out in Yemen, found out an adherence to set guidelines on TTS of 50-75% in only 45% of the critical care nurses.

Even though the safe suction pressure is commonly proposed as ranging from 100-150mmHg in adults in many studies and below 200mmHg by the 2022 AARC Clinical Practice Guidelines albeit weak evidence, their association with VAE, tracheal mucosal injuries, length of mechanical ventilation, duration of tracheal tube placement, length of ICU stay and ICU mortality is not known neither is their effectiveness fully explored.

In view of the above gaps, there was need to determine the relationship between adult TTS at 100mmHg and at 180mmHg with incidence of VAE, bloody tracheal secretions, length of mechanical ventilation, duration of tracheal tube placement, length of stay in ICU, ICU mortality, the average number of catheter passes that clear tracheal secretions and their accompanying cardiorespiratory indices in order to provide insight on their suitability, safety and effectiveness.

1.2 Statement of the Problem

There is no universal consensus regarding the optimal negative suction pressure for effective and safe secretion removal globally. The 2022 American Association for Respiratory Care (AARC) Clinical Practice Guideline recommends that suction pressure for adult tracheal tube suctioning be maintained below 200 mmHg, and neonatal/ pediatric suction pressures below 120 mmHg albeit existence of low evidence on the matter. This guideline acknowledges that this recommendation is based on low-quality evidence (Level C) and in addition, it advises practitioners to use the lowest suction pressure capable of effectively removing secretions. The guideline further concludes that the optimal suction pressure that simultaneously maximizes

secretion clearance while minimizing airway injury has not yet been established because of the limited quantity and quality of available evidence.

Suction pressures of 100–150 mmHg have been widely used in adult clinical practice and are recommended by many institutional protocols; the supporting evidence is largely derived from small clinical trials and expert opinion rather than properly designed randomized controlled studies (Blakeman et al. (2022). The Nursing Council of Kenya recommends a suction pressure range of 80–120 mmHg for open tracheal suctioning in adults (NCK, 2019); however, in clinical practice, nurses in Kenya often use suction pressures exceeding this recommended range. Existing studies have demonstrated that excessively high suction pressures may increase tracheobronchial mucosal trauma, bleeding, pain, and adverse physiological responses, whereas excessively low pressures may fail to adequately remove secretions, potentially leading to secretion retention and its associated complications. Consequently, the balance between suction effectiveness and patient safety remains uncertain, highlighting the need for further high-quality randomized trials to establish the optimal negative suction pressure for adult tracheal tube suctioning.

There is limited evidence in literature that compares a suction level of 180mmHg with the usual level of 100mmHg in open tracheal tube suctioning among adults. At local level there is inadequate context-specific evidence to determine whether the current recommended suction level is optimal or whether a higher suction pressure which is still within the internationally accepted limit could produce a better balance of effectiveness and safety. The available randomized trials have evaluated only a limited number of suction pressure combinations, and their findings remain inconsistent regarding physiological responses, secretion clearance, and suction-related complications. Evidence from Africa is particularly scarce, with little context-specific research to guide clinical practice, and until this study was conducted, there was no accessible data on any other randomized controlled trial conducted in Kenya comparing the safety and effectiveness of two different negative suction pressures during adult open tracheal tube suctioning. Moreover, no previous study had directly compared 180 mmHg, a pressure that falls within the upper limit of the current AARC recommendation but with a safe margin below 200 mmHg, with the 100mmHg

average negative suction pressure recommended by the Nursing Council of Kenya. This important evidence gap justified the present randomized controlled trial to generate locally relevant and internationally applicable evidence on the optimal balance between effective secretion clearance and patient safety.

This evidence gap created the need to compare a negative suction pressure of 180mmHg against the usual suction pressure of 100mmHg on secretion clearance, safety, cardiorespiratory indices and ICU care outcomes among mechanically ventilated adult patients.

I.3 Justification

This study was formulated to determine safe and effective negative suction pressure in open tracheal tube suctioning by testing two levels of suction pressure on key cardiorespiratory indices, ICU care outcome metrics, safety markers and effectiveness in clearing tracheal secretions.

The study contributes to Sustainable Development Goal (SDG) number three i.e. good health and well-being, particularly Target 3.8 dealing with improving the quality of essential health-care services and Target 3(d) addressing the need for strengthening health systems to reduce health risks (United Nations, 2015). This is particularly so because the study generates evidence on the optimal negative suction pressure for adult open tracheal tube suctioning and by so doing, it seeks to improve patient safety by enhancing secretion clearance, reduce suction-related complications and optimize critical care outcomes among mechanically ventilated patients. The findings are expected to inform evidence-based clinical practice, support the revision of national suctioning guidelines especially by the nursing regulatory body and strengthen the delivery of high-quality critical care services in Kenya and other resource-limited settings.

Determination of the relationship between critical care outcome metrics with suctioning pressures of 180mmHg and 100mmHg alongside comparison on measures of safety and effectiveness has added to hitherto unavailable knowledge on these considerations as key to informing choice of desirable suction pressure. In cognizant

of the fact that a lot of choice of suction pressure during TTS has been on the basis of personal experience, such knowledge is vital.

Anecdotal evidence has shown that critical care nurses in Kenya have applied negative suction pressures exceeding 120mmHg prescribed by NCK probably out of their observation that the prescribed limit is 'too slow' and not powerful enough to suck tracheal secretions effectively. The findings of this study are therefore useful to the critical care team in Kenya and elsewhere particularly in making informed choice about negative pressures during adult TTS on the basis of the cardiorespiratory effects, critical care outcomes, safety and effectiveness. Clinical practice should increasingly be informed by robust locally generated evidence rather than relying predominantly on expert opinion and international recommendations.

The findings of this study make significant contribution in enriching the clinical practice guidelines on the subject of tracheal tube suctioning. The Nursing Council of Kenya should particularly find it useful locally generated scientific evidence for revising her existing guidelines on TTS for adults in Kenya. Researchers, scholars and students should find it a useful information for reference.

This study contributes to the body of knowledge on TTS that critical care team can consider in their systematic reviews in order to crystallize evidence needed to make clinically correct choices on the suitability of suction pressure for open tracheal tube suctioning for adults. These findings are contributory to nursing education and in enhancing training programmes especially on airway management. Such evidence-based practice not only fosters confidence among the practitioners but also promotes health care quality & safety, improved patient outcomes, critical care practitioners' expertise and healthcare cost-effectiveness.

1.4 Objectives

The objectives of this study were: -

1.4.1. Broad

To determine the effects of two levels of negative pressure in open tracheal tube suctioning on airway clearance, patient safety, cardiorespiratory indices, and care outcomes among adult patients in Intensive Care Unit at Machakos Level Five Hospital.

1.4.2. Specific

The specific objectives were: -

- i. To compare effectiveness and safety of 180mmHg versus 100mmHg negative suction pressures in open tracheal tube suctioning among mechanically ventilated adult patients.
- ii. To compare specific cardiorespiratory effects of open tracheal tube suctioning at negative suction pressure of 180mmHg with those produced at 100mmHg among mechanically ventilated adult patients.
- iii. To compare patient care outcomes between those on negative pressures at 180mmHg and 100mmHg in open tracheal tube suctioning among mechanically ventilated adult patients.

1.5 Research Hypotheses

The hypotheses of the study were: -

H₀₁ There is no statistically significant difference in the number of catheter passes required for effective tracheal secretion clearance between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

H_{a1} There is a statistically significant difference in the number of catheter passes required for effective tracheal secretion clearance between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

H₀₂ There is no statistically significant difference in safety, as measured by the occurrence of blood-tinged tracheal secretions and ventilator-associated events, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

Ha₂ There is a statistically significant difference in safety, as measured by the occurrence of blood-tinged tracheal secretions and ventilator-associated events, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

H₀₃ There is no statistically significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) across baseline, intra-suction, 5-minute post-suction, and 20-minute post-suction measurements within either the 180 mmHg or 100 mmHg tracheal suction pressure groups among mechanically ventilated adult patients.

Ha₃ There is a statistically significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) across baseline, intra-suction, 5-minute post-suction, and 20-minute post-suction measurements within either the 180 mmHg or 100 mmHg tracheal suction pressure groups among mechanically ventilated adult patients.

H₀₄ There is no statistically significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) between mechanically ventilated adult patients receiving tracheal suction pressures of 180 mmHg and 100 mmHg at baseline, during suctioning, and at 5- and 20-minutes post-suctioning.

Ha₄ There is a statistically significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) between mechanically ventilated adult patients receiving tracheal suction pressures of 180 mmHg and 100 mmHg at baseline, during suctioning, and at 5- and 20-minutes post-suctioning.

H₀₅ There is no statistically significant difference in critical care outcomes, as measured by duration of mechanical ventilation, duration of tracheal intubation, ICU length of stay, and ICU mortality, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

Ha5 There is a statistically significant difference in critical care outcomes as measured by duration of mechanical ventilation, duration of tracheal intubation, ICU length of stay, and ICU mortality, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.

1.6 Scope

This study was a single-centre randomized controlled trial (RCT) conducted among adult patients admitted to the Critical Care Unit at Machakos Level Five Hospital. The study evaluated the effects of open tracheal tube suctioning performed at negative suction pressures of 180 mmHg and 100mmHg on cardiorespiratory indices, including respiratory rate, peripheral oxygen saturation, heart rate and blood pressure; effectiveness, measured by the number of suction catheter passes required to achieve complete secretion clearance; safety and critical care outcomes determined through the incidences of ventilator-associated events (VAE), bloody tracheal secretions, duration of mechanical ventilation, duration of tracheal intubation, length of ICU stay and ICU mortality. The study confined itself to adult mechanically ventilated patients aged above 18 years undergoing open tracheal tube suctioning via deep suctioning.

1.7 Study Limitations and Delimitations

This study was confined to adult mechanically ventilated patients at the Machakos Level Five Hospital. The findings are therefore only precisely applicable to this age group and not to pediatrics and neonates. Additionally, this study was conducted at a single centre, which may limit the generalizability of the findings. Though, the study was double blind, the nurses were able to guess the suction level set by judging from the flow rate of secretions, nevertheless, they were encouraged to bear with the seemingly slow suction level often presented by the lower suction pressure of 100mmHg and the pressure gauge remained covered with a translucent material. The study dealt with open tracheal tube suctioning as opposed to closed tracheal tube suctioning and the highest suction pressure tested was 180mmHg. This study used deep tracheal tube suctioning technique as opposed to shallow suctioning.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review that follows in this chapter is related to the discussion of effects of various levels of negative pressure during open Tracheal Tube Suctioning (TTS) of mechanically ventilated adult patients. It particularly focuses on the effects of TTS pressures on patient critical care outcomes, safety & effectiveness, and the accompanying cardiorespiratory indices. Theoretical and conceptual framework of the study are discussed as well as the critiques of existing literature. Lastly, a summary is given and research gaps are pointed out.

Conceptual and methodological aspects of the past researches done on this field have been cited in order to provide guidance and a basis for this particular study.

2.2 Important Concepts in Tracheal Tube Suctioning

2.2.1 Tracheal Bronchial Secretions

Tracheal tube patency is commonly compromised by secretions. Mucus or tracheal secretions constitute a complex biological material composed of proteins, glycoproteins, proteoglycans and lipids conferring to it properties of wettability and adhesiveness. It is important in hydration and humidification of air, microbial protection, provides filtration and diffusion barrier and provides transport through ciliary or cough mechanisms (Guyton & Hall, 2000). It is secreted by the epithelial goblet cells in the submucosal glands under regulation of the parasympathetic nervous system and neuro-hormonal local situation so that individuals vary in the amount of mucus secreted. Normally, an average of 100cc/day is secreted. Certain stimulation involving physical devices (tracheal tube, tracheostomy tube, suction catheters), chemicals and infections increase mucus production up to 1L/day (Hill et al., 2022). Mucus can be described as runny, thick or sticky. The epithelial cells all the way from

the nose to the respiratory bronchioles are lined with Cilia that beat at a rate of 10-20 strokes/second to move mucus towards the pharynx (Guyton & Hall, 2000).

2.2.2 Tracheal Tube Suctioning

Tracheal Tube Suctioning (TTS) is a very important nursing procedure among the critically ill intubated patients on mechanical ventilation. According to Krüger et al. (2024) it is one of the most frequently performed procedure by nurses in the Critical Care Unit (CCU). Its historical evolution was mainly driven along by advances in airway management, mechanical ventilation, critical care medicine and evidence-based practice. The advent and increased use of tracheal tubes in the late 19th and early 20th centuries greatly led to application of TTS. Further, the Copenhagen poliomyelitis epidemic of 1952 led to the need for prolonged positive pressure ventilation which resulted to TTS becoming a routine ICU procedure leading to more standardization in 1950s through to 1970s. In 1980s, there was growing interest in research targeting suction related complications of mechanically ventilated patients. Later on in 1990s, Closed Tracheal Suction Systems were introduced. In 1993, the very first AARC clinical practice guidelines were published, then revised in 2010 and in 2020. Currently there has been growth in systematic reviews and Randomized Controlled Trials (RCTs) on Ventilator Associated Pneumonia (VAP); Ventilator Associated Events (VAE), physiological responses to suctioning, catheter design and patient safety but the evidence remains heterogenous (Krüger et al., 2024).

Good knowledge and skills on the right suctioning technique and accompanying considerations are important aspects of quality care leading to improvement in patient outcomes and lowering involved costs and promoting patients' safety. Apart from clearing the airway, suctioning also helps in preventing pneumonia associated with accumulation of secretions and their downwards flow to the lower zones of the airways often aided by force of gravity in semi-fowlers position and the forces from inspirational air current. Tracheal suctioning is not without harm, it is often accompanied by incidences of hypoxemia, hypoxia, atelectasis and tracheal mucosal injury, coughing and discomfort (Krüger et al., 2024; Maras et al., 2020). Its commonly done at suction pressures of 80-150mmHg.

2.2.3 Tracheal Tube Suctioning Approaches

Tracheal Tube Suctioning broadly involves two approaches. These are: Open Tracheal Suction System (OTSS) and Closed Tracheal Suction System (CTSS). In OTSS, the patients are disconnected from the ventilator during suctioning. Oxygenation, humidification and Positive End Expiratory Pressure (PEEP) are therefore stopped or reduced significantly during this time. Loss of PEEP may lead to collapsing of small airways and alveoli consequently causing patient desaturation. CTSS involves multiple-use suction catheter enclosed in a flexible plastic film sleeve. Suctioning is done with mechanical ventilation going on. PEEP is maintained throughout. There is therefore no break in oxygenation and humidification. Additionally, bronchial secretions are not easily spilled out to the environment but instead they are conducted to disinfected receiver containers. These systems are desirable in preventing infectious respiratory diseases like Covid 19 infection that ravaged the entire world from the year 2020.

Less conspicuous are the other approaches encompassing either shallow or deep tracheal suctioning. Shallow suctioning is whereby the catheter tip does not pass below the tip of tracheal tube whereas in deep suctioning, the suctioning catheter goes to about 0.5-1cm above the carina (Blakeman et al., 2022). In a study by El-Hady et al. (2025) that compared the effects of these two methods of clearing airway among adult intubated ICU patients at El-Mansoura Hospital in Egypt, 120 patients were randomly allocated to either shallow or deep suctioning arm (RCT with a pretest/post-test equivalent control design). Outcome measures were Heart Rate (HR), Respiration Rate (RR), Peripheral Oxygen Saturation (SpO₂), Systolic, Diastolic and Mean Arterial Pressure measured just before, immediately after suction, 5 min post suctioning and 10 minutes post suctioning. Suctioning was done at 100-120mmHg. Data was analyzed through repeated measures ANOVA, Independent t-test and Chi-square. Results indicated that there was a significant difference ($p < .05$) between the two groups in HR, DBP and SpO₂ immediately after suctioning, at 5 minutes post suctioning there were significant differences between the groups on HR, SBP, DBP, SpO₂ and RR. At 10 minutes post suctioning, significant differences were found in all the six indices (HR, SBP, DBP, SpO₂ RR & MAP). The deep suction group had higher values for these indices. Deep suctioning group had significantly ($p < .05$) higher

incidences of tracheal mucosal injury, hypoxemia and cardiac dysrhythmias than the shallow suction group. The AARC guidelines for 2022 have recommended use of shallow suctioning as a routine and use of deep suctioning only when shallow suctioning does not lead to good airway clearance (Blakeman et al., 2022). In Kenya, empirical evidence on the depth of tracheal tube suctioning remains limited (Amutalla, 2023). However, anecdotal observations suggest that deep suctioning continues to be widely practiced, particularly in county-level health facilities where many intensive care units are located.

2.2.4 Tracheal Tube Suctioning and Airway Devices

Medical devices often used to secure airway patency include: Oropharyngeal Airway (OPA), Nasopharyngeal Airway (NPA), supraglottic airway devices and Endotracheal Airway (ETA). These are selected based on patient's level of consciousness, airway anatomy, and ventilatory requirements (Butterworth et al., 2023). The presence of tracheal (or tracheostomy) tube impedes the muco-ciliary activity leading to accumulation of secretions on the lower tracheal and bronchial airways (Krüger et al. (2024).

According to Butterworth et al., (2023), although modern tracheal tube cuffs are higher volume and low pressure, there is still small leakage of oropharyngeal secretions into the lower airway often carrying accompanying micro-organisms to the lower airway. This could largely be responsible for occurrence of Ventilator Associated Pneumonia. *Pseudomonas*, *Klebsiella*, and *Staphylococcus* species are still commonly associated with endotracheal/tracheostomy tube biofilm as well as with oral dysbiosis and diseases (Deshmukh-Reeves et al., 2025). Artificial airways therefore increase incidence of nosocomial pneumonia. Indeed, Howroyd et al. (2024) indicated that VAP is still the common nosocomial infection in the ICU impacting 20–36% of critically ill patients. They add that tracheal tubes are the most important risk factor, even though patients' reduced consciousness, trauma, older age and illness severity play a role too. This risk may be reduced by good oral hygiene, effective secretions removal, maintaining effective cuff pressure (20-30cm H₂O), matching the tracheal tube size with gender specifications (i.e. men 20-25cm and women 15-21 cm), use of

PEEP $\geq$ 5cm H₂O and use of tracheal tubes with sub-glottic suction (Butterworth et al. 2023; Goodfellow et al., 2024).

Critical care nurses are specifically required to assess the need for tracheal suctioning by assessing the following: obvious secretions on the airway, ineffective cough, high peak airway pressure on volume control mode or decrease in tidal volume, saw-tooth pattern on the ventilator display, deteriorating peripheral oxygen saturation, increased respiration rate, noisy breathing and increased level of partial pressure of carbon dioxide (Blakeman et al., 2022).

2.2.5 Key Considerations During Tracheal Tube Suctioning

According to Blakeman et al. (2022) & Pinto et al. (2020) critical care nurses have to put certain considerations during tracheal suctioning as presented in Table 2.1 below:

Table 10.1: Key Considerations during Suctioning

Ser	Consideration	Remark
1.	Assessment	Establish need for suctioning and appropriate material/procedure to apply
2.	Suctioning on need basis	Not on routine basis
3.	Patient preparation	Explanation to the patient, administration of pain relief measures
4.	Hand hygiene prior to the procedure	Essential in preventing Health Care Associated Infections (HCAI)
5.	Personal Protective Equipment	Donning appropriate Personal Protective Equipment (PPE) is an infection prevention measure
6.	Pre-oxygenation prior to suctioning	A measure that prevents hypoxemia associated with TTS
7.	Catheter size	Appropriate catheter size is necessary to avoid hypoxemia & atelectasis. The formula is French = (ETT size mm -2) X 2. Should not occlude more than half of the lumen of ETT.

8. Suction pressure	Lowest as possible (80-below 200mmHg)
9. Number of catheter passes	Maximum of three (3) per procedure
10. Catheter sterility	Non-touch suctioning procedure, use of sterile technique.
11. Duration of suctioning	10-15 seconds with each catheter pass (entrance)
12. Post suctioning oxygenation	With 100% oxygen for at least 30 seconds to restore normal SpO ₂ level
13. Reassessment	In terms of SpO ₂ , RR, HR, BP, Ventilatory parameters
14. Hand hygiene post suctioning	Prevent HCAI
15. Documentation	For accountability and communication

The amount and viscosity of mucus, size of suction catheter, suction duration and negative suction pressure influence the efficiency of airway clearance.

2.3 Suction Pressure and Effectiveness

Several TTS pressures tested have indicated greater effectiveness with higher suction pressures (>150mmHg) compared to lower suction pressures (<120mmHg) with inconsistent demonstration of severe adverse effects.

In a prospective quasi experimental study by Maras et al. (2020) involving 47 adult mechanically ventilated patients in ICU whose aim was to compare the effectiveness of three tracheal suction pressures (i.e. 80mmHg, 150mmHg and 250mmHg) determined by the volume of secretions suctioned and cardiorespiratory indices produced in open tracheal tube suctioning, the results showed that negative pressure of 250mmHg was the most effective and equally safe. There were statistically significant differences between the three pressures in terms of the volume of secretion obtained ($p < .001$). Moreover, there were no significant differences in oxygen desaturation and increase in blood pressure ($p > .05$). Tachycardia, bradycardia, hypoxaemia, tracheal mucosal damage or mucosa bleeding were not observed. Liu et al. (2025) conducted a double blind randomized controlled trial aimed at establishing

safe and effective pressure of endotracheal tube suctioning based on sputum viscosity grades during open suctioning procedure. 438 patients receiving mechanical ventilation were put into low, medium or high-pressure groups i.e. 120mmHg, 150mmHg and 200mmHg suction groups according to their sputum viscosity grades. They observed only low changes in outcome variables of HR, SpO₂, MAP and low incidence of mucosal bleeding with good sputum removal. Its clinical value is in the point that suction pressure should at best be selected on the basis of sputum viscosity and not 'one-fit-for-all' principle. At the same time, a pressure of 200mmHg was found tolerable. The AARC latest guidelines of 2022 recommended a suction pressure below 200mmHg (Blakeman et al., 2022).

Yazdannik et al. (2019) undertook a study to compare the efficacy between 100mmHg and 200mmHg suction pressures using Closed Tracheal Suction System (CTSS) on the premise that CTSS require higher pressures for secretion removal. His study involved 42 patients, randomly allocated to the study groups (each with 21 patients) with a cross over design. Efficacy of suctioning was determined by the absence of secretion flow at the end of 10 seconds of suctioning. CTSS using 200 mmHg resulted in an efficacy of 96% for removing secretions, compared to 34% for 100mmHg. There was a statistically significant difference {1.72, (95% CI: 1.4-2.0) $p < .001$ } in terms of efficacy of secretion removal. Secretion flow after 10 seconds was significantly low with 200mmHg suction pressure ($p < 0.001$). Therefore, a suction pressure of 200mmHg was found to be more effective.

The Nursing council of Kenya (NCK) clinical procedure manual in nursing and midwifery 4th edition prescribes a suction pressure of 80-120mmHg for adults (NCK, 2019). There is currently limited published evidence describing the suction pressures actually used in Kenyan intensive care units. Anecdotal evidence shows that some nurses increase suction pressure above 120mmHg when managing tenacious secretions in an attempt to improve secretion clearance; however, this practice has not been systematically documented in Kenya. This evidence gap underscores the need for studies evaluating both current practice and the comparative safety and effectiveness of higher suction pressures.

2.4 Suction Pressure and Safety

Suction pressure is an important safety factor during tracheal tube suctioning because the degree of negative pressure applied may influence the level of mechanical irritation and injury to the tracheobronchial mucosa. Such airway trauma may manifest as bloody tracheal secretions and may also compromise mucosal integrity, potentially creating conditions that increase susceptibility to respiratory infections and subsequent ventilator-associated events (VAEs). Further discussion on the relationship of suction pressure with VAE and bloody tracheal secretions is as described below.

2.4.1 Tracheal Tube Suction Pressure and Ventilator Associated Events

Tracheal tube suction pressure is postulated to influence the development of Ventilator-Associated Events (VAEs) through two complementary mechanisms: its potential injury to tracheobronchial mucosal and its role in determining the effectiveness of tracheobronchial secretion removal. While inadequate secretion removal may promote pulmonary complications including infections, the independent contribution of suction pressure to mucosal injury remains poorly established.

Dripping of oral secretions down the airway on the sides of the tracheal tube leads to accumulation above the cuff. This may eventually leak to the lower respiratory airways causing bacterial colonization and therefore posing a risk for respiratory infection. Strategies used to reduce this risk include frequent TTS, oral care with chlorhexidine antiseptic 4 hourly and use of special tracheal tubes with subglottic suctioning capability (Goodfellow et al., 2024; Terragni et al., 2020). Surveillance for VAP has become problematic owing to different diagnostic criteria especially on timelines and the reliance on chest radiograph which lacks good specificity (Centers for Disease Control and Prevention [CDC], 2026). Instead, Ventilator Associated Events (VAE) is the new concept adopted by CDC to bring about inclusion of other complications arising from mechanical ventilation. It has three tier criteria: Tier-1 is Ventilator Associated Condition (VAC): where there is worsening respiratory status causing hypoxaemia that requires increase in PEEP $\geq 3\text{cmH}_2\text{O}$ and FIO_2 by 20% after two days of stability. Tier-2 is Infection-related Ventilator Associated Complication (IVAC) where there is change in white blood cell count ($>12,000/\text{cm}^3$ or $<4,000/\text{cm}^3$) and/or

temperature ($>38^{\circ}\text{C}$ or $<36^{\circ}\text{C}$) and a new antimicrobial prescription is started and sustained for at least four days. Tier-3 is Possible Ventilator-associated Pneumonia (PsVAP) where there is evidence for lower respiratory airway infection confirmed by purulent secretions and/or culture (CDC, 2026). A schematic presentation is shown in Appendix 19: Ventilator Associated Event Algorithm.

Evidence suggests that while Ventilator-Associated Events (VAEs) provide a standardized surveillance measure for complications arising during mechanical ventilation, they do not necessarily correspond directly with conventional ventilator-associated respiratory infections such as ventilator-associated pneumonia (VAP) or ventilator-associated tracheobronchitis (VAT). Pouly et al. (2020) in their study that investigated the relationship between VAE and Ventilator Associated Lower Respiratory Tract Infection (VA-LRTI) including VAP and Ventilator Associated Tracheal-bronchitis (VAT), found that VAE are only moderately correlated to VAP and not to VAT. More still, VAE and VA-LRTI are common in mechanically ventilated patients and have a significant impact in mechanical ventilation days and ICU length of stay.

In Europe, a recent multi-centre observational study involving 3,446 mechanically ventilated patients reported a VAP incidence of 18.6 episodes per 1,000 ventilator-days and a cumulative incidence of 17.1%. ICU mortality of 34.2% was seen in patient who developed VAP compared to 29.3% of those who did not develop VAP. Again, VAP patients stayed longer i.e. 17 days in ICU compared to 7 days for those who did not suffer VAP (Blot et al., 2025). In Kenya, there is scarcity of data on VAP, but a study done in KNH by Wambua et al. (2026) on incidence, predictors, and prevention practices of VAP among critically ill patients at the critical care unit found a VAP prevalence rate of 37.1% noting that this is a reduction from 54.4% in 2018.

Rahmawati et al. (2025) conducted a scoping review aimed at exploring the risk factors for VAE in the intensive care units through a search on eight data bases in publications between 2013 and 2024. A total of 19 studies were analyzed. The following factors were identified as commonly associated with VAE: Decreased level of consciousness, chronic lung diseases, invasive operation, duration of Mechanical

Ventilation, trauma, fluid overload, reintubation, enteral feeding, administration of sedation and stress ulcer prophylaxis.

Earlier on Kallet (2019) identified significant risk factors for VAE including use of mandatory modes of ventilation (OR= 3.4; 95% CI, 1.6–8.0); positive fluid balances (OR= 1.2 per L positive; 95% CI, 1.0–1.4); starting benzodiazepines prior to intubation (OR= 5.0; 95% CI, 1.3–29); total opioid exposures (OR= 3.3 per 100 µg fentanyl equivalent/ kg; 95% CI, 0.90–16); paralytic medications (OR= 2.3; 95% CI, 0.79–80) and presence of a Orogastric Tube.

In addition, the usual ventilator bundle elements, including oral care with chlorhexidine, semi-recumbent positioning, stress ulcer prophylaxis, venous thromboembolism prophylaxis, daily spontaneous breathing trials, and sedative interruptions were not found to be associated with VAE or IVAC.

2.4.2 Tracheal Tube Suction Pressure and Bloody Tracheal Secretions

Tracheal suctioning has for a long time being associated with injury to tracheal bronchial mucosa leading to coffee ground material expressed out via the suction catheters. Initial suction catheters had a single terminal opening and this was observed to cause trauma on mucous membrane, subsequently the suction catheters were improved with multiple additional side holes for dissipation of suction pressure and this led to weaker sucking of mucous membrane and hence less injury (Butterworth et al., 2023). Researchers have also endeavored to find the relationship between suction pressure and mucosal injury.

Available literature on the relationship between suction pressure and blood-stained secretions does not categorically give an impression that the higher the suction pressure, the higher the incidence of blood-stained secretions. Liu et al. (2025) tested three suction levels (120, 150 & 200) mmHg on the basis of the viscosity of secretions, where thick tenacious secretions were matched with highest suction pressure of 200mmHg. It was a double-blind study involving 438 patients. They found out that higher pressures did not automatically increase bleeding, rather, excessively high pressure for thin secretions or inadequate pressure requiring repeated suction passes increased the incidence of bleeding. Again, Maras et al. (2020) carried out a

comparative study in which they evaluated three suction pressures (80, 150 & 250) mmHg for effectiveness measured by amount of secretion produced, disturbance to cardiorespiratory indices and tracheal bleeding. They found no significant difference among the groups on tracheal mucosa bleeding.

Sequin et al. (2018) investigated the effect of Intermittent Suctioning of Subglottic Secretions (ISSS) at a negative pressure of 100mmHg against Continuous Suctioning of Subglottic Secretions (CSSS) using a negative pressure of 20mmHg on tracheal mucosa among 53 patients. They found no significant difference between the groups on tracheal mucosal changes ($p > .05$).

Therefore, the available literature does not directly establish suction pressure as an independent predictor of tracheobronchial mucosal injury. It is likely that airway trauma is a result of combined effects of suction pressure, catheter size, suction duration, contact with tracheal wall, frequency of catheter passes, secretion characteristics and suctioning technique.

2.5 Suction Pressure and Cardinal Cardiorespiratory Indices

Tracheal tube suctioning has for a long time being known to disturb the commonly monitored cardiorespiratory indices. This likelihood makes critical care nurses inherently concerned with the physiological stability of the patient during TTS. Commonly monitored indices are the Heart Rate (HR), Peripheral Oxygen Saturation (SpO_2), Respiration Rate (RR), Blood Pressure (BP) & End Tidal Carbon Dioxide ($EtCO_2$).

According to Shi et al. (2022) pulse oximetry involves a non-invasive device that is able to pass a beam of light through the skin into blood and infer SpO_2 reading from the amount of light absorbed. A reading of 94% and above is taken to be normal for adults. There is substantial evidence showing that TTS causes transient reduction in SpO_2 but there is recovery in about 1-5 minutes. Higher suction pressure alone has not been shown to produce bigger desaturation than lower pressures when suction duration, catheter size and pre-oxygenation are standardized (Liu et al., 2025; Rajakumari et al., 2020; Yılmaz & Özden, 2024). During open TTS, patients are

disconnected from the ventilator circuit hence stopping oxygen source. More still, the physical presence of the suction catheter not only impedes air entrance but also sucks out some of the alveolar residue air alongside the secretions and this physiologically leads to slower diffusion of oxygen across the alveolar capillary membrane predisposing patients to transient hypoxaemia.

Respiration Rate (RR) denotes the number of breaths per minute. The five-lead cardiac monitor system and the mechanical ventilators indicate breath rate among their monitored parameters. The normal rate for adults is 12-20 bpm during quiet breathing (Kareem et al., 2026). Studies have consistently found that RR increases transiently during TTS but generally returns to baseline within 1-5 minutes. This change is likely mediated via airway irritation, hypoxaemic reflex response and sympathetic activation. Comparative studies have not found different levels of suction pressure resulting into significant differences in RR (Liu et al., 2025; Yılmaz & Özden, 2024)

Heart Rate (HR) is the number of heart beats per minute. The physiological level at rest for adults is 60-100 bpm. Any rate lower than 60 bpm is bradycardia and rate higher than 100 bpm is tachycardia. Cardiac monitors indicate the heart rate as well as heart rhythm. Just like it's the case for RR, HR increases transiently during TTS. This increase is believed to be due to airway stimulation, cough reflex, sympathetic activation, hypoxaemia or even patient discomfort. Different suction pressure levels have not led to significant differences in HR (Lie et al., 2025). Moreover, El-Hady et al. (2025) in their study aimed at comparing deep and shallow suctioning approaches noted that HR was significantly higher immediately, 5 minutes and 10 minutes post suctioning compared to pre suctioning in both groups.

Blood pressure (BP) is defined as the force exerted by the blood against a unit area of the blood vessel wall. Blood pressure is commonly measured in millimeters of Mercury. Pressure of 60mmHg refers to the same pressure that can be used to raise a column of mercury 60mm against gravity. Systolic blood pressure is the pressure wave that coincides with cardiac systole and diastolic pressure coincides with cardiac diastole. Mean Arterial Pressure (MAP) is an average of the two in such a way that $2 \times \text{diastolic reading} + 1 \times \text{Systolic reading}$ divided by 3 equals the MAP (Guyton &

Hall, 2000). The preferred MAP for greater majority of patients in ICU is 55-105mmHg. A MAP of >65mmHg is recommended for critically ill patients and Schizodimos et al. (2020) recommended a Systolic Blood Pressure (SBP) of >110mmHg for ICU patients aged 15-49 years or >70 years and a MAP of >100mmHg for those aged 50-69 years so as to keep Cerebral Perfusion Pressure (CPP) between 60-70mmHg.

Touching the carina by the suction catheter stimulates cough reflex. Cough mechanism involves build-up of thoracic and abdominal pressures. Increased intra-abdominal pressure increases cardiac after-load and this leads to increase in systolic blood pressure. Likewise increase in intra-thoracic pressure creates resistance to venous return and increases preload pressure and hence diastolic pressure is raised. Increase in systolic and diastolic pressure leads to increase in Mean Arterial Pressure (Guyton & Hall, 2000).

Preservation of adequate tissue perfusion and organ function depends on blood pressure remaining within normal physiological range. This ensures constant supply of oxygen and nutrients and removal of waste products from the tissues. Abnormal states interfere with this function in different ways. Sustained hypotension leads to tissue hypoperfusion and organ dysfunction while severe hypertension may impair vascular integrity and increase the work of the heart (Khasawner & Arora, 2025). Studies have shown increase in blood pressure during and after suctioning but they are inconclusive about differences attributable to different suction pressures. Rajakumari et al. (2020), in their RCT involving adults compared a suction level of 120mmHg with 200mmHg on cardiorespiratory indices among other outcomes. There was no statistically significant difference between the groups on MAP but the within group difference between pre and intra suctioning MAP was statistically significant for 120mmHg group and not for 200mmHg group. Lower suction pressure (120mmHg) was seen to have a bigger effect on blood pressure than higher suction pressure (200mmHg). El-Hardy et al. (2025) compared deep suctioning with shallow suctioning in a RCT involving 120 mechanically ventilated adults. The DBP and SBP values remained consistently higher 5 minutes and 10 minutes post suctioning in the

deep suctioning group. Deep suctioning therefore was seen to elevate blood pressure more than shallow suctioning.

In addition to the above-mentioned studies, several others done earlier have also shown increase in heart rate, respiration rate and blood pressure; and decrease in oxygen saturation during endotracheal suctioning.

Low suction pressures (<120mmHg) in adults are associated with ineffectiveness in secretion removal and more catheter entrances but on the other hand they result into more stable respiratory and hemodynamic indices as opposed to suction pressures above 120mmHg (Rajakumari et al., 2020).

Suparti et al., (2021) with a sample size of 40 subjects tested a pressure of 20kPa (150mmHg) and 25kPa (187mmHg) on cardiorespiratory indices during open endotracheal tube suctioning. This study found significant changes in HR, SpO₂ and MAP within each group ($p < .001$) during suctioning.

Capnography or End Tidal Carbon Dioxide (EtCO₂) is a measurement of partial pressure of blood carbon dioxide. It is an important monitored parameter on expired air. Its normal range is between 35-45mmHg. It was not used in this study alongside HR, SpO₂, RR and BP.

Peak Inspiratory Pressure (PIP): -is the maximum ventilatory pressure involved in driving the set inspiration volume into the patient's lungs. The normal range is 20-40 cmH₂O. It was not used in this study.

2.6 Suction Pressure and Patient Care Outcomes

Lower suction pressures have been linked with higher incidences of lower respiratory system infections possibly due to many suction catheter passes causing cumulative tracheobronchial mucosal contact often translating to trauma and inadequate secretion removal, creating a possibility of leakage downwards leading to Infection-related Ventilator Associated Complication (IVAC) or Ventilator Associated Pneumonia (VAP). IVAC and VAP result in prolonged mechanical ventilation days and length of

stay in ICU and hospital (Pouly et al., 2020). In a multi-centered (i.e. 18 ICUs) study done by Nakahashi et al. (2025) in Japan involving 1,094 patients aged 12 years and above, it was established that VAEs were associated with about 53% lower rate of discharge from the ICU (HR 0.47, 95% CI [0.23-0.96]), about a 92% higher instantaneous risk of dying in the ICU (HR 1.92, 95% CI [1.03-3.57]) and twice the hazard of death within 30 days compared to those without VAE (HR 2.00, 95% CI [1.23-3.26]).

Data on the long-term ICU outcomes in relation to suction pressure is limited. A lot of studies have concentrated on short term physiological changes associated with common suction pressures tested rather than long term patient outcomes. Recent evidence does not indicate worsening of ICU outcomes with use of high suction pressures (Liu et al., 2025). However, ICU care outcomes in Kenya have been studied. For instance, a registry-based cohort study in Kenya on ICU outcomes by Njoki et al. (2024) found length of mechanical ventilation of 7 days (IQR 3-21days), length of ICU stay of 3 days (IQR 1-6 days) and a mortality of 30.3%. Earlier on, Parker et al. (2019) in a prospective study on mortality prediction in rural Kenya found a median ICU stay of 4 days (IQR 3-8), median mechanical ventilation of 3 days (IQR 2-5) and a mortality of 60.7% and Debebe et al. (2022) in their cross-sectional study involving 160 mechanically ventilation patients at Tikur Anbessa Specialized Hospital in Addis Ababa, Ethiopia found ICU length of stay of 5 days (IQR 2-10), median mechanical ventilation of 3 days (IQR 2-7) and a mortality of 60.7%. Some studies have investigated the factors affecting ICU outcome metrics. For instance, Ooro et al. (2025) identified predictors of prolonged mechanical ventilation as acute respiratory distress syndrome (ARDS; aOR=5.25, 95% CI: 2.35-11.75), Chronic Obstructive Pulmonary Disease (COPD; aOR=5.28, 95% CI: 2.38-11.73), Pneumonia (aOR=1.82, 95% CI: 0.8-4.14 and Sepsis (aOR=1.56, 95% CI: 0.69-3.52). This means that ARDS and COPD are important independent predictors of mechanical ventilation. Probably due to the large disruption of function of the lung tissue. Anecdotal data put ICU mortality at Machakos hospital at 38.7% during the year 2022 and 43.8% in 2024 (Machakos Level Five hospital, 2024). Evidence on the relationship between tracheal tube suction pressure and ICU outcome metrics remains limited.

2.7 The Theoretical Framework

The present study is guided by two complementary theories: Bertalanffy's General Systems Theory and Virginia Henderson's Need Theory. These theories provide a comprehensive conceptual foundation for understanding the physiological responses to open tracheal tube suctioning and the nursing interventions required to optimize patient outcomes. While the Henderson's Need Theory emphasizes the nurse's responsibility to assist patients in meeting their fundamental physiological needs, particularly the need to breathe normally, the General Systems Theory explains the interdependence and dynamic interactions among body systems in response to internal and external stimuli. The integration of these theories therefore offers both a physiological and nursing perspective for examining the effects of different levels of negative suction pressure on cardiorespiratory indices and critical care outcomes.

General Systems Theory views the human body as an integrated system in which the respiratory, cardiovascular and other organ systems continuously interact to maintain homeostasis through complex feedback mechanisms. In critically ill mechanically ventilated patients, airway obstruction by retained secretions disrupts this equilibrium, impairing gas exchange and potentially compromising tissue oxygenation and organ function. Open tracheal tube suctioning serves as an external intervention intended to restore airway patency and re-establish physiological balance. However, because suctioning itself may provoke adverse physiological responses, including alterations in heart rate, blood pressure, oxygen saturation and respiratory function, determining the optimal level of negative suction pressure becomes essential. This theory therefore provides the physiological basis for investigating how varying suction pressures influence cardiorespiratory indices, ventilator-associated events, duration of mechanical ventilation, duration of tracheal intubation, ICU length of stay and ICU mortality.

Virginia Henderson's Need Theory complements this systems perspective by emphasizing the nurse's professional responsibility to assist patients in meeting essential physiological needs that they are temporarily unable to meet independently. Among Henderson's fourteen fundamental needs, the ability to breathe normally is the

most immediate and indispensable requirement for sustaining life and maintaining cellular metabolism. Mechanically ventilated patients are unable to clear airway secretions effectively and therefore depend on skilled nursing judgement and interventions such as tracheal tube suctioning to maintain airway patency and adequate oxygenation. Consequently, nurses must perform suctioning in a manner that achieves effective secretion clearance while minimizing physiological disturbances and airway injury. The integration of General Systems Theory and Henderson's Need Theory therefore provides a robust theoretical framework for this study by explaining both the physiological mechanisms through which suction pressure influences patient outcomes and the nursing obligation to deliver evidence-based, safe and effective airway management that promotes recovery and preserves homeostasis.

2.7.1 General Systems Theory

This theory emanated from Ludwing Von Bertalanffy (1901-1972). According to him, a system is a set of distinct parts that interact to form the whole. Generally, it has inputs, throughput and outputs in the context of a particular environment (Katrakazas, 2020). Human organ systems mimic the general systems theory in that they exhibit cause and effect interaction with accompanying feedback loops that ensures homeostasis is sustained within the tissues for optimal biochemical functioning that guarantees continuous existence and growth even in presence of changing internal and external environment. Human cell must get raw materials mainly oxygen and nutrients and give out waste matter i.e. carbon dioxide, urea, excess electrolytes. Critical care nurses are able to observe the outcome of the interaction among organ systems from the monitored parameters involving the heart rate, SpO₂, respiration rate, blood pressure and VAE through other tests. Tracheal tube suctioning is required when the airway is blocked by secretions to an extent that oxygenation and exhalation are compromised. This suctioning, though beneficial, also carries potential for negative effects. A titration art on the level of negative pressure for tracheal suctioning and good outcome vis-à-vis any harm is an inherent concern for critical care practitioners. The conceptual application of the General Systems theory to the phenomena under study is as illustrated in Figure 2.1 below:

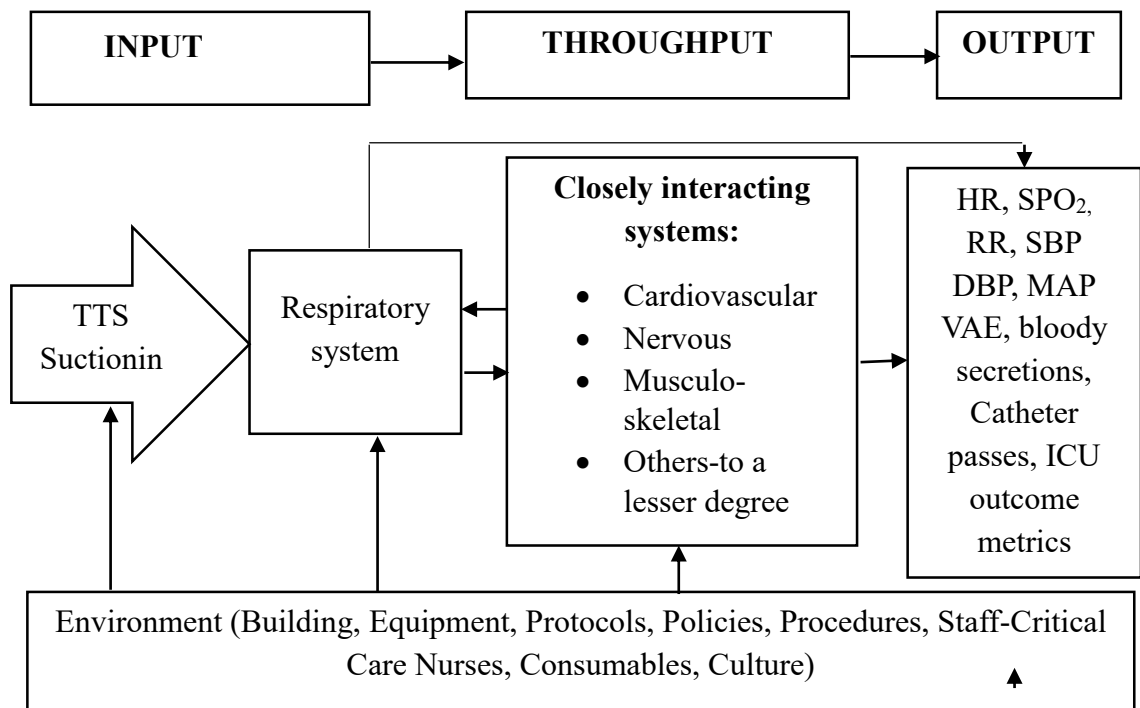


Figure 10.1: Application of General Systems Theory to Open Tracheal Tube Suctioning

In the Figure 2.1 above, Tracheal Tube Suctioning is done on the respiratory system as a way of removing the airway blocking secretions to promote good air flow. The act of suctioning may cause changes on HR, SpO₂, RR, Systolic BP, Diastolic BP, MAP and may lead to complications like VAE & bloody tracheal secretions with a possibility of worsening metric ICU outcomes. These changes are mediated via other systems interacting with the respiratory system to bring about normalcy in oxygenation and carbon dioxide excretion. The environment provides the necessities for TTS including the critical care nurses who have an inherent duty to ensure a clear airway and promote patient safety during and after the procedure within the context of set protocols, procedures, guidelines, culture and resource limitations.

2.7.2 Virginia Henderson's Theory

Virginia Henderson proposed that every individual has fourteen fundamental needs that are essential for health, recovery and independence. She envisaged the

performance of the 14 fundamental needs as a requirement for all human persons regardless of whether they have the knowledge, will and/or strength to meet them and which spelt out the nurses' role as to assist individual(s) meet these needs and enable them to become independent as soon as possible (Fadlalmola, 2021). According to Vera (2024), these needs can be prioritized using Abraham Maslow's Hierarchy of Needs framework as physiological needs; safety; love and belonging; esteem needs and self-actualization in that ascending order as illustrated in Figure 2.2. The requirement to 'Breathe Normally' is a basic physiological need that is critical in maintaining cellular function where biochemical energy is harvested from organic substrates (i.e. glucose) and stored in energy-carrying biomolecule (Adenosine Triphosphate) through utilization of oxygen and production of carbon dioxide and water as bi-products.

Accordingly, Henderson's Need Theory provides the nursing foundation for this study by supporting the evaluation of negative suction pressure as a modifiable nursing intervention intended to meet the patient's fundamental need to breathe normally while optimizing cardiorespiratory stability, airway safety, and critical care outcomes.

Maslow's Hierarchy of Needs complements Henderson's theory by emphasizing that higher-order needs cannot be effectively addressed until the basic physiological requirements necessary for survival have been satisfied (Alligood, 2022). In critically ill patients, the inability to breathe normally due to respiratory failure or airway obstruction represents a disruption of the most fundamental physiological need. Consequently, maintaining airway patency and effective gas exchange becomes the immediate priority before other needs, such as safety, social & psychological well-being, or rehabilitation, can be addressed. Henderson's nursing interventions therefore operationalize Maslow's hierarchy by providing practical measures through which nurses help patients meet these essential physiological needs especially the need to breathe adequately.

In mechanically ventilated patients, the need to breathe normally is temporarily supported through mechanical ventilation and complementary nursing interventions such as tracheal tube suctioning. Retained tracheobronchial secretions usually obstruct

the airway, cause impairment of gaseous exchange, increase the work of breathing, and predispose patients to pneumonia or other ventilator-associated events, prolonged mechanical ventilation, and ICU stay (Blakeman et al., 2022; Ramirez-Estrada et al., 2023). Open tracheal tube suctioning is therefore an indispensable nursing intervention aimed at restoring airway patency and maintaining adequate oxygenation and ventilation. On the other hand, suctioning may also induce adverse physiological responses or airway trauma if performed inappropriately. Nurses must therefore balance effective secretion clearance with patient safety considerations by applying evidence-based suction pressures. Within the context of the present study, Henderson's Need Theory, supported by Maslow's Hierarchy of Needs, provides the nursing and human needs perspective for evaluating whether there is any difference between the two levels of negative suction pressure in meeting the patient's fundamental physiological need to breathe normally while minimizing physiological disturbances and improving critical care outcomes. The conceptual application of the Virginia Henderson's Human Needs Theory superimposed into Abraham Maslow's Hierarchy of Needs is as illustrated in Figure 2.2 below:

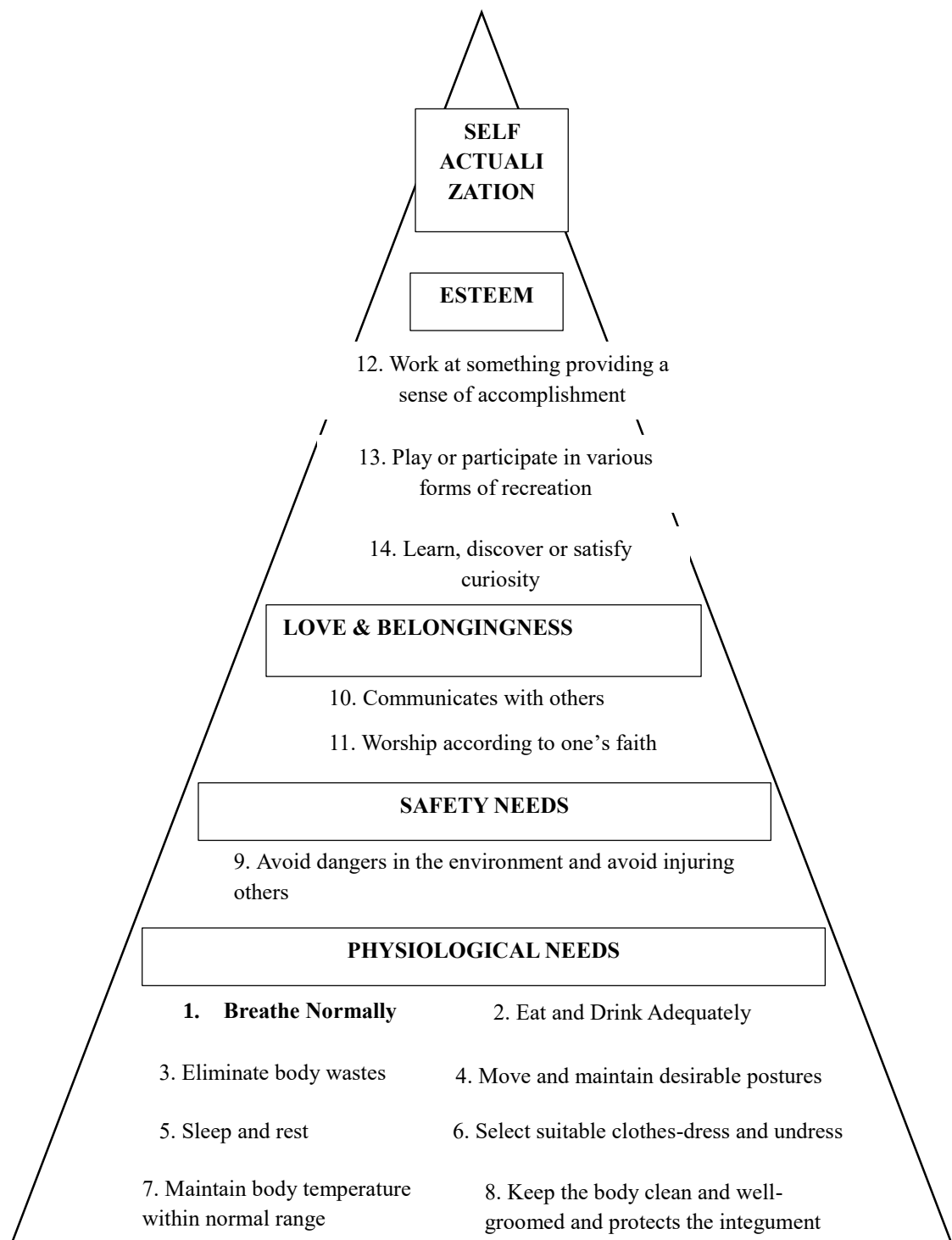


Figure 10.2: Hierarchy of Virginia Henderson's Human Needs Superimposed into Abraham Maslow's Hierarchy of Needs

Often, critical illness compromises the function of ‘breathing normally’ and patients must therefore require support through artificial means that involve insertion of tracheal or tracheostomy tube and initiation of mechanical ventilation with its on-going care. Tracheal tube suctioning becomes integral on-going activity in ensuring a clear airway.

2.8 Conceptual Framework

The Conceptual Framework for this study depicts the hypothesized relationship between the Independent Variable (IV) - Tracheal Tube Suctioning (TTS) and the Dependent Variables (DV) labelled number 1-11 which represent the measurable study outcomes. Tracheal tube suctioning was hypothesized to elicit physiological responses that subsequently influence the eleven dependent variables (DVs 1–11). These outcomes may, however, also be influenced by nine identified extraneous variables (EVs 1–9), which could potentially confound the relationship between the intervention and the study outcomes. Randomization was employed to minimize the influence of these extraneous variables and enhance comparability between the two study groups. Chi-square test was applied to show baseline comparability between the two groups’ categorical variables while either the independent t-test or Mann–Whitney U test was used to establish comparability of quantitative variables between the two study groups. This relationship is presented diagrammatically in Figure 2.3 below:

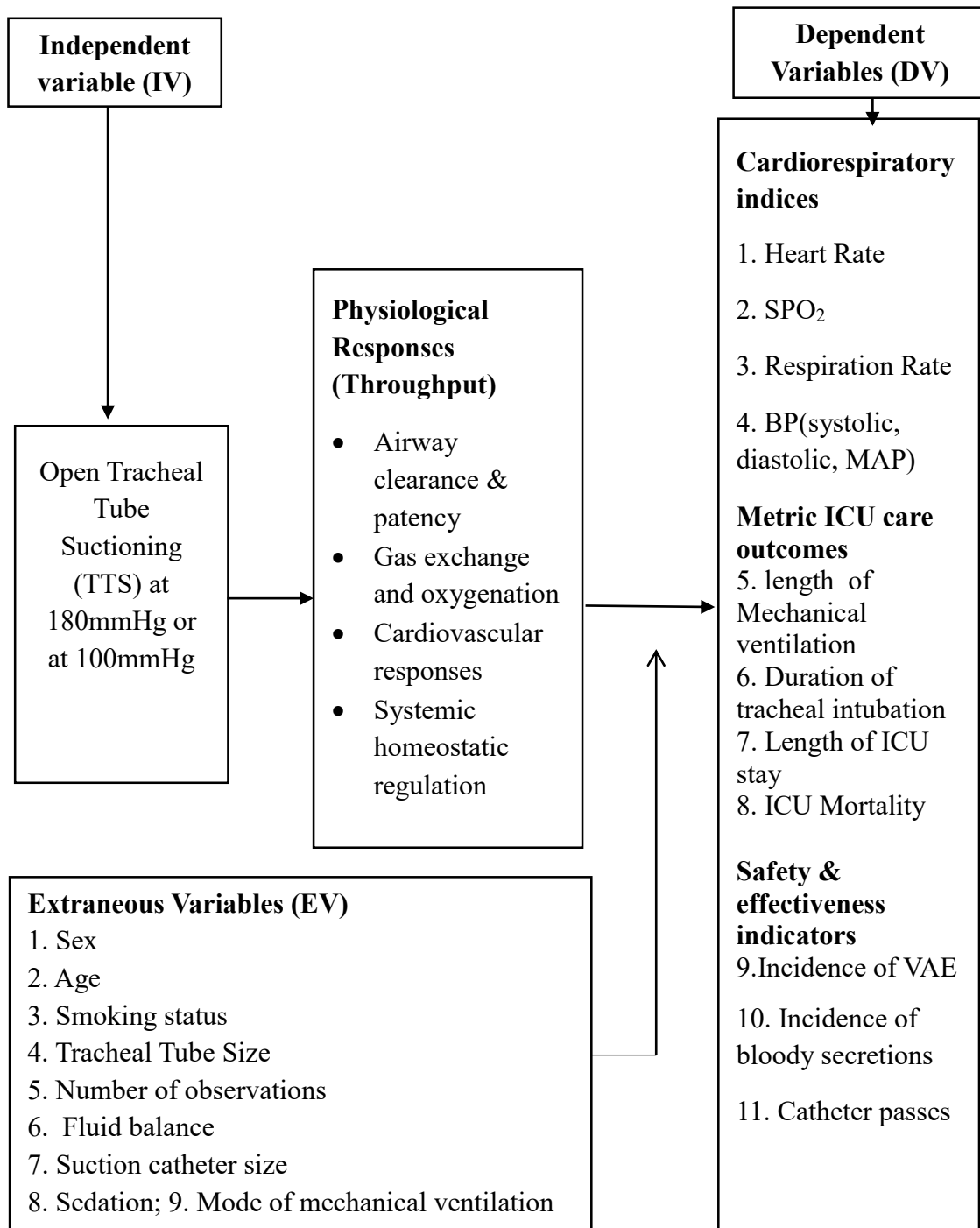


Figure 10.3: Conceptual Framework

2.9 The Critique of the Existing Literature

It is widely agreed that tracheobronchial toileting through suctioning is an essential procedure and one of the most frequently done by nurses in a critical care setting. However, there are many inconsistencies in assigning the required negative suction pressure. Commonly, suction pressure is determined by individual nurses' experiences since the existing evidence is non-conclusive (Maras et al., 2020). Consequently, there are wide choices ranging from 80 mmHg to 300 mmHg in adult TTS. Recommended pressures range from 80 mmHg to below 200 mmHg (Blakeman et al., 2022), while experimental studies have investigated pressures extending to 250 mmHg or higher. The systematic reviews and singular studies cited here have revealed the existing diversity, inconsistencies and controversies in opinion and recommendations on choice of TTS pressures coupled with the absence of reliable data on the relationship between chosen suction pressures with ICU care outcomes involving incidences of VAE, bloody tracheal secretions, length of mechanical ventilation, length of tracheal intubation, length of ICU stay, ICU mortality and effective catheter passes (entrances).

In Kenya, the Nursing Council recommends a suction pressure of 80mmHg to 120mmHg for adults (NCK, 2019). Anecdotal evidence shows that nurses in Kenya use higher negative pressures for adult tracheal tube suctioning than it is recommended. More recent evidence indicates that suction pressure selection continues to vary widely and is often influenced by clinician preference, institutional protocols, and the absence of definitive comparative evidence, resulting in substantial variation in the pressures used (Blakeman et al., 2022).

The available studies are highly heterogeneous in their methodologies, including suction pressures tested, catheter characteristics, suction duration, patient populations, study designs, and outcome measures. Such heterogeneity limits comparability among these studies and make it difficult to isolate an evidence-based optimum suction pressure.

Most previous studies have primarily focused on immediate physiological responses such as heart rate, blood pressure, respiratory rate and oxygen saturation. Comparatively there is little evidence regarding the influence of suction pressure on

clinically meaningful ICU outcomes such as ventilator-associated events, duration of mechanical ventilation, length of tracheal intubation, ICU length of stay and mortality particularly so in our local setting.

Patient safety has received considerable attention in some of the studies done but comparatively little research has objectively evaluated suction effectiveness. There is scarcity of studies that have quantified secretion clearance using measurable indicators such as the number of suction catheter passes required, thereby limiting understanding of the balance between suction efficiency and patient safety.

The principal determinants of suction-related airway trauma remain poorly understood. Even though tracheobronchial mucosal injury is widely recognized as a complication of tracheal suctioning, existing studies have not clearly established the relative role of suction pressure, catheter insertion depth, frequency of catheter passes, suction duration or operator skill.

Much of the contemporary literature comparing open and closed suction systems has focused on infection prevention, aerosol control and maintenance of oxygenation, particularly during the COVID-19 pandemic. Relatively little attention has been directed towards determining the optimal negative suction pressure for open tracheal tube suctioning, despite its continued widespread use in many resource-limited settings.

Despite increasing evidence supporting shallow suctioning as a safer alternative to deep suctioning, deep catheter insertion remains widely practiced in many ICUs. The reasons underlying this persistent discrepancy between emerging evidence and clinical practice remain insufficiently explored.

A great deal of studies on optimal suction pressure are predominantly derived from high-income countries. Comparable randomized evidence from sub-Saharan Africa is scarce, despite substantial differences in disease burden, ICU resources, staffing patterns and clinical practice. Consequently, the applicability of existing recommendations to Kenyan critical care settings remains unknown. Further, absence of randomized controlled trials from Kenya limits the applicability of current

recommendations. These gaps underscore the need for rigorously designed trials to establish an evidence-based suction pressure that optimally balances secretion clearance, physiological stability, patient safety and critical care outcomes in resource-limited settings.

2.10 The Summary

There exists uncertainty regarding the optimal negative suction pressure for open tracheal tube suctioning. The current evidence is characterized by inconsistent recommendations, heterogeneous methodologies and narrow focus on short term physiological responses to suctioning as opposed to clinically important ICU care outcomes. Moreover, the determinants of tracheobronchial mucosal injury remain largely unknown. The effectiveness of commonly applied suction pressures have not been sufficiently evaluated objectively. Evidence from sub-Saharan Africa is scarce, and no other Kenyan randomized controlled trial was identified that compares suction pressure of 180mmHg with 100mmHg in relation to cardiorespiratory indices, secretion clearance, patient safety and critical care outcomes. These gaps provide the scientific basis for this study.

2.11 The Research Gaps

The literature revealed has indicated that the historically known tracheal bronchial suctioning is an important procedure for maintaining airway patency for optimal oxygenation and ventilation. However, substantial inconsistencies persist regarding the optimal negative suction pressure for adult open tracheal tube suctioning. Existing recommendations range widely from 80 mmHg to below 200 mmHg, while experimental studies have evaluated pressures extending beyond these limits and reported conflicting findings on their safety and effectiveness.

A lot of studies have concentrated on immediate physiological outcomes such as heart rate, hemoglobin oxygen concentration, respiration rate and blood pressure while there is scarcity of evidence on clinically meaningful critical care outcomes including ventilator-associated events, bloody tracheal secretions, duration of mechanical ventilation, length of tracheal intubation, ICU length of stay, and mortality.

Furthermore, the available evidence remains methodologically heterogeneous, differing in suction pressures tested, suctioning techniques, catheter characteristics, outcome measures, and study populations, thereby limiting comparability and preventing definitive conclusions.

The literature also reveals unresolved controversies regarding the relative merits of open versus closed suction systems and the continued use of deep versus shallow suctioning. While emerging evidence supports use of closed-circuit suction systems with shallow suction approach, there is limited information about the amount of optimal negative suction pressure in open tracheal suction which continues to be widely practiced in many resource-limited settings. Moreover, the main determinants of tracheobronchial mucosal injury remain unclear, with limited evidence distinguishing the contributions of suction pressure, catheter insertion depth, number of suction catheter passes, suction duration, and operator skill.

There are limited high-quality randomized controlled trials evaluating the relationship between suction pressure, suction effectiveness, cardiorespiratory indices, patient safety, and long-term ICU outcomes, particularly in sub-Saharan Africa and Kenya. No randomized controlled trial was identified comparing 180 mmHg and 100mmHg negative suction pressures while simultaneously assessing physiological responses, secretion clearance effectiveness, patient safety and critical care outcomes. These gaps provided the scientific justification for the present study, which sought to generate context-specific evidence to guide evidence-based suctioning practices and improve the quality and safety of critical care among mechanically ventilated adult patients.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

A Randomized Controlled Trial (RCT) research design was adopted for this study. It was an approach involving comparison of two levels of negative pressure in open tracheal tube suctioning on their cardiorespiratory effects and care outcomes as well as their safety and effectiveness for mechanically ventilated adult patients at Machakos county hospital Intensive Care Unit (ICU). RCTs, although uncommon compared to phase 1 and 2 trials, are regarded as the ‘gold standard’ in establishing safety and efficacy of interventions (Gale et al., 2023). They eliminate a great deal of confounding biases that can be found in many other designs (Fultinaviciute & Maragkou, 2023; Sheldrick, 2023). However, it is important to note that the ‘Gold Standard’ design is whatever design that gives the information required in the most reliable way (Gerstman, 2023). The experimental suction pressure in this study was 180mmHg while the control or the usual suction pressure was 100mmHg. Tracheal Tube Suctioning (TTS) was therefore the Independent Variable (IV) while the Dependent Variables (DV) were: number of catheter passes needed to clear tracheal secretions, incidence of VAE and blood tinged secretions; cardiorespiratory indices: Heart Rate (HR), Peripheral Oxygen Saturation (SpO₂), Respiration Rate (RR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP); and lastly metric ICU care outcomes: length of mechanical ventilation, duration of tracheal tube placement, length of ICU stay and Mortality in ICU.

This study design was suitable for establishing a cause-and-effect relationship between an intervention (tracheal tube suctioning at either 180mmHg or 100mmHg) and outcome (effectiveness and safety indicators, cardiorespiratory indices and metric patient care outcomes) as described by Bertrand et al. (2023) and World Health Organization [WHO], (2024). The design involved randomization of cases into the study and the control groups which balanced participants observed and non-observed

characteristics and this minimized bias allowing attribution of the changes in the dependent variables to the open tracheal tube suctioning pressure. Randomization was done by putting cases into major critical care diagnostic categories (Appendix 5: Block Randomization Consort Diagram)

Allocation concealment was employed to minimize selection bias during participant assignment. It was achieved through rotation of totals per diagnostic category during every round of replacement from four to six and vice versa (Appendix 5). The patients and/or their surrogates did not know which suction group they belonged to. The staff carrying out the suctioning did not also know the suction allocation of the cases they were dealing with, hence making this study double blinded. The desk-based research records did not indicate the suction group of the patients. This was kept away from the data collection point.

In this experimental study, the researcher therefore randomly allocated participants to either the Experimental Arm (180mmHg Tracheal Tube Suction Group) or the Control Arm (100mmHg Tracheal Tube Suction Group) and then assessed the average number of catheter passes needed to clear tracheal secretions; incidences of VAE & blood-tinged secretions; cardiorespiratory indices produced at four measurement time points (immediately before, during suctioning, 5 minutes post suctioning and 20 minutes post suctioning); mechanical ventilation days; duration of tracheal tube placement; length of stay in ICU; and ICU mortality within the two groups.

3.2 Study Site

This study was conducted at Machakos County level 5 hospital Critical Care Unit. This hospital is a typical County hospital in Kenya among the 47 counties. It is located between the capital city and the larger eastern Kenya region. It shares border with Muranga, Kirinyaga, and Embu to the north, Kitui to the east, Makueni to the south and Nairobi, Kiambu and Kajiado to the west and North West. It covers an area of 6,037.3 KM². The main economic activity is agriculture particularly livestock keeping and farming. The Nairobi-Mombasa Road transverses the county. It has an approximate population of 1.5M. The County is administratively and politically structured into eight (8) constituencies, nine (9) sub counties, twenty-seven (27)

divisions, forty (40) wards, seventy-six (76) locations and 239 sub locations (County Government of Machakos, 2023).

The county operates the Kenya Essential Package for Health (KEPH) structure, with services organized from community health units (Level 1) through dispensaries (Level 2), health centres (Level 3), sub-county hospitals (Level 4), and the county referral hospital (Level 5). There are over 367 registered health facilities distributed among public, faith-based, private, and non-governmental providers including 193 county government facilities, 32 faith-based facilities, 9 NGO facilities, and 128 privately owned facilities. There is one level five hospital, 4 level four hospitals and 20-25 level three hospitals (County Government of Machakos, 2023).

It's among the eight county hospitals ranked position six in terms of ICU bed capacity. Additionally, it has an elaborate prehospital emergency service (Barasa et al., 2020). During the period covered by this study, the hospital had a 4-bed capacity ICU with a bed occupancy of 3 patients. Overall ICU admission during this period was 137 patients from November 2023 to October 2024 (Machakos Level Five Hospital, 2024). The Machakos County hospital therefore provided a suitable ICU environment for undertaking this study.

3.3 Target Population

ICU intubated and mechanically ventilated patients, 18 years and above, were the target group. The patients who met the admission criteria were recruited and randomly allocated into either the 180mmHg TTS group or the 100mmHg TTS group.

3.4 Sample Size

A sample size of 76 cases was used in this study. A balance of cases between the groups was not exactly reached due to possibilities of imbalance produced by simple random sampling within each stratum with additional intent to observe concealment. Therefore, the Experimental Group had 39 cases while the Control Group had 37 cases. The sample size was calculated using a formula by Cheng, et al. (2024) for a RCT.

Where σ^2 is the common population variance for the two groups

$$n = \frac{2 \sigma^2 (Z_{1-\alpha/2} + Z_{1-\beta})^2}{(\delta)^2}$$

The indices used in the formulae are as indicated in Table 3.1 below:

Table 12.1: Statistical Parameters Used in Sample Size Calculation

Parameter	Value
α	0.05
$(Z_{1-\alpha/2})$	1.960
β	0.2
$(Z_{1-\beta})$	0.842

1.960 is the value of Z for a two-tailed test at 95% Confidence Level and 0.842 is the value of Z at the chosen power of 80% (Sauro & Lewis, 2020).

δ is the target or anticipated difference in mean outcomes between the two groups. It is calculated as difference between means divided by the difference in standard deviation of the means. The smallest of the calculated or literature reviewed δ and the largest of σ are adopted for this study. The studies indicated in table 3.2 were the empirical sources of δ and σ used for calculation of sample size in which the smallest Effect Size and the largest population variance were adopted.

Table 12.2: Determination of δ and σ Values

STUDY	MEANS & SD	δ, σ	SAMPLE SIZE USED
In a study on volume of TTS secretions between 100mmHg and 200mmHg suctioning by Yazdannik et al., (2019)	Mean difference = 1.724 (0.164)	$\delta = 10.5$	Sample size was 50 with a cross over design
In a study by Kostekli et al. (2022) comparing efficacy of shallow and deep suctioning, the following were the values		$\delta = 6.8$ $\sigma = 10.47$	74 (both groups)

TTS: Tracheal Tube Suctioning

Out of literature reviewed, the smallest level of $\delta = 6.8$ was adopted and the largest of $\sigma = 10.5$

$$n = \frac{2 \sigma^2 (Z_{1-\alpha/2} + Z_{1-\beta})^2}{(\delta)^2}$$

$$n = 2 \times 10.5^2 \times (1.960 + 0.842)^2 / 6.8^2$$

$$n = 2 \times 10.5^2 \times (2.802)^2 / 6.8^2$$

$$n = 2 \times 110.25 \times 7.8512 / 46.24$$

n = 37.44

n = 38 (per group of the study)

3.5 Sampling Techniques

Participants were recruited into the study as they are admitted into the ICU for mechanical ventilation but randomly allocated to the two groups of the study. Simple randomization method was inappropriate if used alone due to possibility of creating imbalance between the two groups. According Zhao (2024), a sample size of 40 (total for two groups) can attract an imbalance of 52.7% while a larger sample size of 200 subjects reduces the possibility of this imbalance to 15.7%. Permissible imbalance is 45-55% among the groups. In order to mitigate this, stratification followed by simple random sampling was used for allocating the 76 subjects to either the 180mmHg suction group or the 100mmHg suction group. The strata were based on ICU major diagnostic categories. These are Gastrointestinal Tract (GIT) diseases & surgery; Severe infections, autoimmune disorders, shock and cardiac diseases; head injuries; neurological disorders; renal disorders; multiple trauma; endocrine disorders; obstetric & gynaecological emergencies; poisoning and then all other diagnoses (Ingraham, 2022; Machakos Level Five Hospital, 2024; Soares, 2024).

Blocks of four and six were adopted for randomization to promote better concealment. Simple random sampling was then applied to allocate participants in each block to the two groups of the study. A schematic diagram showing the randomization process is in Appendix 5.

3.6 Selection Criteria

The selection of participants was done as described below: -

3.6.1 Inclusion Criteria

- Patients who were admitted into the ICU
- Patients put on mechanical ventilation through a tracheal tube as a modality of care

- Patients who were 18 years and above

3.6.2 Exclusion Criteria

- Those patients with confirmed chest infection. This was put as a condition owing to the fact that this study sought to establish the relationship between suction pressure and ICU care outcomes particularly involving Ventilator Associated Events including Ventilator Associated Pneumonia. Any existing chest infection had to be ruled out.
- Intubated before arrival to hospital: Again, this safeguarded against recruiting a patient who was already exposed to pneumonia causative micro-organisms occasioned by non-adherence to aseptic technique during intubation.
- Known blood coagulation disease: This condition was necessary for avoiding patients who had a tendency to bleed easily so that the bloody tinged secretions that this study sought to find would happen from suctioning but not because of existing coagulation disorder.

3.7 Study Variables

The study variables were:

3.7.1 Independent Variables

Tracheal Tube Suctioning at either 180mmHg or 100mmHg were the independent variables.

3.7.2 Dependent Variables

These were: cardiorespiratory indices involving observation of the heart rate as a count of heart beats per minute and oxygen saturation as captured in the cardiac monitor as a percentage of hemoglobin saturated with oxygen; observation of respiration rate as a count of breathes per minute as displayed on the mechanical ventilator user-interface screen; measurement of blood pressure to include three indices: Systolic, Diastolic and Mean Arterial Pressure as measured in millimeters of mercury by use of cuff pressure applied to the upper arm and read on the cardiac monitor; the number of catheter passes used for effective clearance of tracheal secretions written as a numerical count;

number of episodes of bloody tracheal secretions, recorded as a numerical count; Ventilator Associated Events captured in 3-tier format as described in Appendix 19. These were: Tier-1 is Ventilator Associated Condition (VAC): where there was worsening respiratory status causing hypoxaemia that required increase in PEEP $\geq$ 3cmH₂O and FIO₂ by 20% after two days of stability. Tier-2 is Infection-related Ventilator Associated Complication (IVAC): where there was a change in white blood cell count ($>12,000/\text{cm}^3$ or $<4,000/\text{cm}^3$) and/or temperature ($>38^\circ\text{C}$ or $<36^\circ\text{C}$) and a new antimicrobial prescription was started and sustained for at least four days. Tier-3 is Possible Ventilator-associated Pneumonia (PsVAP): where there was evidence for lower respiratory airway infection confirmed by culture of tracheal aspirate; determination of metric ICU patient care outcomes involving: - length of mechanical ventilation, duration of tracheal tube placement, length of stay in ICU and mortality in ICU.

Length of Stay: -Was the number calendar days that the study subjects remained admitted in the Intensive Care Unit. Calculated with precision of an hour as a fraction of a day.

Mechanical Ventilation Days (MVD): - Was the number of calendar days exposure to ventilators by each and by all patient(s) in the selected population during the selected time period.

Duration of tracheal tube: -Was the total count in calendar days a patient remained with a tracheal tube.

Mortality in ICU: -Was occurrence of death among mechanically ventilated patients in the Intensive Care Unit.

3.8 Study Instruments

Three data collection tools were developed by the researcher, validated and tested for reliability. Patient Data Form 1a (Appendix 1) was used for recording the bio-socio-demographic, initial patient assessment, cardiorespiratory indices, colour of secretions (blood-tinged or not), and number of catheter passes used to clear tracheal secretions.

Patient Data Form 1b (Appendix 2) was a continuation of Patient Data Form 1a and did not therefore capture bio-socio-demographics and the initial patient assessment but contained the rest of data. The third tool (Patient Data Form 2-Appendix 3) was used mainly for recording designated patient care outcomes (day of mechanical ventilation, day of tracheal tube, day in ICU, incident of mortality and VAE. The tools were prepared by the researcher from the literature reviewed and validated by a panel of experts in critical care department at the Defence Forces Memorial Hospital (DFMH) consisting of critical care nurses, critical care physician, anesthesiologists, medical statistician and tested at the Machakos hospital ICU for reliability using 12% of the calculated sample size (i.e. 10 clients) following which the Cronbach's alpha was calculated as presented in Tabel 3.3 below:

Table 12.3: Reliability Assessment of Data Collection Tool

Serial	Variable	Cronbach's alpha	N of Items
1.	Heart Rate	.990	4
2.	SpO ₂	.958	4
3.	Respiration Rate	.886	4
4.	SBP	.890	4
5.	DBP	.755	4
6.	MAP	.855	4
	Average	.889	

All the variables had a Cronbach's alpha of >0.7. The average Cronbach's alpha was 0.89.

The Content Validity of the tools was determined by an assessment of the relevance of the items in relation to the objectives of the study by two specialists in critical care (anaesthesiologist-Intensivist and critical care nurse specialist). The items were rated as very relevant (4), quite relevant (3), somewhat relevant (2) and not relevant (1). The calculated Content Validity Index (CVI) was 0.88 (CVI = Items rated 3 or 4 by both experts divided by the total number of items in the tool). A reliability and Validity

coefficient of at least 0.70 is acceptable (Mahadik & Topkar, 2023). The biomedical staff performed equipment maintenance and output comparative checks every fortnight and whenever else required.

3.9 Pretesting of the Tools

Data collection tools were pretested with 12% of the sample size (10 patients) who were then excluded from the study. Tools were then rearranged to produce logical flow during data recording and re-align with the practical approach in performing open tracheal tube suctioning. Positioning of the clock was also done to facilitate best visualization for timing the 15-second-suction duration.

3.10 Data Collection Procedures

These are described as follows: -

3.10.1 General

This was a double-blind study. The patients or their relatives did not know which suction group they belonged to. The staff doing the suctioning did not know which group the clients belonged to nor did they participate in setting the suction pressure. The pressure gauge remained covered with a translucent material after setting and testing for the appropriate suction pressure level.

Prior to commencement of the study and in every two weeks the biomedical department of the hospital checked and confirmed proper functioning of the central pressure systems and the cardiac monitors of the ICU.

The suctioning procedure was carried out as outlined in Appendix 4.

3.10.2 Application of Data Collection Tools

Patient Data Form 1a and 1b were filled by the researcher or his assistants upon patient admission and during the course of care. The first part (Patient Data Form 1a) involved recording of bio-socio-demographics, ventilatory and initial assessment together with

the second part that involved measurement of cardiorespiratory indices during open Tracheal Tube Suctioning at four time points (i.e. just before, during (just after 2nd catheter pass), after 5 minutes and 20 minutes post suctioning); observation of occurrence of bloody tracheal secretions; number of catheter passes required to clear tracheal secretions (each catheter pass took a duration of 15 seconds during suctioning and therefore the number of catheter passes required to clear tracheal secretions represented effectiveness of the suction pressure). Subsequent data involved only the second part described above and was recorded on Patient Data Form 1b (Appendix 2).

Follow up assessment tool (Patient Data Form 2-Appendix 3) was used to capture information relating to Metric ICU patient care outcomes & VAE: patients' day in ICU, day of mechanical ventilation, day on tracheal tube, Fraction of Inspired Oxygen, level of PEEP, white blood cell count, patient temperature, new antibiotic therapy initiated, chest X-ray changes, positive culture results for tracheal aspirate and occurrence of death in ICU as shown on Appendix 3.

3.10.3 Recruitment of Cases

Data collection exercise begun in November 2023 with admission of the first 10 cases for pretesting of the tools following which revision of the tools was done. The ten cases were excluded from the study. Case recruitment was done at an average rate of 7 cases per month. Case recruitment for the month of April 2024 was zero due to medical staff industrial action that resulted into their absence from work, halting patient admission into the hospital and ultimately into the ICU. Total cases evaluated for eligibility were 137.

Actual case recruitment started in December 2023 up to October 2024 as presented in Figure 3.1 below:

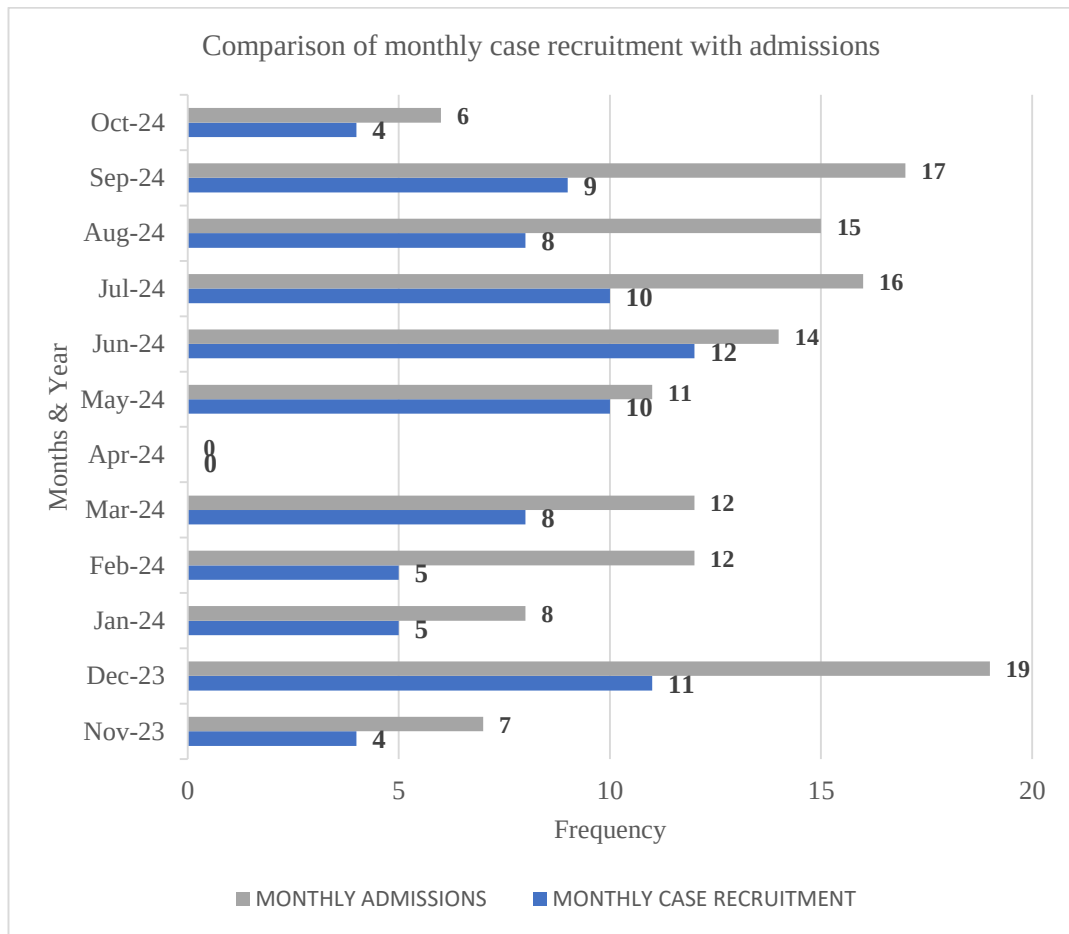


Figure 12.1: Case Recruitment over Time

Overall, monthly case recruitment generally reflected the pattern of ICU admissions, with recruitment remaining lower than admissions in all months. The gap between admissions and recruitment varied from month to month. Higher admission months tended to yield greater recruitment, while no admissions or recruitment were recorded in April 2024. The highest admission volume occurred in December 2023, whereas the highest monthly recruitment was recorded in June 2024.

3.11 Data Processing

The CONSORT Flowchart diagram below summarizes the processing of participants for the study:

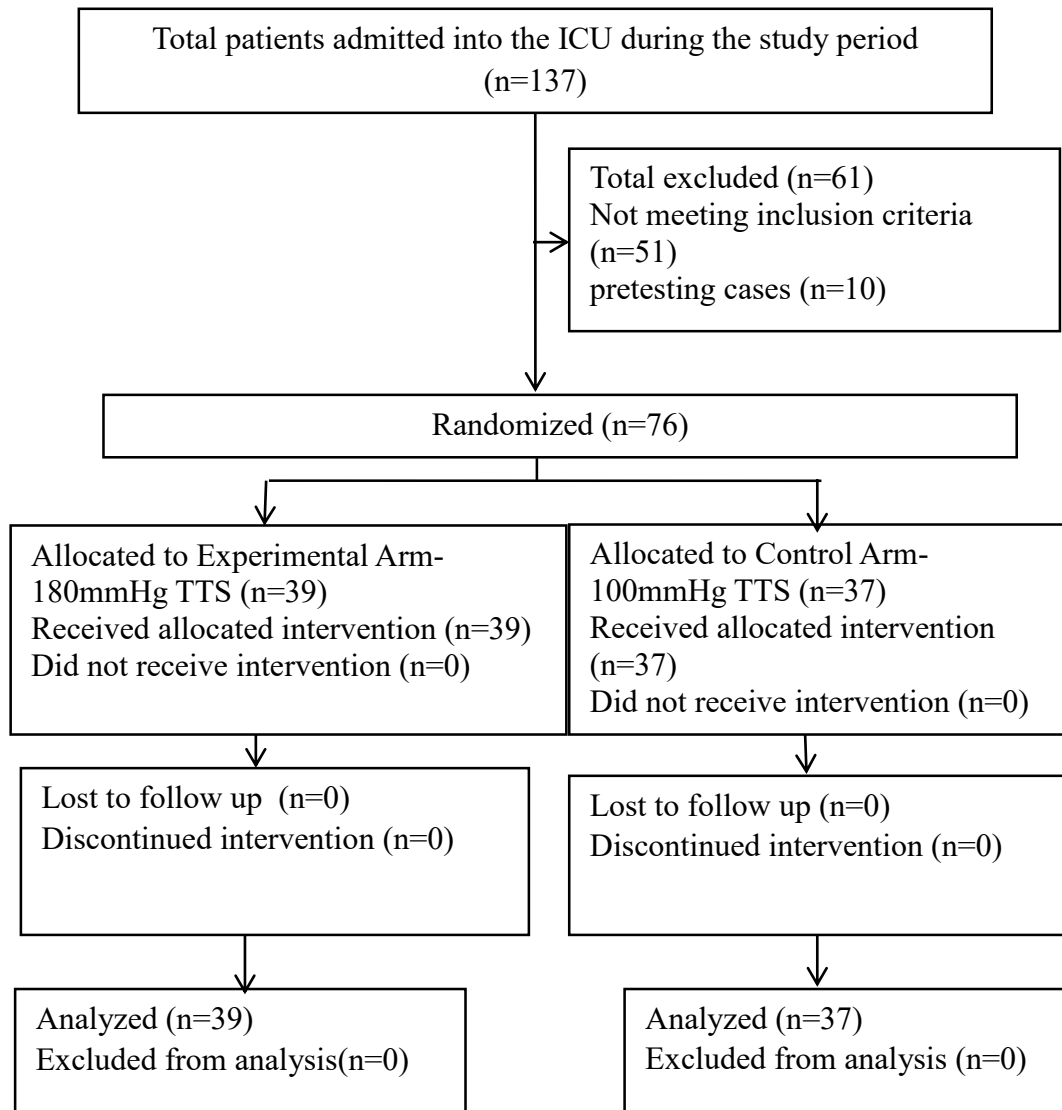


Figure 12.2: Participants CONSORT Flowchart Diagram

Figure 3.2 above presents the flow of participants in the study. A total population of 137 patients were admitted into the ICU during the study period. Among them, 61 were excluded because 10 participated in the pre-testing of the tools and the remaining

51 did not meet the eligibility criteria due to various reasons as tabulated in Table 3.4 below:

Table 12.4: Reasons for Non-recruitment of the Excluded Patients

Serial	Reason for non-recruitment	Frequency
1.	Not intubated	31
2.	No opportunity for suctioning	11
3.	Under age (<18 years)	7
4.	Bleeding disorder	1
5.	Intubated out of hospital	1
Total		51

Majority of those who were excluded from the study despite having been admitted into the critical care unit were not intubated. These are patients who despite not having been intubated, they required constant close observation. The Machakos hospital ICU served as High Dependency Unit too (HDU). The second level of patients did not present an opportunity for suctioning meaning that they were extubated or died before being suctioned. As an ethical requirement for informed consent, those below 18 years were excluded from the study. One patient had hemorrhagic disorder while the other one was intubated before admission to Machakos Level Five Hospital.

A total of 76 eligible mechanically ventilated adult patients were recruited consecutively, with 39 randomized into experimental group and 37 into the control group. All participants received their allocated interventions and were included in the final analysis, resulting in no loss to follow-up or post-randomization exclusions.

3.12 Data Management

Data was sorted out, cleaned and entered into International Business Machines Corporation (IBMC) Statistical Package for Social Sciences (SPSS) software version 26 for analysis. Descriptive and inferential statistics were calculated. Independent t-

test or its non-parametric equivalent was used to compare the two groups age, duration of mechanical ventilation, duration of tracheal tube, length of ICU stay, tracheal tube size, daily fluid balance, catheter passes and also between the two group's cardiorespiratory indices. Chi-square test was used to determine homogeneity of group's sex, exposure to sedation, smoking status, VAE and ICU mortality between the two groups. Repeated Measures Analysis of Variance (ANOVA) or its non-parametric equivalent was used to determine differences in the physiological indices within each group (i.e. HR, SpO₂, RR, SBP, DBP and MAP) at the four suction time points. Alpha level of 0.05 was chosen and therefore p was significant if $p < .05$.

3.13 Ethical Consideration

Key parts of the consenting process were articulated as described below: -

3.13.1 Authority

Authority to carry out the study was granted by the Jomo Kenyatta University of Agriculture and Technology Institutional Scientific and Ethics Review Committee via approval letters: JKU/ISERC/02316/0914 and dated 13th July 2023 (Appendix 10) and its renewal dated 6th June 2024 (Appendix 14); National Commission for Science, Technology and Innovation (NACOSTI) issued a research permit referenced: NACOSTI/P/23/28497 for a period that ended on 16th August 2024 (Appendix 11) and a renewal permit referenced: NACOSTI/P/24/37702 for the period that ended on 24th July 2025 (Appendix 15); and the Machakos County government provided authority via the initial acceptance letter referenced: MKS/DHES/RSCH/VOL1/317 dated 29/9/2023 (Appendix 13) and renewal of authority acceptance letter referenced: MKS/DMS/RESEARCH APPROVALS/2024/30 dated 6th September 2024 (Appendix 16).

3.13.2 Informed Consent

Patients and/or their legal guardians were explained to about the study and requested to participate. The principal investigator (PI) or Research Assistant (RA) obtained

informed consent from authorized representative (proxy) as soon as feasible after admission or within the designated enrolment period.

All participants were not able to give consent owing to their clinical state and therefore, their legal guardian or parents gave informed consent. The legal guardians were made aware that there was no monetary gain in their participation but the results of this study would contribute to the body of knowledge regarding tracheal tube suctioning for mechanically ventilated patients in any Intensive Care Unit.

The guardians had autonomy to decline participation or withdraw their patients from the study without any intimidation or any other consequences. The consent process was available in both English and Kiswahili and an interpreter was sought for when needed. Consent was documented. The Consent documents are as shown on Appendix 5-9.

3.13.3 Potential Harm

There was no anticipated or extra ordinary harm from the tracheal suctioning since the suction pressures of 100mmHg and 180mmHg or thereabout had been tried without reported harm and suctioning was only done when clinically indicated. An anecdotal clinical comparison between the groups did not reveal any obvious disadvantage to either group. A mini-trial mid-point pre-analysis of data by the author did not suggest possibility of a difference that constituted an obvious disadvantage to either group. It involved a comparison between the two groups on blood-tinged secretions and mortality. The Chi-square test results are as presented in Table 3.5 below:

Table 12.5: Mid-term Comparison on Blood-tinged Secretions and Mortality

Serial	Variable	Chi-square test results
1.	Blood-tinged secretions	$X^2 (1, N=277) = 1.76, p = .675$
2.	Mortality	$X^2 (1, N=39) = .268, p = .605$

There was no significant difference between the two groups on the two variables

($p > .05$).

3.13.4 Anonymity, Privacy and Confidentiality

Records of data from the patients were coded using numerical numbers from 01 to 76. Participant's name, phone number, or obvious identification labels were not used on data record sheets. All data was kept under lock and key to prevent unauthorized access and hence promote privacy and confidentiality. Sharing of information obtained from the study was only done for clinical reasons for the benefit of the patient and with the persons involved in making decision or taking actions on care of the patients. Study results, recommendations and conclusion have been shared with professionals and stakeholders without any identity of participants. Publication in peer reviewed journals has been done for bigger benefit to medical professionals particularly the critical care nursing fraternity, again without revealing the identity of the patients.

3.14 Results Dissemination

The results of this study have been shared with professionals and stakeholders at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Machakos Level Five hospital, Defence Forces Memorial Hospital (DFMH), Defence College of Health Sciences (DCHS) and with critical care nursing fraternity during the 28th Kenya Critical Care Nurses Chapter Annual Scientific Conference held at Reef hotel, Mombasa city on 2/10/25. Publication in peer reviewed journals has been done in the East African Medical Journal, Journal of Agriculture, Science and Technology and in the Kenyan Journal of Nursing and Midwifery.

CHAPTER FOUR

RESULTS

4.1 Introduction

This experimental study investigated the effects of open tracheal tube suctioning on specific cardiorespiratory indices, patient care outcomes, safety and effectiveness between a suction level of 180mmHg (Experimental Group) and a suction level of 100mmHg (Control Group) among adult mechanically ventilated patients in a Critical Care Unit at Machakos level five hospital. This chapter presents the results.

The study was conducted on 76 subjects. 39 were randomly allocated to the Experimental (Expt) Group while 37 were randomly allocated to the Control (Ctrl) Group.

4.2 Baseline Characteristics of Study Participants

4.2.1 Demographic Characteristics of Study Participants

There were 41 male (54%) and 35 female (46.0%) subjects, with a mean age of 41.5 years (range 18-96 years). Participants' demographics are presented in Table 4.1 below:

Table 14.1: Baseline Demographic Characteristics of Participants

ITEM	Expt (180mmHg)	Ctrl (100mmHg)
Age	$\bar{x}$ =40.51, SD=17.81, Mdn=35.00, IQR=5.05	$\bar{x}$ =42.43, SD=17.63, Mdn=39.00, IQR=30.00
Sex	Male=21 (53.8%) Female=18 (46.2%)	Male= 20 (54.1%) Female= 17 (45.9%)

IQR: Interquartile Range; Mdn: Median; SD: Standard Deviation

The table shows a close match on age and sex between the two study groups.

4.2.2 Baseline Comparability of Experimental and Control Groups

Baseline characteristics and selected extraneous variables were compared between the experimental and control groups to assess the effectiveness of randomization and determine whether the groups were comparable before the intervention. There was no significant difference between the Experimental and Control groups of the study on the variables tested for comparability ($p > .05$).

The results are presented in Table 4.2 below:

Table 14.2: Comparability of the Experimental and Control Groups on Selected Extraneous Variables

Serial	Extraneous Variable	Suction Group		Type of test	Test statistic	p-value
		Experimental (180mmHg) n=39	Control (100mmHg) n=37			
1.	Sex	Male=21 Female=18	Male=20 Female=17	X^2		0.985
2.	Age	$\bar{x}$ = 40.51 Mdn=35.00	$\bar{x}$ = 42.43 Mdn=39.00	(1, N=76) =0.000 Mann Whitney U Test	.494	0.621
3.	Smoking	σ = 17.81 Yes=7	σ = 17.63 Yes=8	X^2		0.688
4.	ETT size	No=32 $\bar{x}$ = 7.04 Mdn=7.00	No=29 $\bar{x}$ = 7.08 Mdn=7.00	(1, N=76) =0.1621 Mann Whitney U Test	.426	0.670
5.	No. of Observations	σ = 0.44 $\bar{x}$ = 7.46 Mdn=4.00 σ = 9.695	σ = 0.46 $\bar{x}$ = 8.68 Mdn=6.00 σ = 9.724	Mann Whitney U Test	1.058	0.290

6.	Fluid balance	$\bar{x}$ = 1621.04 Mdn=1300.00	$\bar{x}$ = 1704.65 Mdn=1600.00	Mann Whitney U Test	1.024	0.306
7.	Suction Catheter size	σ = 1366.46 $\bar{x}$ =13.20 Mdn=13.89	σ = 1020.98 $\bar{x}$ =13.44 Mdn=14.00	Mann Whitney U Test	-1.192	0.233
8.	Sedation	σ =0.93 Yes=25 No=14	σ =0.81 Yes=29 No=8	X^2		0.170
9.	Mode of Mechanical Ventilation	AC= 25 SIMV= 11 CPAP= 3	AC= 22 SIMV= 14 CPAP= 1	(1, N=76) =1.881 X^2 (2, N=76) =1.500		0.472

AC: Assist Control; CPAP: Continuous Positive Airway Pressure; ETT: Endotracheal Tube; Mdn: Median; SIMV: Synchronized Intermittent Mandatory Ventilation

4.2.3 Distribution of Study Participants by Diagnostic Category

The study subjects were put in diagnostic categories representing disease conditions being managed in the ICU. The largest proportion was from neurological disorders at 27.6%, followed by severe infections, autoimmune disorders, shock, and cardiac diseases at 22.4%. Multiple trauma, obstetric and gynaecological disorders were grouped with other rare diagnoses and accounted for 11.9%, while head injuries accounted for 9.2%. Endocrine disorders represented 6.6% of participants, whereas gastrointestinal diseases and surgery, poisoning, and renal disorders accounted for the rest as presented in Table 4.3 below:

Table 14.3: Disease Conditions of the Study Subjects

Serial	Disease Condition	%
1.	Neurological disorders	27.6
2.	Severe infections, autoimmune disorders, shock and cardiac diseases	22.4
3.	Multiple Trauma	11.9
4.	Obstetrics & Gynaecology disorders and other diagnosis	11.9
5.	Head Injuries	9.2
6.	Endocrine disorders	6.6
7.	GIT diseases and Surgery	3.9
8.	Poisoning	3.9
9.	Renal disorders	2.6
	Total	100

GIT: Gastrointestinal

4.2.4 Comparison of Diagnostic Categories between the Experimental and Control Suction Groups

The diagnostic categories were fairly well distributed across both suction groups, with neurological disorders forming the largest category in each group. Overall, the distribution of disease conditions was broadly similar between the 180mmHg experimental group and the 100mmHg control group. This is presented in Table 4.4 below.

Table 14.4: Diagnostic Categories between the Experimental and Control Suction Groups

SERIAL	DIAGNOSTIC CATEGORY	SUCTION GROUP	
		180mmHg (Expt)	100mmHg (Ctrl)
1.	Neurological disorders	10	11
2.	Severe infections, autoimmune disorders, shock and cardiac diseases	9	8
3.	Multiple Trauma	5	4
4.	Obstetrics & Gynaecology disorders and other diagnosis	5	4
5.	Head Injuries	3	4
6.	Endocrine disorders	3	2
7.	GIT diseases and Surgery	2	1
8.	Poisoning	1	2
9.	Renal disorders	1	1
	TOTAL	39	37

Expt: Experimental, Ctrl: Control

Other findings of this randomized controlled trial are reported according to the specific objectives they are intended to address.

4.3 Effectiveness and Safety of 180mmHg and 100mmHg Suction Pressures

In order to achieve the first objective of this study, data pertaining to the number of catheter passes (entrances) performed to clear tracheal secretions, incidence of Ventilator Associated Events (VAE) and blood-tinged secretions for each group of study was collected and comparison made in order to test the hypothesis that ‘There is no significant difference in the number of catheter passes required for effective tracheal secretion clearance between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients’ and that ‘There is no significant difference in safety, as measured by the occurrence of blood-tinged tracheal secretions

and ventilator-associated events, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients’.

The results indicated that there was a statistically significant difference in catheter passes between the Experimental Group ($\bar{x}$ = 2.24, SD= 0.35) and the Control Group ($\bar{x}$ = 3.46, SD = 0.55), $p < 0.001$, with a very large Effect Size (Hedge’s g =2.66). However, the two groups did not show a significant difference in blood-tinged secretions and VAE incidence rate ($p > .05$). Table 4.5 presents the comparison.

Table 14.5: Comparison of Effectiveness and Safety between 180mmHg and 100mmHg Negative Suction Pressures

Serial	Variable	Expt (180mmHg) n=39	Ctrl (100mmHg) n=37	Statistical test	p-value
1.	Average catheter passes	$\bar{x}$ = 2.24 Mdn=2.00 SD = 0.35	$\bar{x}$ = 3.46 Mdn=3.50 SD = 0.55	Mann Whitney U test	.000* Hedge’s d=2.66
2.	Incidence of blood-tinged tracheal secretions	Yes=51 No=240	Yes=59 No=260	X^2 (1, N=610) =0.097	.756
3.	VAE Incidence & VAE Rate	Yes=6 No=33 6/131.43*1000 =45.65/1000 MVD	Yes=8 No=29 8/142.51* 1000 =56.14/1000 MVD	X^2 (1, N=76) = .491 z=.7047	.483 .760

VAE: Ventilator Associated Events; MVD: Mechanical Ventilation Days.

The 180mmHg negative suction level required less catheter passes (entrances) to clear tracheal secretions and its therefore more effective. The null hypothesis that ‘There is no significant difference in the number of catheter passes required for effective

tracheal secretion clearance between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients,’ was therefore rejected ($p < .05$).

Pearson Chi-square test was used to estimate the odds of bloody tracheal secretions and VAE associated with the 180mmHg suction pressure compared with the 100mmHg suction pressure and the results are presented in Table 4.6 below:

Table 14.6: Comparison between groups on Bloody Tracheal Secretions and Ventilator-Associated Events

Outcome	OR	95% CI	<i>p</i> -value	Interpretation
Bloody tracheal secretions	0.94	0.62–1.42	.76	Odds were slightly lower in the 180mmHg group but the difference was not statistically significant
Ventilator-Associated Event	0.66	0.205–2.124	.48	Odds were lower in the 180mmHg group but the association was not statistically significant

Although there was no significant difference between the 180mmHg suction group and the 100mmHg suction group in terms incidence of VAE and blood-tinged secretions ($p > .05$), Pearson Chi-square test showed that the Odds of developing bloody tracheal secretions (OR=0.936, 95% CI: 0.619-1.416) and VAE (OR=0.659, 95% CI: 0.205-2.124) were lower in the 180mmHg suction group than the 100mmHg group. Those suctioned at 180mmHg had 6% lower Odds of bloody tracheal secretions and 34% lower Odds of developing VAE. The researcher therefore failed to reject the null hypothesis that ‘There is no significant difference in safety, as measured by the occurrence of blood-tinged tracheal secretions and ventilator-associated events, between suction pressures of 180 mmHg and 100 mmHg among mechanically ventilated adult patients’ ($p > .05$).

4.4 Tracheal Tube Suctioning and Cardiorespiratory Indices

4.4.1 Effects of Tracheal Tube Suctioning on Cardiorespiratory Indices

In order to meet the requirements for the second objective of this study, readings of cardiorespiratory indices of Heart Rate (HR), Peripheral Oxygen Saturation (SpO₂), Respiration Rate (RR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP) were taken just before, during, after 5 minutes and after 20 minutes of open tracheal tube suctioning at 180mmHg and at 100mmHg negative pressures as per subjects grouping. Analysis of data was carried out in order to test the hypothesis that ‘There is no significant difference in the means of cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP & MAP) within the 180mmHg tracheal suction group and within the 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’.

Readings within each suction group across the various suction time points were compared using Repeated Measures Analysis of Variance or its non-parametric equivalent after which a statistical significance was determined. Percentage change and Effect Size of the change between the pre and intra suctioning levels was calculated. Changes on six cardiorespiratory indices as a result of tracheal tube suctioning were determined and the results are herewith presented in text, graphs and tables.

4.4.1.1 Effects of Tracheal Tube Suctioning on Heart Rate at Four Suction Time Points

Tracheal Tube suctioning increased Heart Rate by 5.7% in 180mmHg suction group and by 4.8% in the 100mmHg suction group. Normalization occurred in about 20 minutes with a slight reduction in both groups. Figure 4:1 presents the results of the change in heart rate at the four measurement time points.

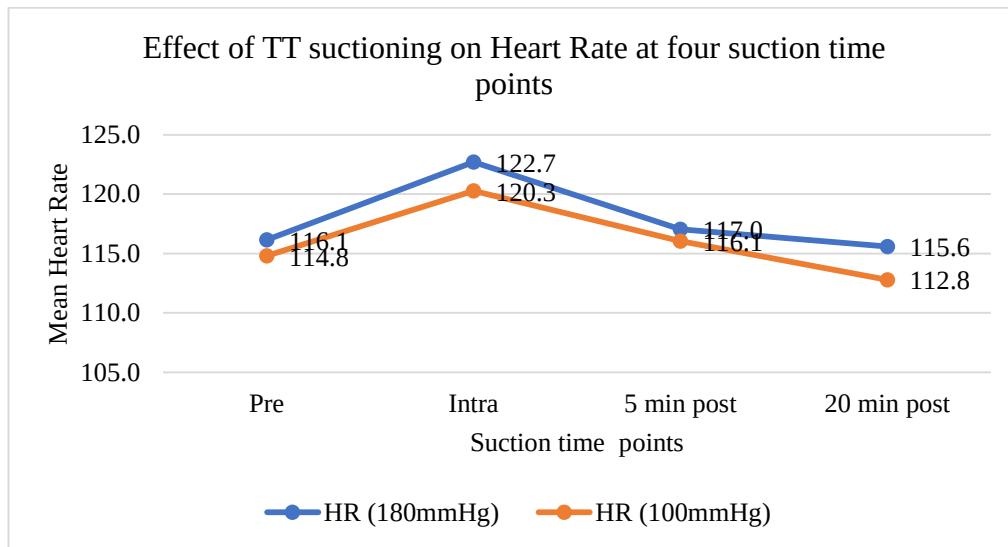


Figure 14.1: Effect of TT Suctioning on Heart Rate at Four Suction Time Points

Repeated Measures ANOVA was conducted to determine whether there was a statistically significant difference in Heart Rate in at least two suction time points in each suction group. Results indicated a significant difference within each group as presented in Table 4.7 below:

Table 14.7: Comparison of Mean and SD of HR/min in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

Heart Rate Time	Negative Pressure (mmHg)	
	Expt (180), n=39	Ctrl (100), n=37
Pre suction (just before)	116.14±18.42	114.79±20.69
Intra suction	122.71±16.38	120.26±18.87
5 min post suction	117.03±17.54	116.05±20.65
20 min post suction	115.60±19.05	112.79±20.40
Repeated measures	[F (3, 152) = 12.464,	[F (3, 144) = 13.671,
ANOVA	$p < .001$].	$p < .001$].
Effect Size (pre vs intra)		
Cohen's d	0.38	0.28

ANOVA: Analysis of Variance, SD: Standard Deviation, HR: Heart Rate, vs: Versus

A post hoc comparison of the differences in Heart Rate across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning mean HR was statistically higher than pre, 5 min post and 20 min post suctioning for both groups ($p < .001$) with a small Effect Size in both groups between pre and intra levels. The null hypothesis that 'there is no significant difference in the means of cardiorespiratory indices (HR) within the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients' was rejected ($p < .05$).

4.4.1.2 Effects of Tracheal Tube Suctioning on Peripheral Oxygen Saturation (SpO₂)

Tracheal Tube suctioning reduced SpO₂ by 2.4% in the 180mmHg suction group and by 2.0% in the 100mmHg suction group. Normalization was achieved in about 20 minutes post suctioning. These changes across the four measurement time points are presented in Figure 4.2 below:

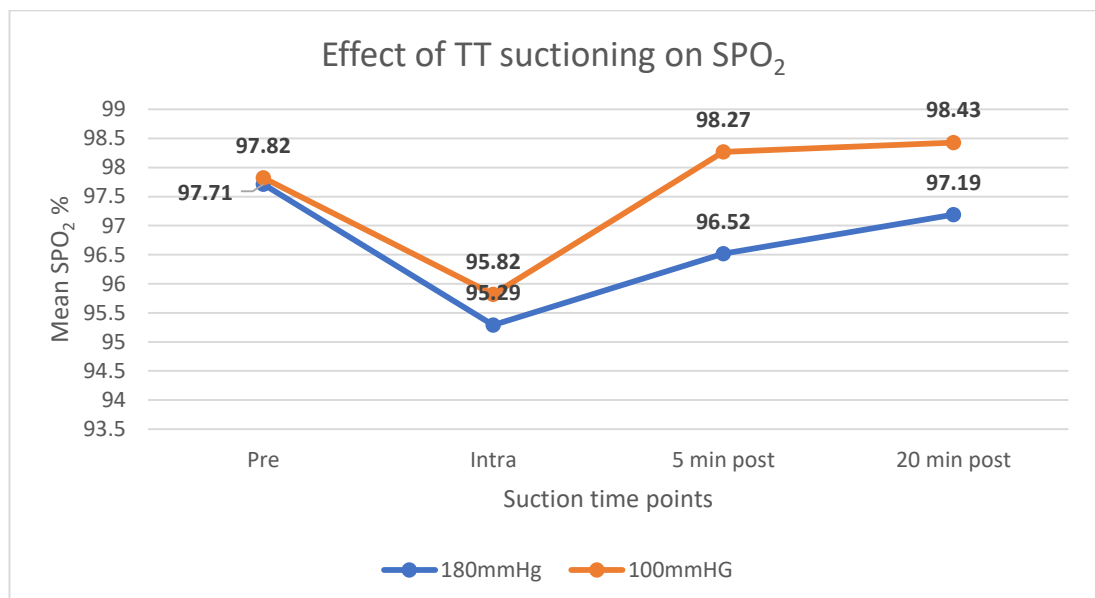


Figure 14.2: Effects of TT Suctioning on SpO₂ at Four Suction Time Points

A Friedman test was conducted to determine whether there was a rank ordered difference in SpO₂ across the various suction time points in each suction group. Results indicated a difference within each suction group as presented in Table 4.8 below:

Table 14.8: Comparison of Mean and SD of SpO₂ in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

SpO ₂	Negative Pressure	
	(mmHg)	
	Expt	Ctrl
	(180)	(100)
Time	n=39	n=37
Pre suction (just before)	97.71±3.70	97.82±3.06
Intra suction	95.29±4.95	95.82±4.52
5 min post suction	96.52±5.16	98.27±2.09
20 min post suction	97.19±4.12	98.43±2.02
Repeated measures	X ² (3) = 36.193,	X ² (3) = 38.906,
ANOVA (Friedman test)	<i>p</i> < .001	<i>p</i> < .001
Effect Size (pre vs intra)	0.55	0.52
Cohen's d		

ANOVA: Analysis of Variance, SD: Standard Deviation, SpO₂: Peripheral Oxygen Saturation, vs: Versus

A post hoc comparison of the rank ordered differences in SpO₂ across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning mean SpO₂ was statistically lower than pre, 5 min post and 20 min post suctioning for both groups (*p* < .001) with a medium Effect Size

in both group between pre and intra levels (larger for 180mmHg). The null hypothesis that ‘there is no significant difference in the means of cardiorespiratory indices (SpO₂) within the 180mmHg tracheal suction group and within 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’ was rejected ($p < .05$).

4.4.1.3 Effects of Tracheal Tube Suctioning on Respiration Rate

Tracheal Tube suctioning increased Respiration Rate by 18.1% in 180mmHg suctioning group and by 8.5% in 100mmHg suctioning group. Figure 4.3 presents the changes in RR across the four measurement time points.

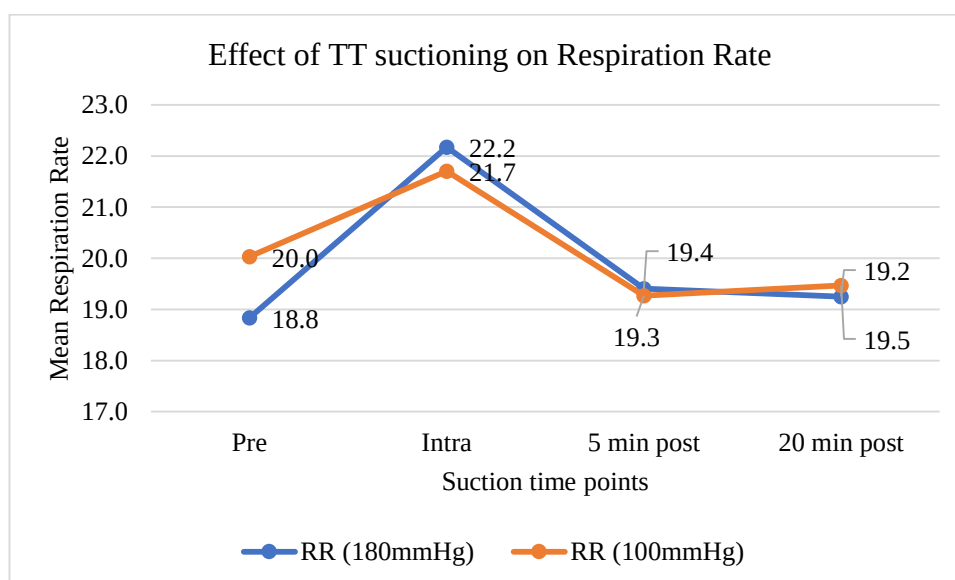


Figure 14.3: Effects of TT Suctioning on Respiration Rate at Four Suction Time Points

A Friedman test was conducted to determine whether there was a rank ordered difference in respiration rate across the various suction time points in each suction group. Results indicated a difference within each suction group as presented in Table 4.9 below:

Table 14.9: Comparison of Mean and SD of RR in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

Respiration Rate	Negative Pressure	
	(mmHg)	
	Expt	Ctrl
	(180)	(100)
Time	n=39	n=37
Pre suction (just before)	18.84±4.17	20.03±5.31
Intra suction	22.18±4.31	21.70±4.82
5 min post suction	19.41±4.50	19.27±5.06
20 min post suction	19.25±6.69	19.47±7.59
Repeated measures	$X^2 (3) = 33.926,$	$X^2 (3) = 24.842,$
ANOVA (Friedman test)	$p < .001$	$p < .001$
Effect Size (pre vs intra)	0.79	0.33
Cohen's d		

ANOVA: Analysis of Variance, RR: Respiration Rate, SD: Standard Deviation: vs: Versus

A post hoc comparison of the rank ordered differences in RR across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning mean RR was statistically higher than pre, 5 min post and 20 min post suctioning for both groups ($p < .001$) with a medium Effect Size on the 180mmHg group between pre and intra levels. The null hypothesis that 'there is no significant difference in the means of cardiorespiratory indices (RR) within the 180mmHg tracheal suction group and within 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients' was rejected ($p < .05$).

4.4.1.4 Effects of Tracheal Tube Suctioning on Systolic Blood Pressure (SBP)

Tracheal Tube suctioning increased SBP by 7.5% in the 180mmHg suction group and by 9.9% in the 100mmHg suction group. Normalization was achieved in about 20 minutes post suctioning with a slight reduction in blood pressure in both groups. The changes across the four measurement time points are as presented in Figure 4.4 below:

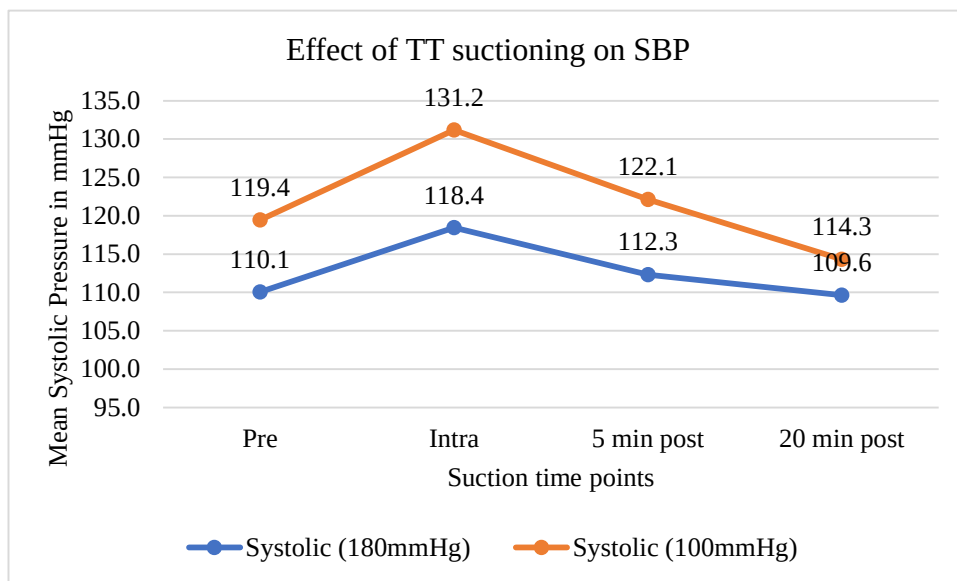


Figure 14.4: Effects of TT Suctioning on Systolic Blood Pressure at Four Suction Time Points

Repeated Measures ANOVA was conducted to determine whether there was a statistically significant difference in SBP in at least two suction time points in each suction group. Results indicated a significant difference in each suction group as presented in Table 4.10 below:

Table 14.10: Comparison of Mean and SD of SBP in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

SBP	Negative Pressure	
	(mmHg)	
	Expt	Ctrl
	(180)	(100)
Time	n=39	n=37
Pre suction (just before)	110.07±26.00	119.43±26.05
Intra suction	118.43±28.50	131.17±31.54
5 min post suction	112.17±29.97	122.32±30.05
20 min post suction	109.64±26.94	114.30±27.32
Repeated measures	[F (3, 152) = 12.828, [F (3, 144) = 17.288,	
ANOVA	$p < .001$].	$p < .001$].
Effect Size (pre vs intra)	0.31	0.41
Cohen's d		

ANOVA: Analysis of Variance, BP: Blood Pressure, SD: Standard Deviation: vs: Versus

A post hoc comparison of the differences in SBP across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning mean SBP was statistically higher than pre, 5 min post and 20 min post suctioning for both groups ($p < .001$) with a small Effect Size between pre and intra levels. The null hypothesis that 'there is no significant difference in the means of cardiorespiratory indices (SBP) within the 180mmHg tracheal suction group and within 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients' was rejected ($p < .05$).

4.4.1.5 Effects of Tracheal Tube Suctioning on Diastolic Blood Pressure (DBP)

Tracheal Tube suctioning increased Diastolic blood pressure by 6.3 % in the 180mmHg suction group and by 10.9% in the 100mmHg suction group. Figure 4.5 presents the results of the changes in DBP across the four measurement time points.

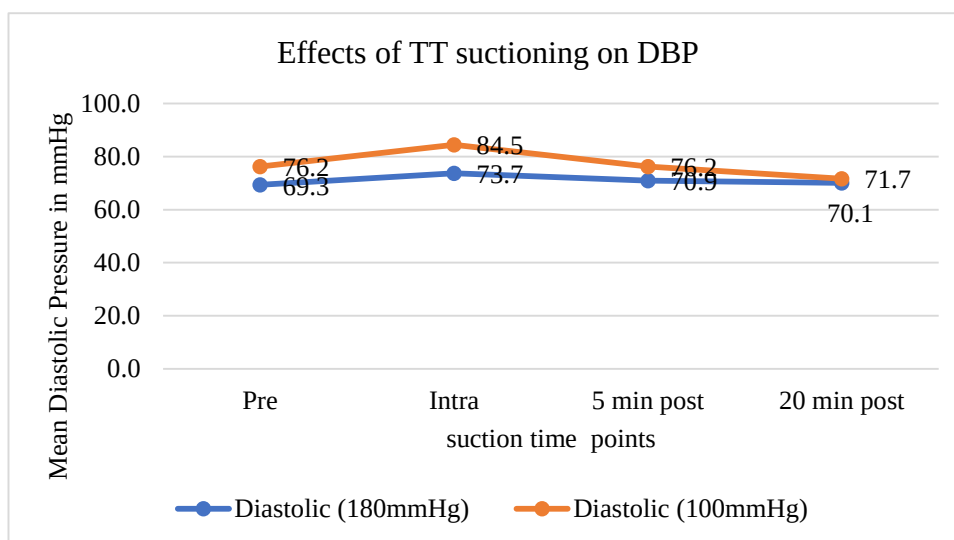


Figure 14.5: Effects of TT Suctioning on Diastolic Blood Pressure at Four Suction Time Points

Repeated Measures ANOVA was conducted to determine whether there was a statistically significant difference in DBP in at least two suction time points in each suction group. Results indicated a significant difference in each suction group as presented in Table 4.11 below:

Table 14.11: Comparison of Mean and SD of DBP in Repeated Measures ANOVA for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

DBP	Negative Pressure	
	(mmHg)	
	Expt (180)	Ctrl (100)
Time	n=39	n=37
Pre suction (just before)	69.32±16.98	76.23±19.93
Intra suction	73.70±18.70	84.47±18.24
5 min post suction	70.95±18.84	76.23±19.47
20 min post suction	70.11±17.49	71.67±18.92
Repeated measures	[F (3, 152) = 3.689,	[F (3, 144) = 15.557 $p < .001$].
ANOVA	$p = .025$].	
Effect Size (pre vs intra)	0.25	0.48
Cohen's d		

ANOVA: Analysis of Variance, BP: Blood Pressure, SD: Standard Deviation, vs: Versus

A post hoc comparison of the differences in DBP across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning mean DBP was statistically higher than pre for 180mmHg suction group and also higher than pre, 5 min post and 20 min post suctioning for 100mmHg suction group ($p < .05$) with a small Effect Size for both groups between pre and intra levels. The null hypothesis that 'there is no significant difference in the means of cardiorespiratory indices (DBP) within the 180mmHg tracheal suction group and within 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients' was rejected ($p < .05$). The 100mmHg suctioning level had more profound effect on DBP than the 180mmHg suctioning level based on the larger Effect Size.

4.4.1.6 Effects of Tracheal Tube Suctioning on Mean Arterial Blood Pressure (MAP)

Tracheal Tube suctioning increased MAP by 6% in the 180 mmHg suction group and by 10.9% in the 100mmHg suction group. The changes of MAP across the four measurement time points are as presented in Figure 4.6 below:

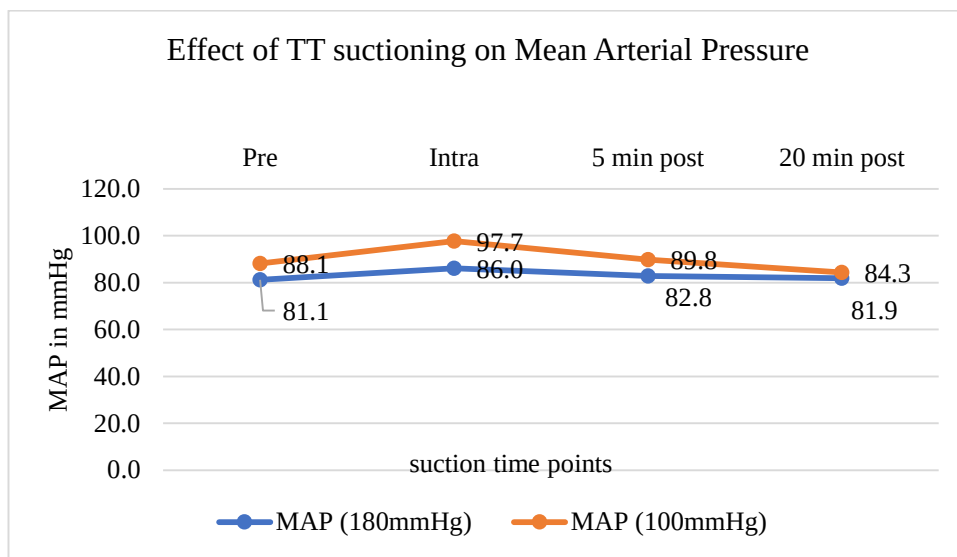


Figure 14.6: Effects of TT Suctioning on MAP at Four Suction Time Points

A Friedman test was conducted to determine whether there was a rank ordered difference in MAP across the various suction time points for 180mmHg suction group and Repeated Measures ANOVA was conducted to determine whether there was a statistically significant difference in MAP in at least two suction time points in the 100mmHg suction group.

Results indicated a significant difference within each suction group as presented in Table 4.12 below:

Table 14.12: Comparison of Mean and SD of MAP in Repeated Measures ANOVA (and Friedman test) for the Two Groups of Open Tracheal Suction at Negative Pressures of 180mmHg and 100mmHg Respectively

MAP	Negative Pressure (mmHg)	
Time	Expt (180) n=39	Ctrl (100) n=37
Pre suction (just before)	81.12±17.58	88.09±17.86
Intra suction	86.04±19.78	97.7±20.79
5 min post suction	82.77±21.19	89.82±21.00
20 min post suction	81.89±19.30	84.26±20.45
Friedman test & Repeated measures ANOVA	$X^2 (3) = 23.922, p < .001$	$[F (3, 144) = 16.553, p < .001]$
Effect Size (pre vs intra)	0.26	0.49
Cohen's d		

ANOVA: Analysis of Variance; MAP: Mean Arterial Pressure, SD: Standard Deviation, vs: Versus

A post hoc comparison of the rank ordered differences (180mmHg) and differences in means (100mmHg) of MAP across suction time points was conducted using Bonferroni's post hoc test. Results of this analysis indicated that the intra-suctioning MAP was statistically higher than pre & 20 min post in 180mmHg suction group

($p < .001$) and higher than pre, 5 min post and 20 min post suctioning for 100mmHg group ($p < 0.001$) with a medium Effect Size for 100mmHg group and a small Effect Size for 180mmHg between pre and intra levels. The null hypothesis that 'there is no significant difference in the means of cardiorespiratory indices (MAP) within the 180mmHg tracheal suction group and within 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients' was rejected ($p < .05$).

4.4.1.7 Summary of Cardiorespiratory Indices

Open tracheal tube suctioning at the tested negative pressures increases Heart Rate, Respiration Rate, Systolic, Diastolic and Mean Arterial Pressure but decreases SpO₂. The changes were statistically significant for all the indices ($p < .05$). This summary is presented in table 4.13 below:

Table 14.13: Summarized Effects of Tracheal Tube Suctioning on Cardiorespiratory Indices within Groups

Serial	Cardiorespiratory indices	Suction Group	Change during suctioning	Statistical significance	Effect Size - Cohen's d (Pre vs intra)
1.	Heart Rate	180 mmHg	Increase	($p < .001$)	0.38
		100mmHg	Increase	($p < .001$)	0.28
2.	SpO ₂	180 mmHg	Decrease	($p < .001$)	0.55
		100mmHg	Decrease	($p < .001$)	0.52
3.	Respiration Rate	180 mmHg	Increase	($p < .001$)	0.79
		100mmHg	Increase	($p < .001$)	0.33
4.	SBP	180 mmHg	Increase	($p < .001$)	0.31
		100mmHg	Increase	($p < .001$)	0.41
5.	DBP	180 mmHg	Increase	($p = .025$)	0.25
		100mmHg	Increase	($p < .001$)	0.48
6.	MAP	180 mmHg	Increase	($p < .001$)	0.26
		100mmHg	Increase	($p < .001$)	0.49

DBP=Diastolic Blood Pressure; MAP=Mean Arterial Pressure; SBP=Systolic Blood Pressure; SpO₂=Peripheral Oxygen Saturation

4.4.2 Comparison of Cardiorespiratory Effects of Suctioning between Experimental and Control Suction Groups

In order to compare the groups on cardiorespiratory indices resulting from the two suction levels, readings of cardiorespiratory indices from the Experimental and Control Groups were taken and comparison between the two groups at the four suction time points done. Analysis of data was done in order to test the hypothesis that, ‘There is no significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) between mechanically ventilated adult patients receiving tracheal suction pressures of 180 mmHg and 100 mmHg at baseline, during suctioning, and at 5- and 20-minutes post-suctioning’. Independent t-test was used where the two data sets were normally distributed as confirmed by Kolmogorov-Sminorv and Shapiro-Wilk test with $p > .05$. Otherwise, its non-parametric equivalent (i.e. Mann-Whitney U test) was used to determine the statistical significance of the differences between the two groups. The results are herewith presented in text and tables.

4.4.2.1 Comparison on Heart Rate

Independent *t*-test showed no significant difference in HR values pre, intra, and 5 min and 20 min post suction time points between the two groups ($p = .764$, $p = .547$, $p = .824$ and $p = .537$, respectively). The two levels of suctioning had no difference on their effect on heart rate ($p > .05$). Comparison of the changes in Heart Rate between the two groups is as presented in Table 4.14 below:

Table 14.14: Comparison of the Means and SD of HR at the Four Suction Time Points between Experimental and Control Groups using unpaired T-test

Heart Rate	Negative Pressure		Independent	
	(mmHg)		t-test	
Time	Expt (180)	Ctrl (100)	p -value	t
	n=39	n=37		
Pre suction (just before)	116.14±18.42	114.79±20.69	.764	0.301
Intra suction	122.71±16.38	120.26±18.87	.547	0.604
5 min post suction	117.03±17.54	116.05±20.65	.824	0.224
20 min post suction	115.60±19.05	112.79±20.40	.537	0.621

Ctrl: Control, Expt: Experimental, HR: Heart Rate; SD: Standard Deviation

Thus, the researcher failed to reject the null hypothesis that ‘There is no significant difference in the means of Heart Rate between the 180mmHg tracheal suction group and 100mmHg tracheal suction group at baseline, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients ($p > .05$).’

4.4.2.2 Comparison on SpO₂

Data on SpO₂ was not normally distributed and therefore comparison of the changes in SpO₂ between the two groups was done using the Mann Whitney U test. The results showed no significant difference in SpO₂ mean values at baseline, during, 5 min and 20 min post suction time points between the two groups ($p = .810$, $p = .526$, $p = .212$ and $p = .248$, respectively). Comparison of the changes in SpO₂ between the two groups is as presented in Table 4.15 below:

Table 14.15: Comparison of the Means and SD of SpO₂ at the Four Suction Time Points between Experimental and Control Groups using Mann Whitney U test

SpO ₂	Negative Pressure		Mann Whitney U test	
	(mmHg)			
Time	Expt	Ctrl	<i>p</i> value	<i>z</i>
	(180)	(100)		
	n=39	n=37		
Pre suction (just before)	96.99±4.84	98.07±3.07	.810	-.240
Intra suction	95.29±4.95	95.82±4.52	.526	.635
5 min post suction	96.52±5.16	98.27±2.09	.212	1.248
20 min post suction	97.19±4.12	98.43±2.02	.248	1.156

Ctrl: Control, Expt: Experimental, SD: Standard Deviation, SpO₂: Peripheral Oxygen Saturation

The two levels of suctioning had no difference on their effect on SpO₂ ($p > .05$). Thus, the researcher failed to reject the null hypothesis that ‘There is no significant difference in the means of SpO₂ between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’ ($p > .05$).

4.4.2.3 Comparison on Respiration Rate

Data on respiration rate was not normally distributed and therefore comparison of the changes in respiration rate between the two groups was done using the Mann-Whitney U test. The results showed no significant difference in RR mean values at baseline, during, 5 min and 20 min post suction time points between the two groups ($p = .391$, $p = .574$, $p = .674$ and $p = .823$, respectively). The results of the comparison are presented in Table 4.16 below:

Table 14.16: Comparison of the Means and SD of RR/min at the Four Suction Time Points between Experimental and Control Groups using Mann Whitney U test

Respiration Rate	Negative Pressure		Mann Whitney U test	
Time	(mmHg)		<i>p</i> value	<i>z</i>
	Expt	Ctrl		
	(180)	(100)		
	n=39	n=37		
Pre suction (just before)	18.84±4.17	20.03±5.31	.391	.858
Intra suction	22.18±4.31	21.70±4.82	.574	-.561
5 min post suction	19.41±4.50	19.27±5.06	.674	-.421
20 min post suction	19.25±6.69	19.47±7.59	.823	-.224

Ctrl: Control, Expt: Experimental, RR: Respiration Rate; SD: Standard Deviation

The two levels of suctioning had no difference on their effect on respiration rate ($p > .05$). Thus, the researcher failed to reject the null hypothesis that ‘There is no significant difference in the means of RR between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’($p > .05$).

4.4.2.4 Comparison on Systolic Blood Pressure (SBP)

Comparison of the changes in SBP between the two groups was done using t-test. The results showed no significant difference in SBP mean values at baseline, during, 5 min and 20 min post suction time points between the two groups ($p = .121$, $p = .068$, $p = .159$ and $p = .457$, respectively). The results are presented in Table 4.17 below:

Table 14.17: Comparison of Means and SD of SBP at the Four Suction Time Points between Experimental and Control Groups using unpaired T-test

SBP Time	Negative Pressure (mmHg)		t- test	
	Expt	Ctrl	p value	t
	(180)	(100)		
	n=39	n=37		
Pre suction (just before)	110.07±26.00	119.43±26.05	.121	-0.1567
Intra suction	118.43±28.50	131.17±31.54	.068	-0.1850
5 min post suction	112.17±29.97	122.32±30.05	.159	-0.1423
20 min post suction	109.64±26.94	114.30±27.32	.457	-0.748

Ctrl: Control, Expt: Experimental, SBP: Systolic Blood Pressure, SD: Standard Deviation

The two levels of suctioning had no difference on their effect on SBP ($p > .05$). Thus, the researcher failed to reject the null hypothesis that ‘There is no significant difference in the means of SBP between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’ ($p > .05$).

4.4.2.5 Comparison on Diastolic Blood Pressure (DBP)

Comparison of the changes in DBP between the two groups was done using unpaired t-test. The results showed no significant difference in DBP mean values between the two groups at baseline, 5 min and 20 min post suction time points ($p = .074$, $p = .234$, and $p = .711$ respectively) but a significant difference in intra-suctioning DBP between the Control Group (M=84.47, SD=18.24) and the Experimental Group (M=73.70, SD=18.70); $t(74) = -2.539$, $p = .013$ with a medium Effect Size (Hedge’s $g=0.6$). The results are presented in Table 4.18 below:

Table 14.18: Comparison of Means and SD of DBP at the four Suction Time Points between Experimental and Control Groups using unpaired T-test

DBP Time	Negative Pressure (mmHg)		t- test	
	Expt	Ctrl	p value	t
	(180)	(100)		
	n=39	n=37		
Pre suction (just before)	69.32±16.98	76.23±19.93	.074	-1.813
Intra suction	73.70±18.70	84.47±18.24	.013*	-2.539
			Effect Size (Hedge's g)	
			=0.6	
5 min post suction	70.95±18.84	76.23±19.47	.234	-1.201
20 min post suction	70.11±17.49	71.67±18.92	.711	-0.372

Ctrl: Control, Expt: Experimental, DBP: Diastolic Blood Pressure, SD: Standard Deviation

The Control Group had significantly higher intra-suctioning diastolic BP than the Experimental Group. Therefore, null hypothesis that ‘There is no significant difference in the means of cardiorespiratory variable of DBP between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’ was rejected ($p < .05$).

4.4.2.6 Comparison on Mean Arterial Pressure (MAP)

Comparison of the changes in MAP between the two groups was done using t-test for pre, intra and 5 minutes post suctioning and with Mann–Whitney U test for 20 minutes post suctioning according to the data distribution. The results showed no significant difference in MAP values between the two groups at baseline, 5 min and 20 min post suction time points ($p = .091$, $p = .150$, and $p = .489$ respectively) but a

significant difference in intra-suctioning MAP between the Control Group (M=97.65, SD=20.79) and the Experimental Group (M=86.04, SD=19.78); $t(74) = -2.495$, $p = .015$ with a medium Effect Size (Hedge's $g=0.57$). The results are presented in Table 4.19 below:

Table 14.19: Comparison of Means and SD of MAP at the Four Suction Time Points between Experimental and Control Groups using T-test/Mann Whitney U test

MAP	Negative Pressure		Test statistic	
	(mmHg)			
Time	Expt (180)	Ctrl (100)	p value	t or z
	n=39	n=37		
Pre suction (just before)	81.12±17.58	88.09±17.86	.091	t= -1.713
Intra suction	86.04±19.78	97.65±20.79	.015*	t= -2.495
			Effect Size (Hedge's g)	
			=0.57	
5 min post suction	82.77±21.19	89.82±21.00	.150	t= -1.456
20 min post suction	81.89±19.30	84.26±20.45	.489	z=-.691

Ctrl: Control, Expt: Experimental, MAP: Mean Arterial Pressure; SD: Standard Deviation

Thus, null hypothesis that 'There is no significant difference in the means of cardiorespiratory variable of MAP between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients,' was rejected ($p < .05$).

4.4.2.7 Summary of Differences between 180mmHg and 100mmHg Suction Groups on Cardiorespiratory Indices

The negative pressure of 180mmHg produced bigger changes in HR, SpO₂, and RR during suctioning compared to 100mmHg negative suction pressure as depicted by the

bigger ‘Effect Size ’ of the change between pre and intra suctioning levels. This analysis is presented in Table 4.20 below:

Table 14.20: Effect Size of the Change in HR, SpO₂ & RR during Suctioning

Cardiorespiratory Indices	Suctioning Effect Size (Intra vs Pre) per suction group	
	180mmHg (Expt)	100mmHg (Ctrl)
HR	0.38	0.28
SpO₂	0.55	0.52
RR	0.79	0.33

On the other hand, open tracheal tube suctioning at 100mmHg produced bigger changes in Systolic BP, Diastolic BP and MAP during suctioning than the 180mmHg negative pressure. This analysis is presented in Table 4.21 below:

Table 14.21: Effect Size of the Change in SBP, DBP and MAP during Suctioning

Cardiorespiratory Indices	Effect Size (Intra vs Pre) per suction group	
	180mmHg	100mmHg
SBP	0.31	0.41
DBP	0.25	0.48
MAP	0.26	0.49

Moreover, the lower suction pressure of 100mmHg led to bigger increase in DBP during suctioning ($p < .001$, Cohen’s $d = 0.48$) & MAP ($p < .001$, Cohen’s $d = 0.49$) compared to the higher suction pressure of 180mmHg, which produced comparatively smaller increases in DBP ($p = .025$, Cohen’s $d = 0.25$) & MAP ($p = .001$, Cohen’s $d = 0.26$) as per the Effect Sizes shown. Although the changes observed at both suction pressures were statistically significant, the larger effect sizes at 100 mmHg indicate a greater magnitude of change in DBP and MAP compared with 180 mmHg.

Therefore, tracheal tube suctioning at 100mmHg causes a significant increase in Diastolic and Mean Blood Pressure compared to suctioning at 180mmHg ($p < .05$). There were no differences between the groups in their HR, SpO₂, RR and Systolic pressures at Pre, Intra, 5 min and 20 min post suctioning as well as in their Pre, 5 min and 20 min indices for DBP and MAP ($p > .05$).

The grant average change in cardiorespiratory indices between the two suction groups was similar ($p > .05$). The results of this analysis are presented in Table 4.22 below:

Table 14.22: Comparison of Percentage change in Cardiorespiratory Indices between 180mmHg and 100mmHg Negative Suction Pressures

Cardiorespiratory Indices	Percentage change from baseline (intra vs pre)	
	180mmHg	100mmHg
HR	5.7	4.8
SpO ₂	2.4	2.0
RR	18.1	8.5
Systolic BP	7.5	9.9
Diastolic BP	6.3	10.9
MAP	6	10.9
Average change	7.68	7.83
Mann–Whitney U test (two-tailed)	U = 21.00, z = 0.48, exact $p = .699$	

An independent-samples Mann–Whitney U test showed that the percentage change of cardiorespiratory indices during suctioning did not differ significantly between the two groups ($p > .05$).

4.5 Open Tracheal Tube Suctioning and Metric Patient Care Outcomes

In order to achieve the requirement for the third objective of this study, data pertaining to length of mechanical ventilation, duration of tracheal tube placement, length of stay in the ICU and Mortality in ICU for each group of study was collected and analyzed. Independent t-test or its non-parametric equivalent was used for comparison of the numerical variables while Chi-square test was used for comparison of mortality between the two groups of study.

4.5.1 Determination of Metric Patient Care Outcomes for Experimental and Control Groups

Data on the length of mechanical ventilation, length of stay in ICU, duration of tracheal tube placement and mortality for each group of study was determined and the descriptive statistics calculated as presented in Table 4.23 below:

Table 14.23: Descriptive Statistics of Selected Clinical Outcomes by Suction Pressure Group

Outcome	180 mmHg		100mmHg	
	Median (IQR)	Mean $\pm$ SD	Median (IQR)	Mean $\pm$ SD
Mechanical ventilation, days	1.60 (0.50–3.25)	3.37 $\pm$ 6.27	2.00 (0.75–4.23)	3.85 $\pm$ 5.78
Duration of tracheal tube placement, days	1.60 (0.50–3.50)	4.91 $\pm$ 11.45	2.00 (0.75–5.13)	4.47 $\pm$ 6.76
ICU length of stay, days	3.25 (1.60–5.40)	6.05 $\pm$ 11.18	3.00 (1.30–6.35)	5.41 $\pm$ 6.71
Mortality in ICU	Yes=18 (46.2%) No=21 (53.8%)		Yes=23 (62.2%) No=14 (37.8%)	Average mortality =53.9%

Note. Mdn = median; IQR = interquartile range; SD = standard deviation; TT = tracheal tube; ICU = intensive care unit. Values presented as “Median (IQR)” show the median followed by the 25th–75th percentile range.

The table 4.23 above presents the descriptive statistics of metric ICU outcomes for the both experimental and control groups. The duration of mechanical ventilation was slightly lower in experimental group, with a median of 1.60 days (IQR: 0.50–3.25) compared with the control group which had a median of 2.00 days (IQR: 0.75–4.23). The corresponding means were 3.37 days (SD = 6.27) and 3.85 days (SD = 5.78), respectively. The overall mean duration of mechanical ventilation was 3.60 days.

The duration of tracheal tube placement was also slightly lower in the experimental group with a median duration of 1.60 days (IQR: 0.50–3.50) compared to control group which has a median of 2.00 days (IQR: 0.75–5.13). The corresponding means were 4.91 days (SD = 11.45) and 4.47 days (SD = 6.76), respectively. The overall mean duration of tracheal tube placement was 4.69 days. However, the ICU length of stay was slightly longer in the experimental group with a median of 3.25 days (IQR: 1.60–5.40) compared to the control group which had a median of 3.00 days (IQR: 1.30–6.35). The corresponding means were 6.05 days (SD = 11.18) and 5.41 days (SD = 6.71), respectively. The overall mean duration of ICU stay was 5.73 days. Regarding ICU mortality, 18(46.2%) participants in the experimental group died compared to 23(62.2%) in the control group. Conversely, survival rate among participants in the experimental group was 21(53.8%) compared to 14(37.8%) in the control group. Overall, 41 of the 76 participants (53.9%) died during their ICU stay.

4.5.2 Comparison of Care Outcomes between the Experimental and Control Groups

Data pertaining to length of mechanical ventilation, duration of tracheal tube placement, length of stay in the ICU and Mortality in ICU for both groups of study was compared in order to test the hypothesis that ‘There is no significant difference in critical care outcomes, as measured by duration of mechanical ventilation, duration of tracheal intubation, ICU length of stay, and ICU mortality, between suction pressure groups of 180 mmHg and 100 mmHg among mechanically ventilated adult patients.’

Comparison was therefore done using Independent Samples’ t-test or its non-parametric equivalent for length of mechanical ventilation, duration of tracheal tube placement and length of stay in ICU; and Chi-square test for mortality in ICU. The results showed that there was no significant difference between the 180mmHg suction group and the 100mmHg suction group in terms of length of mechanical ventilation, duration of tracheal tube placement, length of stay in the ICU and Mortality in ICU ($p = .328$, $p = .411$, $p = .839$, and $p = .162$ respectively). The results are presented in Table 4.24 below:

Table 14.24: Comparison between Experimental and Control Groups on Specific Outcomes of Care Metrics

Serial	Outcome	Expt (180mmHg) n=39	Ctrl (100mmHg) n=37	Statistical test	Test statistic	p- value
1.	Length of Mechanical Ventilation (days)	$\bar{x}$ = 3.37 Mdn=1.60 SD = 6.27	$\bar{x}$ = 3.85 Mdn=2.0 SD = 5.78	Mann Whitney U Test	.977	.328
2.	Duration of TT (days)	$\bar{x}$ = 4.91 Mdn=1.60 SD = 11.45	$\bar{x}$ = 4.47 Mdn=2.0 SD = 6.76	Mann Whitney U Test	.821	.411
3.	Length of Stay in ICU (days)	$\bar{x}$ = 6.05 Mdn=3.25 SD = 11.18	$\bar{x}$ = 5.41 Mdn= 3.00 SD = 6.71	Mann Whitney U Test	.203	.839
4.	Mortality in ICU	Yes=18 No=21	Yes=23 No=14	X^2 (1, N=76) =1.958		.162

Ctrl: Control, Expt: Experimental, ICU: Intensive Care Unit; MVD: Mechanical Ventilation Days; TT: Tracheal Tube

Therefore, the researcher failed to reject the null hypothesis that ‘There is no significant difference in critical care outcomes between the 180mmHg tracheal suction group and 100mmHg tracheal suction group among mechanically ventilated adult patients’ ($p > .05$).

CHAPTER FIVE

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter explores the meaning of the findings of this study and compares them with previous researches done on tracheal tube suctioning in an effort to bring out the similarities, differences and to draw out lessons. A conclusion and recommendations are made at the tail end.

5.2 Discussion

The study findings on safety, effectiveness and effects of open tracheal tube suctioning on specific cardiorespiratory indices and critical care outcomes using negative pressures of 180mmHg and 100mmHg in comparison with other studies are hereby examined, described and explained.

5.2.1 Effectiveness and Safety Between Experimental and Control Group Suction Pressures

The comparison between any two open tracheal tube suction pressures involves considerations of effectiveness and safety among other important outcomes. This is particularly important because there has to be a good balance between adequate removal of secretions and likelihood of causing suction-related adverse effects. In this study, the effectiveness of the experimental suction pressure of 180 mmHg compared with the control pressure of 100mmHg was evaluated based on the number of suction catheter passes required to achieve airway clearance, while safety was assessed using the occurrence of bloody tracheal secretions and Ventilator-Associated Events. The findings demonstrated significant differences in suction effectiveness between the two pressure levels with the higher suction pressure of 180mmHg being the most effective. The 180mmHg negative suction level required significantly less catheter passes ($\bar{x}$ = 2.24, Mdn =2.00, SD = 0.35) in order to clear tracheal secretions compared to the lower suction pressure of 100mmHg ($\bar{x}$ = 3.46, Mdn =3.50, SD = 0.55), $z=7.172$, $p < .001$. and hence demonstrating better effectiveness. The American Association of

Respiratory Care, 2022 clinical practice guidelines recommended use of suction pressure less than 200mmHg and a maximum of three catheter passes per suctioning session (Blakeman et al., 2022). The higher suction level in this study required 2-3 catheter passes while the lower suction pressure required 3-4 catheter passes to clear tracheal secretions. It is therefore an ideal suction level that meets the requirement for only three catheter passes per session of suctioning. In a study conducted by Maras et al. (2020) involving 47 adult mechanically ventilated patients in ICU whose objective was to compare the effectiveness of three tracheal suction pressures (i.e. 80mmHg, 150mmHg and 250mmHg) determined by the volume of secretions suctioned and cardiorespiratory indices produced, the results showed that negative pressure of 250mmHg was the most effective followed by a pressure of 150mmHg. There were statistically significant differences between the three pressures in terms of the volume of secretion obtained ($p < .001$). The current study deployed an experimental pressure that lies between the 150mmHg and 250mmHg tested by Maras et al (2020). Although, the methods of establishing effectiveness were different, but the outcomes demonstrate that the bigger the pressure, the more effective it is likely to be. AARC put a cautionary caveat of the safe suction pressure at 200mmHg albeit a weak evidence base (Blakeman et al., 2022).

The two study groups did not reveal a statistically significant difference in the aspect of safety, more so regarding tendency to cause bloody tracheal secretions and Ventilator Associated Events. Despite this finding, the Odds of bloody tracheal secretions were slightly lower in the 180mmHg suctioning group (OR = 0.94, 95% CI: 0.62–1.42, $p = .76$) and the Odds of VAE were also slightly lower in 180mmHg suction group (OR=0.66, 95% CI: 0.205-2.124, $p = .48$). This is probably due to fewer catheter entrances required to clear tracheal secretions and therefore less tracheal mucosal damage. This study therefore suggests that the average number of catheter passes may have a stronger relationship with occurrence of bloody tracheal secretions than the factor of suction pressure. Otherwise, there would have been more bleeding within the group receiving suctioning at higher negative pressure. Indeed, El-Hardy et al. (2025) made a similar observation that friction and constant contact with tracheobronchial mucosa is often the primary mechanism by which bloody secretions occur. They undertook a randomized controlled trial comparing deep and shallow suctioning on

occurrence of bloody tracheal secretions among other outcome measures. The study involved 120 patients randomly allocated to either group and suction pressure was maintained at 100-120mmHg. The level of bloody secretions was statistically higher in the deep suction group ($p < .001$). Again, Rashwan et al. (2022) also found more tracheal bleeding associated with deep suctioning among neonates at 44.4% compared to 16.7% of those who underwent shallow suctioning with same suction pressure for the two groups. Further, Liu et al. (2025) demonstrated that appropriately selected negative suction pressures of up to 200 mmHg could achieve effective secretion clearance with minimal airway mucosal bleeding. In the present study, the lower number of catheter passes required at higher pressure of 180mmHg without corresponding rise in bloody secretions suggests that it is the repeated catheter manipulation and contact with airway mucosa that are possibly important contributors to tracheal mucosal injury.

Although, there is no direct evidence linking suction induced tracheobronchial injury to VAE, disruption of the epithelial mucosa compromises its defensive role, potentially facilitating bacterial colonization, hence increasing the possibility of lower respiratory tract infection. Howroyd et al. (2024) found out that interference with the integrity of tracheobronchial mucosa contributes to pathogenesis of VAP. The higher suction pressure of 180mmHg was therefore less likely to cause this disruption and therefore by the same logic, less likely to lead to VAE.

The higher suction level of 180mmHg is therefore safer in terms of causing tracheal mucosal injury and development of Ventilator Associated Events.

5.2.2 Open Tracheal Tube Suctioning and Specific Cardiorespiratory Indices

This study sought to establish the effect of suctioning at the tested negative pressures on specific cardiorespiratory indices following which a comparison of the effects between the two groups was carried out.

5.2.2.1 Effects of Open Tracheal Tube Suctioning on Specific Cardiorespiratory Indices

Data analysis and interpretation revealed that open tracheal tube suctioning using either of the negative pressures tested increases Heart Rate (HR), Respiration Rate (RR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP) but reduces Peripheral Oxygen Saturation (SpO₂) significantly ($p < .05$) during suctioning and normalization occurs in about 20 minutes post-suctioning. A similar study by Rajakumari et al. (2020) using a higher negative suction pressure of 200mmHg found statistically significant increase in HR ($p < .001$) & Respiration Rate ($p = .046$) and a statistically significant decrease in SpO₂ ($p < .001$). Suparti et al. (2021) also found significant changes in HR, SpO₂ and MAP within each of the two groups of study ($p < .001$) during suctioning. These findings were from a randomized controlled trial using a sample size of 40 subjects, testing a pressure of 20kPa (150mmHg) and 25kPa (187mmHg) on cardiorespiratory indices during open endotracheal tube suctioning. Similar results were shared by Shamali et al., (2019) who found significantly bigger changes in SpO₂, SBP, DBP and MAP ($p < .05$) among 64 adult mechanically ventilated patients within the routine suction group (deep suctioning using a suction pressure of 100-200mmHg) compared to the minimally invasive suction group (shallow suctioning using a suction pressure of 80-120mmHg). These studies support the evidence that open tracheal tube suctioning at the tested pressures of 80-200mmHg cause significant changes in cardiorespiratory indices during suctioning.

In this current study, a lower suction pressure of 100mmHg led to bigger increase in DBP during suctioning ($p < .001$, Cohen's $d = 0.48$) & MAB ($p < .001$, Cohen's $d = 0.49$) while the higher suction pressure of 180mmHg caused a comparatively smaller increase in DBP ($p = .025$, Cohen's $d = 0.25$) & MAP ($p = .001$, Cohen's $d = 0.26$) though both changes were statistically significant ($p < .05$). This finding is shared by Rajakumari et al. (2020) who compared pre and intra suctioning mean values of MAP, and found a significant increase in MAP during suctioning ($p = 0.012$) at the lower suction pressure of 120mmHg but no significant change in MAP with higher suction pressure of 200mmHg ($p = .112$). The consistency of this finding strongly supports

the assertion that lower suction pressure increases DBP and MAP more than higher suction pressure. This finding suggests that lower suction pressure may be beneficial to hypotensive patients and could also be potentially harmful to hypertensive patients now that the effect was seen to persist even at 20 minutes post suctioning.

The observed relationship between DBP and MAP is physiologically explained by the fact that DBP is main contributor to MAP. This relationship is as depicted by equation 1 and 2 below:

$$MAP = DBP + \{(SBP - DBP)/3\} \dots\dots\dots \text{Equation 1}$$

$$\text{or } \{(2 \times DBP) + SBP\}/3 \dots\dots\dots \text{Equation 2}$$

(McGraw Hill Medical products, 2024; Soumitra et al., 2022)

The changes in the cardiorespiratory indices due to open tracheal tube suctioning are in keeping with the physiological explanation for changes in heart rate, respiration rate and blood pressure caused by lowered oxygen tension during open tracheal tube suctioning. The physical presence of suction catheter during open tracheal tube suctioning impedes any further air entrance into the respiratory tract and negative suction pressure removes some residue alveolar air often leading to atelectasis. These occurrences cause hypoxaemia and subsequently hypoxia stimulating reflex mechanisms involving stimulation of chemoreceptors at the carotid bodies and aortic arch. Feedback response pathways through the central nervous system stimulates increased respiration and cardiac activity resulting into upward changes in the cardiorespiratory indices tested here (Hall & Hall, 2021).

Touching the respiratory surface especially near the Carina with the suction catheter together with the chest physiotherapy manoeuvres involving squeezing and chest vibration stimulates a cough reflex which is usually accompanied by build-up of both intra-abdominal and intra-thoracic pressures. Increased intra- abdominal pressure raises cardiac afterload, hence increasing systolic blood pressure. Similarly, increased intra-thoracic pressure produces impendence to venous return to the heart, hence increasing cardiac preload and diastolic blood pressure. Increase in diastolic pressure

directly leads to elevation of mean arterial pressure as demonstrated by equation 1 & 2 above.

These findings led to rejection of the null hypothesis that ‘There is no significant difference in the mean cardiorespiratory indices (HR, SpO₂, RR, SBP, DBP, and MAP) across baseline, intra-suction, 5-minute post-suction, and 20-minute post-suction measurements within either the 180 mmHg or 100 mmHg tracheal suction pressure group among mechanically ventilated adult patients’ ($p < .05$).

5.2.2.2 Comparison of Cardiorespiratory Effects of Open Tracheal Tube Suctioning between the Experimental and the Control Groups

As earlier reported in Chapter four, open tracheal tube suctioning cause transient changes in cardiorespiratory indices due to airway stimulation, oxygen deprivation, changes in intra-abdominal and intrathoracic pressures and autonomic responses. Hence, the need to compare these changes between the two groups. Data analysis and interpretation of observations made at four suction time points demonstrated no significant difference between experimental and control groups in the means of HR, SpO₂, RR, and SBP pre, intra, 5 minutes and 20 minutes post-suctioning ($p > .05$) but there were significant differences between the two groups on DBP and MAP ($p < .05$) intra-suction indices.

This meant that even though the two negative suction pressures caused comparably similar changes on HR, SpO₂, RR, and SBP but on the other hand, they led to significantly different levels of change in DBP & MAP with the lower suction pressure of 100mmHg resulting into a bigger change. A lower suction level of 100mmHg was associated with significant elevation of DBP and MAP in this study. The null hypotheses that ‘there is no significant difference in the means of cardiorespiratory indices of HR, SpO₂, RR, SBP, DBP & MAP between the 180mmHg tracheal suction group and 100mmHg tracheal suction group before, during, after 5 minutes and 20 minutes post-suctioning among mechanically ventilated adult patients’ was rejected ($p < .05$). This finding is shared by Suparti et al. (2021), who with a sample size of 40 subjects, testing a pressure of 20kPa (150mmHg) and 25kPa (187mmHg) did not find a significant difference between the two groups regarding HR, RR and SpO₂ but found

a significant difference in MAP ($p < .05$). Rass et al. (2020) observed that endotracheal tube suctioning causes increase in DBP and MAP as a net effect of competing autonomic influences especially the predominantly increased sympathetic peripheral vascular tone. The total physiological stimulus produced by the lower suction pressure of 100mmHg was greater probably owing to higher catheter passes and hence, a more sustained peripheral vascular tone.

According to Ohm's law, blood flow increases with increase in blood pressure holding the factor of resistance constant i.e. $F = \Delta P/R$ (Hall & Hall, 2021). The lower suction pressure of 100mmHg, having been found to increase the blood pressure more, is associated with increased blood flow to tissues, a factor that contributes to their better physiological functioning. Hypotensive patients (MAP<65mmHg), who constitute around 40% of critically ill patients (Schizodimos et al., 2020) in ICU are therefore likely to benefit more from low negative suctioning pressure. However, this stand point requires validation with this sub group of critically ill patients.

A negative suction pressure of 180mmHg is therefore not associated with additional harm relating to hypoxaemia, tachycardia, bradycardia, tachypnoea or elevation in blood pressure compared to a negative pressure of 100mmHg.

It is therefore noteworthy that the 2022 AARC Clinical Practice Guidelines (CPG) had recommended a negative suction pressure of less than 200mmHg for adults albeit existence of low evidence on the matter (Blakeman et al., 2022).

5.2.3 Comparison of Patient Care Outcomes between Experimental and Control Groups

Data analysis and interpretation regarding length of mechanical ventilation, length of ICU stay, duration of tracheal tube placement and ICU mortality showed no statistically significant difference between the experimental and control groups ($p > .05$) despite the suction pressure of 180mmHg being more effective in secretion removal than the 100mmHg suction pressure.

Regarding the length of mechanical ventilation, patients in the 180mmHg suction group had a median duration of 1.60 days ($M = 3.37$, $SD = 6.27$), while those in the 100mmHg suction group had a median duration of 2.00 days ($M = 3.85$, $SD = 5.78$) with no statistical difference (Mann Whitney U test, $p = .328$). The data was positively skewed indicating that some patients stayed much longer on mechanical ventilation, hence pulling the mean to the right of median.

The grand mean duration of mechanical ventilation was 3.6 days. This finding compares well with a study by Parker et al. (2019) in a prospective study on mortality prediction in rural Kenya who reported a mechanical ventilation mean of 3 (IQR 2-5) days. It also compares well with a cross-sectional study involving 160 mechanically ventilation patients at Tikur Anbessa Specialized Hospital in Addis Ababa, Ethiopia by Debebe et al., (2022) that recorded a mechanical ventilation duration of 3 (IQR 2-7) days. The duration reported in this study is however much shorter than a duration of mechanical ventilation of 7 (3-21 days) reported by Njoki et al. (2024).

This finding means that increasing suction pressure to 180mmHg does not influence the length under which patients remain ventilated. These differences are likely attributable to variations in ICU admission criteria, patient case mix and weaning protocols in different settings. Regarding the length of ICU stay, the two groups did not differ significantly ($p = .839$). The 180mmHg suction group had a median ICU stay of 3.25 days ($M = 6.05$, $SD = 11.18$) compared with 3.0 days ($M = 5.41$, $SD = 6.71$) among the 100mmHg suction group. The grand means ICU stay was 5.7 days. This finding suggests that suction pressure alone was not a determinant of ICU length of stay. Instead, ICU stay is more likely influenced by other factors like: underlying illness, occurrence of complications, response to treatment, and institutional discharge practices (Bekele et al., 2024).

This finding is fairly comparable to Parker et al. (2019) who reported ICU length of stay of 4 (IQR 2-8 days) and 5 (IQR 2-10) from Debebe et al. (2022). The world-wide average length of ICU stay is 5-7 days (McLarty et al. (2024). Duration of tracheal tube placement did not significantly differ between the groups (Mann–Whitney U test, $p = .411$). The experiment group had a median intubation duration of 1.6 days

(M=4.91, SD=11.45) days while the control group had a median of 2.0 days (M=4.47, SD=6.76) days. Again, the data was positively skewed, meaning that some few patients stayed with the tube for abnormally much longer. This finding suggests that although higher suction pressure improved secretion clearance, it did not accelerate extubation. Successful extubation depends on numerous factors beyond airway clearance, including neurological recovery, respiratory muscle strength, gas exchange, hemodynamic stability, resolution of the underlying disease and existing ICU protocol for extubation (Bekele, 2024).

Regarding ICU mortality, 46.2% of patients in the 180mmHg group died compared with 62.2% in the 100mmHg group. The mortality was numerically lower in the higher-pressure group but the difference did not reach statistical significance $\chi^2 (1, N = 76) = 1.96, p = .162$. Therefore, the observed reduction in mortality cannot be attributed to the suction pressure intervention alone. Mortality among critically ill mechanically ventilated patients is multifactorial and is primarily influenced by disease severity, comorbid conditions, organ dysfunction, timing of ICU admission, and quality of overall critical care management rather than by suction pressure alone (Abate et al., 2023).

The overall mortality observed in this study is lower than the 60.7% by Parker et al. (2019) and the 60.7% from Debebe et al. (2022) but higher than 30.3% from Njoki et al. (2024). Though, the observed mortality level is worth noting, it is not unusual, especially so for mechanically ventilated patients. Several studies put ICU mortality among mechanically ventilated patients at 20% to 70% (Alamav et al., 2024; Parker et al., 2019; Tadesse et al. 2023). In a study of ICU Outcomes of Critically Ill Patients in Cameroon by Linwa et al. (2023), the overall ICU mortality was found to be 59.4%. Nevertheless, the worldwide annual Crude ICU mortality is 19.9% (Pisani et al., 2022).

Overall, these findings demonstrate that 180 mmHg and 100mmHg open tracheal suction pressures resulted in comparable ICU care outcomes, including duration of mechanical ventilation, length of ICU stay, duration of tracheal tube placement, and ICU mortality. Consequently, the researcher failed to reject the null hypothesis that

‘There is no significant difference in critical care outcomes between the 180mmHg tracheal suction group and 100mmHg tracheal suction group of mechanically ventilated adult patients’ ($p > .05$).

The findings further suggest that while a higher suction pressure may enhance immediate secretion clearance, it does not independently improve broader ICU outcomes, which are determined by a complex interplay of many factors that are patients’ and critical care related.

5.3 Conclusion

This study aimed at establishing a safe and effective negative suction pressure in open tracheal tube suctioning by testing a negative pressure of 180mmHg against a usual negative pressure of 100mmHg. The study was undertaken against a backdrop of continuing global uncertainty, divergent recommendations, and variations in clinical practice regarding the optimal negative suction pressure for open tracheal tube suctioning. In the absence of definitive evidence, the selection of suction pressure has often been influenced by institutional practices and individual practitioner preferences. The study therefore compared the two suction pressure levels in relation to tracheal secretion clearance, cardiorespiratory responses, and selected ICU care outcomes.

Tracheal clearance was assessed in terms of the effectiveness of secretion removal, while physiological responses were evaluated using changes in heart rate (HR), hemoglobin oxygen saturation (SpO_2), respiratory rate (RR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP). These cardiorespiratory indices were assessed just before suctioning, during suctioning, and at 5 and 20 minutes after suctioning at both pressure levels. Selected ICU care outcomes, including duration of mechanical ventilation, duration of tracheal intubation, length of ICU stay, and ICU mortality, were also assessed and compared between the two groups. Collectively, these measures provided a basis for determining the relative effectiveness and safety of the two negative suction pressure levels in open tracheal tube suctioning.

This study has demonstrated that higher level suctioning at 180mmHg has significantly better secretion removal; causes less tracheal mucosal bleeding and less Ventilator Associated Events, though not statistically significant. Therefore, its more effective and safer.

The higher suction level of 180mmHg does not lead to worse disruption of cardiorespiratory indices in comparison with the lower suction pressure of 100mmHg. Suctioning at either of the two negative pressures produced comparable physiological changes on six cardiorespiratory indices measured in this study.

Even though the lower suction pressure of 100mmHg was observed to cause significantly bigger increase in DBP & MAP, further studies involving hypotensive and hypertensive patient sub-groups are required before suction-pressure recommendations are made on these populations.

Open tracheal tube suction pressure was not associated with statistically significant differences in the measured ICU care outcomes. Length of mechanical ventilation, duration of tracheal tube placement, length of ICU stay, and ICU mortality were comparable between patients suctioned at 180 mmHg with those suctioned at 100 mmHg.

The evidence gathered in this study indicates a greater benefit for using the 180mmHg negative suction pressure during open tracheal tube suctioning in comparison with lower negative suction pressure levels.

5.4 Recommendations

5.4.1 Nursing Practice

A suction pressure of 180 mmHg may be considered for open tracheal tube suctioning in mechanically ventilated adult patients, as it achieved more effective secretion clearance, requiring fewer catheter passes, without a significant increase in the measured safety outcomes compared with 100 mmHg.

The lower suction pressure of 100mmHg is likely beneficial to hypotensive patients due to its tendency to increase diastolic and mean arterial pressure. On the other hand, it may worsen blood pressure for already hypertensive patients but further research is required to validate this finding among these sub groups.

5.4.2 Policy

There is need to for the Nursing Council of Kenya to review the current guidelines on open tracheal tube suctioning in view of the emerging evidence including findings from this study on application of higher suction pressure of up to 180mmHg.

5.4.3 Education

Nursing education and continuing professional development programmes should incorporate current evidence on the selection and safe application of suction pressure during open tracheal tube suctioning. Training should emphasize the effectiveness and safety of suction pressures up to 180 mmHg, appropriate haemodynamic monitoring of responses during suctioning, and individualized clinical assessment when selecting suction pressure. Particular attention should be given to monitoring changes in diastolic blood pressure and mean arterial pressure, especially among patients with haemodynamic instability. Simulation and competency-based training should also be used to strengthen nurses' skills in performing open tracheal tube suctioning safely and effectively.

5.4.4 Further Research

Further research is needed to:

- Validate these findings in larger, multicenter studies; in hypotensive and hypertensive patient subgroups.
- Determine the effects of shallow open tracheal tube suctioning at 180mmHg and 100mmHg on similar outcome variables.
- Determine the effects of shallow closed tracheal tube suctioning at 180mmHg and 100mmHg on similar outcome variables.

- Establish the independent (and combined) effects of suction pressure, catheter insertion depth, number of suction catheter passes, and operator skill on tracheobronchial mucosal injury.
- Compare the effects of 180 mmHg and 100mmHg suction pressures on intracranial pressure.

REFERENCES

- Abate, S. M., Basu, B., Jemal, B., Ahmed, S., Mantefardo, B., & Taye, T. (2023). Pattern of disease and determinants of mortality among ICU patients on mechanical ventilator in Sub-Saharan Africa: A multilevel analysis. *Critical Care*, 27, Article 37. <https://doi.org/10.1186/s13054-023-04316-w>
- Alamaw, A. W., Abebe, G. K., Abate, B. B., Tilahun, B. D., Yilak, G., Birara, W. A., Azmeraw, M., Habtie T.E. & Zemariam, A. B. (2024). Mortality and Associated Factors Among Intensive Care Unit Admitted Adult Patients with Mechanical Ventilation in Ethiopia: A Systematic Review and Meta-Analysis. *Shock* (Augusta, Ga.), 61(5), 660–665. <https://doi.org/10.1097/SHK.0000000000002340>
- Alkubati, S. A., Al-Sayaghi, K. M., Alrubaiee, G. G., Hamid, M. A., Saleh, K. A., Al-Qalah, T., & Al-Sadi, A. K. (2022). Adherence of critical care nurses to endotracheal suctioning guidelines: A cross-sectional study. *BMC Nursing*, 21, Article 312. <https://doi.org/10.1186/s12912-022-01092-w>
- Alligood, M. R. (2022). *Nursing theorists and their work* (10th ed.). Elsevier.
- Amutalla, S. (2023). *Nurses' practices on closed endotracheal tube airway suctioning at Kenyatta National Hospital adult critical care unit*. Unpublished MSc Thesis, Nairobi: University of Nairobi.
- Ardehali, S. H., Fatemi, A., Rezaei, S. F., Forouzanfar, M. M., & Zolghadr, Z. (2020). The Effects of Open and Closed Suction Methods on Occurrence of Ventilator Associated Pneumonia; a Comparative Study. *Archives of Academic Emergency Medicine*, 8(1), e8. <https://pubmed.ncbi.nlm.nih.gov/32021989/>

- Ashry A. E., Khafagy M. A, El Adawi N.M., Bahgat M. & El-Gilany A. H. (2021). Intensive Care Morbidity and Mortality and Their Associated Factors: A National Study in Egypt. Benha Medical Journal. https://bmfj.journals.ekb.eg/article_193632_6548381faf693c80fe6e6a3f9af38bce.pdf Print ISSN 1110-208X
- Barasa E.W., Ouma P.O. & Okiro E.A. (2020). Assessing the hospital surge capacity of the Kenya health system in the face of the Covid-19 pandemic. PLOS ONE. <https://doi.org/10.1371/journal.pone.0236308>.
- Bekele, T. G., Melaku, B., Demisse, L. B., Abza, L. F., & Assen, A. S. (2024). Outcomes and factors associated with prolonged stays among patients admitted to adult intensive care unit in a resource-limited setting: A multicenter chart review. Scientific Reports, 14, 13960. <https://doi.org/10.1038/s41598-024-64911-x>
- Benumof, J. L., & Hagberg, C. A. (Eds.). (2023). Benumof and Hagberg's airway management (4th ed.). Elsevier.
- Bertrand, Y., et al. (2023). What should be done and what should be avoided when comparing two treatments? Best Practice & Research Clinical Haematology, 36(2), 101473. <https://doi.org/10.1016/j.beha.2023.101473>
- Blakeman T.C., Scott J.B., Yoder M.A., Capellari E., and Strickland S.L. (2022). AARC Clinical Practice Guidelines: Artificial Airway Suctioning. *Respiratory Care February*, 67 (2) 258-271; DOI: <https://doi.org/10.4187/respcare.09548>.
- Blot, S., et al. (2025). Perpetual observational study of the clinical and microbiological epidemiology of ventilator-associated pneumonia in Europe. Critical Care, 29. <https://doi.org/10.1186/s13054-025-05753-5>

- Butterworth, J. F., Mackey, D. C., & Wasnick, J. D. (2023). *Morgan & Mikhail's Clinical Anesthesiology* (7th ed.). McGraw Hill.
- Centers for Disease Control and Prevention. (2026). *FAQs: Ventilator-Associated Events (VAE)*. <https://www.cdc.gov/nhsn/faqs/faq-vae.html>.
- Chang, S. J., Kim, E., Kwon, Y. O., et al. (2023). Benefits and harms of normal saline instillation before endotracheal suctioning in mechanically ventilated adult patients in intensive care units: A systematic literature review and meta-analysis. *Intensive and Critical Care Nursing*, 78, 103477.
- Chen, W., Hu, S., Liu, X., Wang, N., Zhao, J., Liu, P., Chen, K., & Hu, J. (2021). Intensive care nurses' knowledge and practice of evidence-based recommendations for endotracheal suctioning: A multisite cross-sectional study in Changsha, China. *BMC Nursing*, 20, Article 186. <https://doi.org/10.1186/s12912-021-00715>
- Cheng, X., et al. (2024). Sample size calculations for randomized controlled trials with repeatedly measured continuous variables as primary outcomes need improvements: A cross-sectional study. *Journal of Clinical Epidemiology*, 166, 111235. <https://doi.org/10.1016/j.jclinepi.2023.111235>
- County Government of Machakos. (2023). Machakos County integrated development plan 2023–2027. <https://machakos.go.ke/download/county-integrated-development-plan-2023-2027/>
- Debebe, F., Goffi, A., Haile, T., Alferid, F., Estifanos, H., & Adhikari, N. K. J. (2022). Predictors of ICU Mortality among Mechanically Ventilated Patients: An Inception Cohort Study from a Tertiary Care Center in Addis Ababa, Ethiopia. *Critical care research and practice*, 2022, 7797328. <https://doi.org/10.1155/2022/7797328>

- Deshmukh-Reeves, E., Shaw, M., Bilsby, C., & Gourlay, C. W. (2025). Biofilm formation on endotracheal and tracheostomy tubing: A systematic review and meta-analysis of culture data and sampling method. *MicrobiologyOpen*, 14, e70032.
- El-Hady, M. M., Babkair, L., Alharazi, R. M., Noorsaeed, S. M. W., & Mehrez Mahmoud Ali, M. (2025). Impact of Deep Versus Shallow Tracheal Suctioning on Cardiovascular Indices and Suction Induced Complications Among Mechanically Ventilated Patients. *SAGE open nursing*, 11, 23779608251374140. <https://doi.org/10.1177/23779608251374140>
- Eya, J., Ejikem, M., & Ogamba, C. (2022). Admission and Mortality Patterns in Intensive Care Delivery at Enugu State University of Science and Technology Teaching Hospital: A Three-Year Retrospective Study. *Cureus*. <https://doi.org/10.7759/cureus.27195>
- Fadlalmola H. A., (2021). Application of Henderson Theory of Nursing Care for Pempigus Patients at Khartoum Dermatology Hospital, Sudan. *International Journal of Nursing Education*. DOI:10.37506/ijone.v14il.17739.
- Fultinavičiūtė & Maragkou. (2023). *Should RCTs remain the gold standard? Clinical Trials Arena*. Retrieved from <https://www.clinicaltrialsarena.com/features/rct-gold-standard/>
- Gale R.P., Zhang M.J. & Lazarus H. M. (2023). The role of randomized controlled trials, registries, observational databases in evaluating new interventions, *Best Practice & Research Clinical Haematology*, 36 (4), 2023,101523, ISSN 1521-6926, <https://doi.org/10.1016/j.beha.2023.101523>.
- Gerstman, B. B. (2023). There is no single gold standard study design (RCTs are not the gold standard). *Expert Opinion on Drug Safety*, 22(4), 267–270. <https://doi.org/10.1080/14740338.2023.2203488>

- Goodfellow, L. T., Miller, A. G., Varekojis, S. M., LaVita, C. J., Glogowski, J. T., & Hess, D. R. (2024). AARC Clinical Practice Guideline: Patient-Ventilator Assessment. *Respiratory care*, 69(8), 1042–1054. <https://doi.org/10.4187/respcare.12007>
- Gourd, N. M., & Nikitas, N. (2020). Multiple organ dysfunction syndrome. *Journal of Intensive Care Medicine*, 35(12), 1564–1575. <https://doi.org/10.1177/0885066619871452>
- Guyton, A. C., & Hall, J. E. (2000). *Textbook of medical physiology* (10th ed.). New Gurgaon, New Delhi: Elsevier.
- Hall, J. E., & Hall, M. E. (2021). *Guyton and Hall textbook of medical physiology* (14th ed.). Gurgaon, New: Elsevier.
- Hill, D. B., Button, B., Rubinstein, M., & Boucher, R. C. (2022). Physiology and pathophysiology of human airway mucus. *Physiological reviews*, 102(4), 1757–1836. <https://doi.org/10.1152/physrev.00004.2021>
- Hixson, R., Jensen, K. S., Melamed, K. H., & Qadir, N. (2024). Device-associated complications in the intensive care unit. *BMJ*, 386, e077318.
- Howroyd, F., Chacko, C., MacDuff, A., Gautam, N., Pouchet, B., Tunnicliffe, B., Weblin, J., Gao-Smith, F., Ahmed, Z., Duggal, N. A., & Veenith, T. (2024). Ventilator-associated pneumonia: Pathobiological heterogeneity and diagnostic challenges. *Nature Communications*, 15, 6447. <https://doi.org/10.1038/s41467-024-50805-z>
- Ingraham, N. E., Vakayil, V., Pendleton, K. M., Robbins, A. J., Freese, R. L., Palzer, E. F., Charles, A., Dudley, R. A., & Tignanelli, C. J. (2022). Recent Trends in Admission Diagnosis and Related Mortality in the Medically Critically Ill. *Journal of intensive care medicine*, 37(2), 185–194. <https://doi.org/10.1177/0885066620982905>

Irwin, R. S., & Rippe, J. M. (Eds.). (2023). *Irwin and Rippe's intensive care medicine* (9th ed.). Alphen : Wolters Kluwer.

Kallet R.H. (2019). Ventilator Bundles in Transition: From Prevention of Ventilator-Associated Pneumonia to Prevention of Ventilator-Associated Events. *Respiratory Care*, 64 (8): 994-1006; DOI: <https://doi.org/10.4187/respcare.06966>.

Kareem, M., Gopinath, P., & Para, K. (2026). *Vital Sign Assessment*. StatPearls - NCBIBookshelf. https://ncbi.nlm.nih.gov/books/NBK553213/?utm_source=chatgpt.com

Katrakazas, P., Pastiadis, K., Bibas, A., & Koutsouris, D. (2020). A general systems theory approach in public hearing health: Lessons learned from a systematic review of general systems theory in healthcare. *IEEE Access*, 8, 53018–53033. <https://doi.org/10.1109/ACCESS.2020.2981160>

Khasawneh, F. A., & Arora, R. (2025). *Vital sign assessment*. In *StatPearls*. StatPearls Publishing. Retrieved from <https://www.ncbi.nlm.nih.gov/books/NBK553213/>

Klompas, M., Branson, R., Cawcutt, K., Crist, M., Eichenwald, E. C., Greene, L. R., Lee, G., Maragakis, L. L., Powell, K., Priebe, G. P., Speck, K., Yokoe, D. S., & Berenholtz, S. M. (2022). Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 update. *Infection Control & Hospital Epidemiology*, 43(6), 687–713. <https://doi.org/10.1017/ice.2022.88>.

Kostekli, S., Celik, S., & Keskin, E. (2022). Effect of deep and superficial endotracheal suctioning on hemodynamic parameters and pain in neurosurgical intensive care patients. *Marmara Medical Journal*, 35(2), 237–243. <https://doi.org/10.5472/marumj.1121846>

- Krüger, L., Mannebach, T., Wefer, F., et al. (2024). Suctioning in intubated and tracheotomized patients: A narrative review. *Die Anaesthesiologie*, 73, 340–347. <https://doi.org/10.1007/s00101-024-01400-w>
- Li, W., Cai, J., Ding, L., Chen, Y., Wang, X., & Xu, H. (2024). Incidence and risk factors of ventilator-associated pneumonia in the intensive care unit: a systematic review and meta-analysis. *Journal of thoracic disease*, 16(9), 5518–5528. <https://doi.org/10.21037/jtd-24-150>
- Linwa, E. M. M., Linwa, E. M. M., Bikoi, C. B., Noutakdie, J. T., Ndo, E. N., Bikoy, J. M., Ekoube, C. E., Mogoung, R. F., Ghomsi, I. S., Budzi, M. N., Linwa, E. E. N., Linwa, E. E. N., Meh, M. G., & Mekolo, D. (2023). In-ICU outcomes of critically ill patients in a reference Cameroonian intensive care unit: a retrospective cohort study. *Critical Care Research and Practice*, 2023(1), 6074700. <https://doi.org/10.1155/2023/6074700>
- Liu W, Gu C, Li M, Xiong J. (2025). Safe and effective pressure of endotracheal tube suctioning based on sputum viscosity grades during artificial airway open suctioning procedures: A double-blind randomized controlled trial. *Nurs Crit Care*. 30(4):e13203. doi:10.1111/nicc.13203
- Machakos Level Five Hospital. (2024). *Intensive care unit admission register*. Unpublished raw data Intensive Care Unit, Machakos: Level Five Hospital.
- Mahadik, S., & Topkar, V. (2023). Validity and reliability testing of the questionnaire used to finalize criteria for the evaluation of the contractor's performance. *Archives of Civil Engineering*, 4(4), 477-492. <https://doi.org/10.24425/ace.2023.147671>.
- Maras G. B., Eser I., Senoglu N., Ozkalay Y. O., Dericci Y. K., (2020). Increasing suction pressure during tracheal suctioning increases the volume of suctioned secretions, but not procedure related complications: A

comparative study in open system tracheal suctioning. *Intensive and Critical Care Nursing*, Vol 61, <https://doi.org/10.1016/j.iccn.2020.102928>.

McGraw Hill Medical products (2024). *Mean arterial pressure (map)*. Padley A.P.(Ed.), Westmead Anaesthetic Manual, (5th Ed.) McGraw Hill. <https://accessworldmed.mhmedical.com/content.aspx?bookid=3455§ionid=287610860>

Mwangi, W., Kaddu, R., Muir, C. N., Simiyu, N., Patel, V., Sulemanji, D., Otieno, D., Okelo, S., Chikophe, I., Pisani, L., Dona, D. P. G., Beane, A., Haniffa, R., Misango, D., Waweru-Siika, W., & Investigators, F. T. K. C. C. R. (2023). Organization, staffing and resources of critical care units in Kenya. *PLoS ONE*, 18(7), e0284245. <https://doi.org/10.1371/journal.pone.0284245>

Nakahashi, S., Suzuki, K., Nakashima, T., Hayashi, Y., Tanabe, Y., Tanaka, A., Hashiuchi, S., Yamashita, C., Ito, Y., Wada, T., Yamashita, A., Shima, M., Hoshino, T., Moriyama, K., Kazuma, S., Lee, H. A., Yamaguchi, Y., Nakamura, Y., Kawanobe, Y., Sofue, T., ... Japan VAE study Investigators Group (2025). A reappraisal of association between ventilator-associated events and mortality among critically ill patients using marginal structural model: multicenter observational study. *Intensive care medicine*, 51(10), 1764–1774. <https://doi.org/10.1007/s00134-025-08074-x>

Njoki, C., Simiyu, N., Kaddu, R., Mwangi, W., Sulemanji, D., Oduor, P., Dona, D. G., Otieno, D., Abonyo, T. T., Wangeci, P., Kabanya, T., Mutuku, S., Kioko, A., Muthoni, J., Kamau, P. M., Beane, A., Haniffa, R., Dondorp, A., Misango, D., Waweru-Siika, W. (2024). Epidemiology, clinical characteristics, and outcomes of 4546 adult admissions to High-Dependency and ICUs in Kenya: a Multicenter Registry-Based

observational study. *Critical Care Explorations*, 6(2), e1036.
<https://doi.org/10.1097/cce.0000000000001036>

Nursing Council of Kenya (2019). *Manual of Clinical Procedures in Nursing and Midwifery* (4th ed.). Nairobi.

Ooro, M., Nyangena, E., & Angwa, L. (2025). Demographic and Clinical Risk Factors Contributing to Prolonged Mechanical Ventilation in ICU Patients at Tenwek Hospital. *East African Journal of Health and Science*, 8(3), 129-146. <https://doi.org/10.37284/eajhs.8.3.3986>

Papazian, L., Klompas, M., & Luyt, C. E. (2020). Ventilator-associated pneumonia in adults: a narrative review. *Intensive care medicine*, 46(5), 888–906.
<https://doi.org/10.1007/s00134-020-05980-0>

Parker, R. K., Mwachiro, E. B., Mwachiro, M. M., Pletcher, J., Parker, A. S., & Many, H. R. (2019). Mortality Prediction in Rural Kenya: A Cohort Study of Mechanical Ventilation in Critically Ill Patients. *Critical care explorations*, 1(12), e0067. <https://doi.org/10.1097/CCE.0000000000000067>

Peña L. Y., Ramírez E. S., Rello J. (2019). Ventilator-Associated Events: Definitions and Uses. Reference Module in Biomedical Sciences. B978-0-12-801238-3.11482-5. doi: 10.1016/B978-0-12-801238-3.11482-5. *Epub 2019 Nov 23*. PMID: PMC7157436.

Pinto, H. J., D'Silva, F., & Sanil, T. S. (2020). Knowledge and practices of endotracheal suctioning amongst nursing professionals: A systematic review. *Indian Journal of Critical Care Medicine*, 24(1), 23–32.
<https://doi.org/10.5005/jp-journals-10071-23326>

Pisani, L., Algera, A. G., Serpa Neto, A., Azevedo, L., Pham, T., Paulus, F., Gama de Abreu, M., Pelosi, P., Dondorp, A. M., Bellani, G., Laffey, J. G., &

- Schultz, M. J. (2022). Geoeconomic variations in epidemiology, ventilation management, and outcomes in invasively ventilated intensive care unit patients without acute respiratory distress syndrome: A pooled analysis of four observational studies. *The Lancet Global Health*, 10(2), e227–e235. [https://doi.org/10.1016/S2214-109X\(21\)00485-X](https://doi.org/10.1016/S2214-109X(21)00485-X)
- Pouly O. Lecailtel S., Six S., Préau S., Wallet F., Nseir S., and Rouzé A. (2020). Accuracy of ventilator-associated events for the diagnosis of ventilator-associated lower respiratory tract infections *Ann Intensive Care*, 10(6), <https://doi.org/10.1186/s13613-020-0624-6>.
- Rahmawati, E. D., Ramadhani, D. R., Pakalessy, A., & Setiyarini, S. (2025). Risk factors of ventilator-associated events in patients on mechanical ventilation: A scoping review. *Nursing in critical care*, 30(5), e13261. <https://doi.org/10.1111/nicc.13261>
- Rajakumari S. S, Thenmozhi P., & Barathi S.K. (2020). Two levels of Negative Pressure in Open Endotracheal Tube Suctioning on Physiological Indices. *International Journal of Reasearch in Pharmaceutical Sciences*. 2(11-SPL4) 2020
- Ramirez-Estrada, S., Peña-Lopez, Y., Viecei, T., & Rello, J. (2023). Ventilator-associated events: From surveillance to optimizing management. *Journal of Intensive Medicine*, 3(3), 204–211. <https://doi.org/10.1016/j.jointm.2022.09.004>
- Ramírez-Torres, C. A., Andrade-Gómez, E., Giménez-Luzuriaga, M., Lozano, C., & Sapiña-Beltrán, E. (2024). Closed suction system in tracheal suctioning in the critically ill patient connected to mechanical ventilation: A systematic review. *Archivos de Bronconeumología*, 60(2), 116–118. <https://doi.org/10.1016/j.arbres.2023.11.010>

- Rashwan, Z. I., Eweida, R. S., & Hamad, N. I. (2022). Effect of minimally invasive premeasured suctioning on airway mucosal injury and suction-induced stress among mechanically ventilated neonates: A clinical challenge for nurses. *Journal of Neonatal Nursing*, 28(4), 279–285. DOI: 10.1016/j.jnn.2022.02.003.
- Rass, V., Ianosi, BA., Lindner, A. (2020). Hemodynamic response during endotracheal suctioning predicts awakening and functional outcome in subarachnoid hemorrhage patients. *Crit Care* 24, 432 (2020). <https://doi.org/10.1186/s13054-020-03089-w>
- Sanaie, S., Rahnemayan, S., Javan, S., Shadvar, K., Saghaleini, S. H., & Mahmoodpoor, A. (2022). Comparison of Closed vs Open Suction in Prevention of Ventilator-associated Pneumonia: A Systematic Review and Meta-analysis. *Indian journal of critical care medicine : peer-reviewed, official publication of Indian Society of Critical Care Medicine*, 26(7), 839–845. <https://doi.org/10.5005/jp-journals-10071-24252>
- Sauro, J., & Lewis, J. R. (2020). *Sample size estimation: Module 11–12. MeasuringU*https://measuringu.com/wp-content/uploads/2020/06/FB_Class_Module11-12_SampleSizeEstimation_v5.pdf
- Schizodimos, T., Soulountsi, V., Iasonidou, C., & Kapravelos, N. (2020). An Overview of Management of Intracranial Hypertension in the Intensive Care Unit. *Journal of Anesthesia*, 34(5), 741–757. <https://doi.org/10.1007/s00540-020-02795-7>
- Scott, B. (2020, June 10). *Artificial airway suctioning and clearance* [Webinar]. American Association for Respiratory Care. Retrieved from <https://www.aarc.org/education/artificial-airway-suctioning-and-clearance/>
- Seguin, P., Perrichet, H., Pabic, E. L., Launey, Y., Tiercin, M., Corre, R., Brinchault, G., & Laviolle, B. (2018). Effect of Continuous versus Intermittent

Subglottic Suctioning on Tracheal Mucosa by the Mallinckrodt TaperGuard Evac Oral Tracheal Tube in Intensive Care Unit Ventilated Patients: A Prospective Randomized Study. *Indian journal of critical care medicine : peer-reviewed, official publication of Indian Society of Critical Care Medicine*, 22(1), 1–4. https://doi.org/10.4103/ijccm.IJCCM_350_17

Shamali M., Abbasinia M., Ostergaard B. & Konradsen H. (2019). Effects of minimally invasive endotracheal tube suctioning on physiological indices in adult intubated patients: An open-labelled randomized controlled trial. *Australian Critical Care*. 32 (3) 199-204. DOI: 10.1016/J.aucc. 2018-03-007.

Sheldrick, R. C. (2023). Randomized trials vs real-world evidence: How can both inform decision-making? *JAMA*, 329(16), 1352–1353. <https://doi.org/10.1001/jama.2023.4855>

Shi, C., Goodall, M., Dumville, J., Hill, J., Norman, G., Hamer, O., Clegg, A., Watkins, C. L., Georgiou, G., Hodgkinson, A., Lightbody, C. E., Dark, P., & Cullum, N. (2022). The accuracy of pulse oximetry in measuring oxygen saturation by levels of skin pigmentation: a systematic review and meta-analysis. *BMC Medicine*, 20(1), 267. <https://doi.org/10.1186/s12916-022-02452-8>

Soares, J., Leung, C., Campbell, V., Van Der Vegt, A., Malycha, J., Andersen, C., et al. (2024). Intensive care unit admission criteria: A scoping review. *Journal of the Intensive Care Society*, 25(3), 296–307. <https://doi.org/10.1177/17511437241246901>

Sontakke, N. G., Sontakke, M. G., & Rai, N. K. (2023). Artificial airway suctioning: A systematic review. *Cureus*, 15(7), e42579.

Soumitra K., Ghosh, Pandit J. J. (2022). Neurological and humoral control of blood pressure. *Anaesthesia & Intensive Care Medicine*, 23 (4), 248-252. <https://doi.org/10.1016/j.mpaic.2022.02.007>.

- Suparti, S., Asiandi, & Rasiman (2021). The Effect of Negative Pressure (20 kPa and 25 kPa) Endotracheal Open Suction on the Hemodynamics Indices among Patients in Intensive Care Unit. *Annals of Tropical Medicine and Public Health*, 24.
- Tadesse, E. E., Tilahun, A. D., Yesuf, N. N., Nimani, T. D., & Mekuria, T. A. (2024). Mortality and its associated factors among mechanically ventilated adult patients in the intensive care units of referral hospitals in Northwest Amhara, Ethiopia, 2023. *Frontiers in Medicine*, 11, 1345468. <https://doi.org/10.3389/fmed.2024.1345468>
- Terragni, P., Urbino, R., Mulas, F., Pistidda, L., Cossu, A. P., Piredda, D., Faggiano, C., Falco, D., Magni, G., Mascia, L., Filippini, C., & Ranieri, V. M. (2020). Occurrence of ventilator associated pneumonia using a tracheostomy tube with subglottic secretion drainage. *Minerva Anestesiologica*, 86(8). <https://doi.org/10.23736/s0375-9393.20.13989-0>
- United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. United Nations. United Nations 2030 Agenda for Sustainable Development
- Vera, M. (2024, April 30). *Virginia Henderson: Nursing need theory study guide*. Nurseslabs.<https://nurseslabs.com/virginia-hendersons-need-theory/>
- Wambua, F. K., Mutinda, J. N., & Tsimba, J. C. (2026). Incidence, predictors, and prevention practices of ventilator-associated pneumonia among critically ill patients at the critical care unit, Kenyatta National Hospital, Kenya: A retrospective mixed-methods cohort study. *East African Medical Journal*, 103(2), 2016–2026.
- Waweru-Siika, W., Mung'ayi, V., Misango, D., Mogi, A., Kisia, A., & Ngumi, Z. (2020). The history of critical care in Kenya. *Journal of Critical Care*, 55, 122–127. <https://doi.org/10.1016/j.jcrc.2019.09.021>

- World Health Organization. (2024). *Guidance for best practices for clinical trials*.
<https://www.who.int/publications/i/item/9789240097711>
- Yazdannik, A., Saghaei, M., Haghighat, S., & Eghbali-Babadi, M. (2019). Efficacy of closed endotracheal suctioning in critically ill patients: A clinical trial of comparing two levels of negative suctioning pressure. *Nursing Practice Today*. <https://doi.org/10.18502/npt.v6i2.910>
- Yılmaz, İ., & Özden, D. (2024). The effects of open and closed system endotracheal suctioning methods on suctioning frequency, amount of secretion, and haemodynamics: A single-blind, randomised, 2 × 2 crossover trial. *Australian Critical Care*, 37(1), 25–33. <https://doi.org/10.1016/j.aucc.2023.09.002>
- Zhao, W., Carter, K., Sverdlov, O., Scheffold, A., Ryznik, Y., Cassarly, C., & Berger, V. W. (2024). Steady-state statistical properties and implementation of randomization designs with maximum tolerated imbalance restriction for two-arm equal allocation clinical trials. *Statistics in Medicine*, 43(6), 1194–1212. <https://doi.org/10.1002/sim.10013>

APPENDICES

Appendix I: Patient Data Form 1a

(Part A: Bio-socio-demographic, ventilatory and initial assessment)

CODE.....BED....GENDER:.....AGE.....DOA.....TIME.....

HISTORY (brief).....

.....SMOKER: Yes/No

DIAGNOSIS 1.....DATED.....

2.....DATED.....

INTUBATION: Yes/No. Route: Oral/Tracheostomy. Date.....Size.....

MODE OF VENTILATION: AC(PCV/VCV)/SIMV(PCV/VCV)/CPAP/Other.....

Ventilator settings: PEEP.....FIO₂.....Date.....

Initial investigations: Chest X-ray: yes/no. CT Scan: yes/no (Region.....)

CBC: yes/no. C/S: yes/no (source.....). U/E/.Cr: yes/no. Tracheal aspirate: yes/no

Other (specify.....)

PHYSICAL EXAMINATION: G/C.....GCS..../15. CVC/ yes/no (site.....)

Branular yes/no (site.....) Urinary catheter: yes/no, Type:.....Drugs

(sedatives) specify.....NG Tube..... yes/no

Extubation date.....Time.....

Part B: Respiratory and Cardiovascular Indices

date					date				
FIO ₂	Pre	Intra	5 min	15 min	FIO ₂	Pre	Intra	5 min	15 min
		(2 nd)					(2 nd)		

Time					Time				
HR					HR				
SpO ₂					SpO ₂				
RR					RR				
BP(Sys)					BP(Syst)				
BP(Dia)					BP(Dias)				
BP(MAP)					BP(MAP)				
Cath. size					Cath. size				
No. Cath entrance					No. Cath entrance				
Blood tinge	(Yes).....(No)				Blood tinge	(Yes).....(No)			

Cont: Part B: Respiratory and Cardiovascular Indices

CODE.....GENDER:AGE.....DOA.....Bed No.....

Continuation:

date					date				
FIO ₂	Pre	Intra (2 nd)	5 min	15min	FIO ₂	Pre	Intra (2 nd)	5 min	15 min
Time					Time				
HR					HR				
SpO ₂					SpO ₂				
RR					RR				
BP(Sys)					BP(Syst)				
BP(Dia)					BP(Dias)				
BP(MAP)					BP(MAP)				
Cath. size					Cath. size				
No. Cath entrance					No. Cath entrance				
Blood tinge	(Yes).....(No)				Blood tinge	(Yes).....(No)			

Remarks.....

date					date				
FIO ₂	Pre	Intra (2 nd)	5 min	15min	FIO ₂	Pre	Intra (2 nd)	5 min	15 min
Time					Time				
HR					HR				
SpO ₂					SpO ₂				
RR					RR				
BP(Sys)					BP(Syst)				
BP(Dia)					BP(Dias)				
BP(MAP)					BP(MAP)				
Cath. size					Cath. size				
No. Cath entrance					No. Cath entrance				
Blood tinge	(Yes).....(No)				Blood tinge	(Yes).....(No)			

.....

.....

.....

Appendix II: Patient Data Form 1b (Continuation Form)

CODE..... GENDER: AGE.....DOA.....Bed
No.....

date					date				
FIO ₂	Pre	Intra (2 nd)	5 min	15 min	FIO ₂	Pre	Intra (2 nd)	5 min	15 min
Time					Time				
HR					HR				
SpO ₂					SpO ₂				
RR					RR				
BP(Sys)					BP(Syst)				
BP(Dia)					BP(Dias)				
BP(MAP)					BP(MAP)				
Cath. size					Cath. size				
No. Cath entrance					No. Cath entrance				
Blood tinge	(Yes).....(No)				Blood tinge	(Yes).....(No)			

Continuation:

Remarks.....
.....

Appendix III: Patient Data Form 2

CODE.....GENDER.....AGE.....DOA.....BED NO.....

date					date				
FIO ₂	Pre	Intra (2 nd)	5 min	15min	FIO ₂	Pre	Intra (2 nd)	5 min	15 min
Time					Time				
HR					HR				
SpO ₂					SpO ₂				
RR					RR				
BP(Sys)					BP(Syst)				
BP(Dia)					BP(Dias)				
BP(MAP)					BP(MAP)				
Cath. size					Cath. size				
No. Cath entrance					No. Cath entrance				
Blood tinge	(Yes).....(No)				Blood tinge	(Yes).....(No)			

	Date								
Day in ICU									
MV days									
Day of ETT									
Gastric ulcer prophylaxis									
Fluid balance									
Sedatives (specify)									

Muscle relaxants (specify)								
FIO ₂ change, increment >20%								
PEEP change >3cmH ₂ O								
N-G tube								
Any VAC								
Wbc count <4,000 or >12,000								
Temp(<36 or >38 ⁰ C								
New A/B								
Any IVAC								
Purulent secretions								
Chest x-ray changes								
+ve culture								
Any VAP								
Death								

Remarks.....

.....

.....

.....

.....

.....

.....

Appendix IV: Suction Procedure

Ascertain the need for suctioning by identifying any of the following indications: -

Obvious secretions in the airway (tracheal tube)

Noisy breathing

Tachypnea (RR>25bpm)

Reduced SpO₂ (<94%)

Saw-tooth waveform on the ventilator display

Raised PIP >the set (PEEP + Pressure Support)

Raised EtCO₂ ->40mmHg (PaCO₂->45mmHg)

Explain the procedure to the patient and consider giving analgesic if deemed necessary.

Assemble equipment. Put the suction system on and test the suction pressure (already set and pretested as per patient allocation to study group)

Pour normal saline into a bowl for cleaning tubing.

Wash hands and put on Personal Protective Equipment (PPE) (gloves, apron, goggles)

Place the patient in supine position with head slightly extended.

Pre-oxygenate the patient with 100% oxygen for one minute by activating that function in the mechanical ventilator.

Take readings of HR, SpO₂, RR, systolic BP, diastolic BP, and MAP.

Select appropriate suction catheter by considering [(French gauge =ETT size -2 X 2] and then connect the suction catheter to the main pressure source.

Attach sterile suction catheter while still on its sterile sheath by opening its base and connecting to the main with the non-dominant hand and with assistance from the second person.

Introduce the catheter without suctioning until resistance is felt, then withdraw for about 1cm, then occlude the air-port to turn on the negative suction pressure, withdraw catheter with rotating motions. Take 15 seconds. Discontinue if heart rate is below 50 or above 150 bpm.

Oxygenate the patient with 100% oxygen for one minute by reconnecting the patient to ventilator circuitry and activating that function in the ventilator machine.

Repeat the suctioning for the second time (2nd catheter pass).

Take readings of HR, SpO₂, RR, systolic BP, diastolic BP, and MAP.

Oxygenate the patient with 100% oxygen for one minute by reconnecting the patient to ventilator circuitry and activating that function in the ventilator machine.

Repeat procedure if needed and again oxygenate the patient with 100% oxygen for one minute by reconnecting the patient to ventilator circuitry and activating that function in the ventilator machine. Repeat until there is no flow of secretions. Record the number of catheter entrances done.

Take readings of HR, SpO₂, RR, systolic BP, diastolic BP, and MAP at 5 minutes and at 20 minutes post suctioning. Indicate if there was a tinge of blood in the secretions picked by the catheter.

Rinse catheter and suction tube with normal saline until clear.

Remove the glove from the dominant hand by inverting it over the suction catheter then discard as hazardous waste.

Clear and process other equipment and accessories as per protocol.

Reposition the patient as appropriate.

Document the suction experience.

NB: Take reading of RR from the mechanical ventilator rather than from the cardiac monitor.

AUTHENTICATION

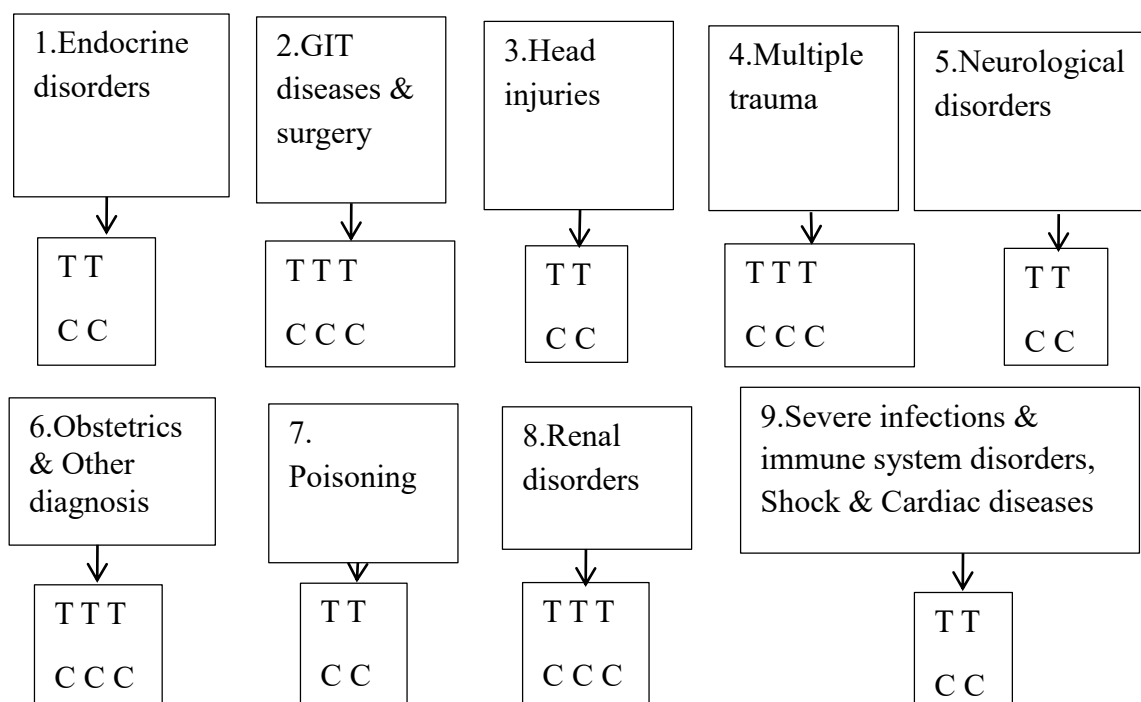
Researcher:

Mark Lewa Ngui

Sign.....Date.....Cell phone number: 0727859138

Appendix V: Block Randomization Consort Diagram

The boxes drawn below indicate the various diagnostic categories in the Critical Care Unit. Under each category, randomization was done by selecting from folded pieces of paper each indicating either T (treatment) or C (control).



In the next round of allocation, the boxes with four participants changed to six. Selection within the boxes was by simple random sampling involving picking of marked folded papers at random. This formed the process of randomization and concealment.

Key:

T: 180 mmHg Arm

C: 100mmHg Arm

Appendix VI: Consent Explanation Form

Introduction

The author of this study is a student at Jomo Kenyatta University of Agriculture and Technology (JKUAT) pursuing a doctoral degree in Critical Care Nursing. As part of fulfillment of the requirements of the programme, the author is expected to conduct a study that will generate new knowledge in the area of specialization. It is in this regard that this study has been formulated. The study is about determining a more suitable suctioning pressure for patients needing clearance of tracheal tube secretions in order to promote gaseous exchange.

Aim

The aim of this study is to 'to establish safe and effective airway clearance by testing two levels of negative pressure in open tracheal tube suctioning and their effect on cardiorespiratory indices and care outcomes among patients in Critical Care Unit at Machakos level five hospital.' Specifically, the study will determine the respiratory and cardiac effects caused by Tracheal Tube Suctioning at 100mmHg and at 180mmHg alongside other effects relating to incident of Ventilator associated Events/Pneumonia, mechanical ventilation days, length of stay in ICU and ICU mortality.

Methodology

Data will be collected from participants through observation and/or measurement of the Heart Rate, Peripheral Oxygen Saturation, Respiration Rate and Blood Pressure; mechanical ventilation days, duration of tracheal tube, length of ICU stay and ICU mortality; catheter entrances used to clear the tracheal secretions; incidence of blood-tinged secretions and Ventilator-Associated Events.

Risks

There is no anticipated or extra ordinary harm from the planned tracheal suctioning since the suction pressures of 100mmHg and 180mmHg have been tried without noticeable harm and suctioning will be done when clinically indicated.

Autonomy

Participation is important but voluntary. One is free to decline to participate or to withdraw at any stage of the process without service being denied to him/her or his/her patient(s). There is no monetary benefit to the participants but it is anticipated that the study findings will result into better application of Tracheal Tube Suctioning in ICU. A total of 76 participants are required in this study. Upon giving consent, participants will be allocated to either 180mmHg or 100mmHg suctioning groups at random.

Anonymity, privacy and confidentiality

Records of data from the patients will be coded in such a way that it's not easy to identify the source. Participant's name, phone number, or obvious identification labels will not be used. All data will be kept under lock and key to prevent unauthorized access and hence promote privacy and confidentiality. Sharing of information obtained from the study will only be done for clinical reasons for the benefit of the patient and with the persons involved in making decision or taking actions. Study results, recommendations and conclusion will be shared with professionals and stakeholders without any identity of participants. Publication in scientific journals will also be done to pass the benefit to more professionals. The results of this study will be availed to any participant upon placing a request.

Any further information, clarification or complaints can be made through the chief investigator or the study supervisors through the following addresses:

Investigator	Supervisor	Supervisor	Supervisor
Mark Lewa	Dr. Kyalo	Dr. Elijah	Dr. Affey
Ngui	Mutisya	Mwangi	Fatuma
School of	School of	School of	School of
Nursing	Nursing	Nursing	Nursing
JKUAT	JKUAT	JKUAT	Garissa Univ.
Box 62000, City	Box 62000,	Box 62000,	Box 1801-
Square, Nairobi.	City Square,	City Square,	70100,
Mobile No:	Nairobi.	Nairobi.	Garissa
0727859138	Mobile No:	Mobile No:	Mobile No:
	0721484869	0722349473	0722731306

Appendix VII: Participants Consent Form

In signing this document, I am giving my consent or that of my relative to be voluntarily involved in a study that seeks to establish safe and effective airway clearance by testing the effects of two negative pressures in open tracheal tube suction on adult mechanically ventilated patients at Machakos level five hospital Intensive Care Unit. I also understand that this study is done as partial fulfillment of the requirements for award of doctor of philosophy in Critical Care Nursing of the Jomo Kenyatta University of Agriculture and Technology.

I understand that participation in this study involves obtaining clinical data pertaining to respiratory and cardiac parameters that result from open tracheal tube suctioning at either 180mmHg or 100mmHg negative pressures of mechanically ventilated patients at Machakos county hospital alongside assessment of other outcomes of care. Effectiveness of the two methods will be derived from number of catheter entrances used to clear tracheal secretions.

I understand that I was selected to participate in this study by the virtual of my admission or relative's admission to Machakos County ICU for mechanical ventilation among other treatment modalities.

I understand that participating in this study does not increase the level of treatment risk that would be experienced ordinarily without such study going on. I have been informed that I can decline involvement or withdrawal from the study at will and at any stage of the study without jeopardizing health care services to myself or my relative. There are no monetary benefits for my participation.

The study will contribute to the body of knowledge pertaining to optimizing patient ventilatory outcome by using the most suitable suction pressure.

I understand that Mr. Mark Lewa Ngui and/or the supervisors: - Dr. Kyalo Mutisya, Dr. Elijah Mwangi and Dr. Affey Fatuma are available to answer any questions or provide clarifications about the study and my rights as a participant and that the results of this study will be given to me if I make a formal request.

Participant's Signature.....Date.....

Investigator	Supervisor	Supervisor	Supervisor
Mark Lewa	Dr. Kyalo	Dr. Elijah	Dr. Affey
Ngui	Mutisya	Mwangi	Fatuma
School of	School of	School of	School of
Nursing	Nursing	Nursing	Nursing
JKUAT	JKUAT	JKUAT	Garissa Univ.
Box 62000, City	Box 62000,	Box 62000,	Box 1801-
Square, Nairobi.	City Square,	City Square,	70100,
Mobile No:	Nairobi.	Nairobi.	Garissa
0727859138	Mobile No:	Mobile No:	Mobile No:
	0721484869	0722349473	0722731306

Appendix VIII: Fomu ya Ufafanuzi wa Makubaliano (Washirika)

Dibaji

Mwandishi was mtaala huu in mwanafunzi katika chuo kikuu cha Jomo Kenyatta kinachohusika na mafunzo ya kilimo na teknolojia. Anasomea shahada ya uzamifu (PhD) katika uuguzi fahamivu (Critical Care Nursing). Kiwango cha masomo ya uzamifu ulenga kutambua mambo mapya katika nyanja maalum. Hii ndio sababu muhimu ya kubuni utafiti huu.

Lengo

Utafiti wenyewe wadhamiria kutambua kiwango kizuri zaidi cha shinikizo hasi (negative pressure) kinachotumika kutoa kikoozi kwa wagonjwa wenye kupewa hewa kupitia kwa machine ya kupulizia hewa huku hewa ikipitia kwa bomba inayowekwa kuunganisha inje ya mdomo na koo la hewa ili kuielekeza kwa mapafu. Shinikizo hasi usika ni 100mmHg na 180mmHg.

Mbinu

Data itachukuliwa kwa njia ya vipimo kuusicha kiwango cha gesi ya oxygen kwa mwili (SpO_2), hesabu ya kupumua kwa dakika, shinikizo ya damu, hesabu ya mapingo ya roho kwa dakika moja baina ya vile vikundi viwili vya wagonjwa. Mengine ya kufichua zaidi ni kama vile kutambua tofauti ya shinikizo hasi usika kwa kiwango cha adhari kwa mapafu, ubora wa kutoa kikoozi, muda wa kupulizia hewa kwa wagonjwa, muda wa kukaa kwa chumba cha wagonjwa mahututi na kiwango cha maafa ndani ya chumba cha wagonjwa mahututi kati ya vikundi hivi viwili.

Hatari

Imebainika kwamba hakuna uwezekano wa hadhari zaidi tukokana na kushiriki kwa utafiti huu. Fauku na hayo, ifaamike kuwa shinikizo hasi ya 100mmHg na ya 180mmHg zimejaribiwa na kuonekana salama kutumika kwa wagonjwa.

Uhuru wa kushiriki

Kushiriki kwa huu utafiti ni kwa hiari ya mtu binafsi. Ingawa wote tumealikwa, ni wale tu ambao watapeana idhini ya kushiriki ndio tu watausishwa. Vile, mshirika yuko na nafasi ya kujitoa wakati wowote bila kuhatarisha matibabu yake ama ya jamaa yake. Ieleweke kwamba hakuna faida ya pesa kwa washirika. Kiasi cha wahusika wanaotazamiwa kushiriki ni watu sabini na sita (76). Baada ya kupeana idhini,

washirika watangawanywa kwa vikundi viwili kwa njia isiyobagua. Moja itahusicha shinikizo hasi ya 100mmHg na ile nyingine shinikizo hasi ya 180mmHg.

Kutojulikana, kuweka faragha na kwa siri

Wahusika hawatatambuliwa kwa majina yao ama njia nyingine yoyote ya wazi. Recodi ya data itawekwa alama tofauti ambazo hazina uhusiano na utambulizi kamili wa wagonjwa. Recodi zote zitawekwa salama kwa kufungiwa kwa kabati. Matokeo ya utafiti huu yatatolewa bila kuonyesha wahusika wenyewe na yatatolewa kwa wale haswa wanaohusika kwa utowaji wa huduma kwa wagonjwa mahututi na wengine walio na uwezo wa kuimarisha hali ya huduma hii. Matokeo pia yatachapichwa kwa jarida ya kisayansi ili kuleta mafanikio kwa wengi.

Matokeo ya utafiti huu yanaweza tolewa kwa yeyote ambaye ataweka agizo. Habari zozote za ziada, ufafanuzi ama malalamiko yoyote yatahughulikiwa na mwandishi wa mtaala ama walimu wake kupitia anwani zifuatazo:

Investigator	Supervisor	Supervisor	Supervisor
Mark Lewa	Dr. Kyalo	Dr. Elijah	Dr. Affey
Ngui	Mutisya	Mwangi	Fatuma
School of	School of	School of	School of
Nursing	Nursing	Nursing	Nursing
JKUAT	JKUAT	JKUAT	Garissa Univ.
Box 62000,	Box 62000,	Box 62000,	Box 1801-
City Square,	City Square,	City	70100,
Nairobi.	Nairobi.	Square,	Garissa
Mobile No:	Mobile No:	Nairobi.	Mobile No:
0727859138	0721484869	Mobile No:	0722731306
		072234947	

Appendix XIV: Fomu ya Ukubali wa Mshirika

Kwa kuweka sahihi kwa mkataba huu ninakubali kushiriki mimi mwenyewe ama jamaa wangu kwa utafiti unaokusudia kutambua kiwango kizuri zaidi cha shinikizo hasi (negative pressure) kinachofaa kutumika kwa kutoa kikoozi kwa wagonjwa mahututi wanaopuliziwa hewa kwenye chumba cha wagonjwa mahututi hospitalini Machakos County, kitengo cha tano.

Ninaelewa kwamba kushiriki kwangu katika huu utafiti kutahusicha kuchukuliwa kwa vipimo kuhusu kiwango cha gesi ya oxygen (SpO_2) mwilini, hesabu ya kupumua kwa dakika, shinikizo hasi ya damu, hesabu ya mapingo ya roho kwa dakika moja baina ya wagonjwa wanaotolewa kikoozi kutumia shinikizo hasi ya 100mmHg na ile ya 180mmHg. Na vile uchuguzi kusiana na adhari kwa mapafu, ubora wa kutoa kikoozi baina na shinikizo hizi mbili na tofauti kuusu jumla ya matokea mengine ya matibabu kwenye chumba cha wagonjwa mahututi.

Nimeelezwa kwamba nilichaguliwa kushiriki katika utafiti huu kwa mujibu wa kuwa mimi ama jamaa yangu amelazwa kwa chumba cha wagonjwa mahututi na kuanzishwa matibabu ya kupuliziwa hewa na kwamba kushiriki kwangu nikwahiri yangu mwenyewe na naweza kujiondoa wakati wowote bila kuhatarisha nafasi ya matibabu yangu ama ya jamaa yangu.

Nimefaamishwa ya kwamba hakuna faida ya pesa kwa washirika lakini matokeo ya utafiti huu yatakuwa ya manufaa kwa kuimarisha shughuli ya kutoa kikoozi kwa wagonjwa mahututi waliowekwa bomba kwa koo la hewa na wanaofaidi kwa matibabu ya kupuliziwa hewa.

Vile ninafahamu kuwa ripoti ya utafiti huu haitawatambua washirika kwa njia yoyote na itachapichwa kwa jarida mbalimbali ili kuwanufaisha wasomi na wahudumu wa afya haswa wale wanaohudumia wagonjwa mahututi. Ninafahamu kwamba naweza pewa matokeo ya utafiti huu kama nitayahitaji. Mtafiti mkuu, kwa jina Mark Lewa Nguu ama walimu wake watakuwa na jukumu la kuyajibu maswali yoyote nitakayokuwa nayo kuhusu jambo lolote linalohusu utafiti huu au haki yangu kama mshirika. Wanaweza kupatikana kupitia anwani zifuatazo: -

Sahihi ya Mshirika.....Tarehe.....\

Investigator	Supervisor	Supervisor	Supervisor
Mark Lewa Ngui	Dr. Kyalo Mutisya	Dr. Elijah Mwangi	Dr. Affey Fatuma
School of Nursing	School of Nursing	School of Nursing	School of Nursing
JKUAT	JKUAT	JKUAT	Garissa Univ.
Box 62000, City Square, Nairobi.	Box 62000, City Square, Nairobi.	Box 62000, City Square, Nairobi.	Box 1801- 70100, Garissa
Mobile No: 0727859138	Mobile No: 0721484869	Mobile No: 0722349473	Mobile No: 0722731306

Appendix X: JKUAT ISERC Approval

Appendix 10: ISERC 1



JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
P.O BOX 62000(00200) NAIROBI, Tel:(067) 58700001-4
(Office of the Deputy Vice Chancellor, Research Production and Extension Division)

JKUAT INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW COMMITTEE

REF: JKU/2/4/896B Date: 13th July, 2023

MARK LEWA NGUI
SCHOOL OF NURSING, JKUAT

Dear Mr. Ngui,

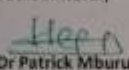
RE: TWO LEVELS OF NEGATIVE PRESSURE IN OPEN TRACHEAL SUCTIONING AND THEIR EFFECT ON CARDIO-RESPIRATORY INDICES AND CARE OUTCOMES AMONG PATIENTS IN CRITICAL CARE UNIT AT MACHAKOS LEVEL FIVE HOSPITAL

This is to inform you that JKUAT Institutional Scientific and Ethical Review Committee has reviewed and approved your above research proposal. Your application approval number is JKU/ISERC/02316/0914. The approval period is 13th July 2023 to 12th July 2024.

- Only approved documents including (informed consents, study instruments, MTA) will be used
- All changes including (amendments, deviations, and violations) are submitted for review and approval by JKUAT ISERC.
- Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to JKUAT ISERC within 72 hours of notification
- Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to JKUAT ISERC within 72 hours
- Clearance for export of biological specimens must be obtained from relevant institutions.
- Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- Submission of an executive summary report within 90 days upon completion of the study to JKUAT ISERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://orls.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely


Dr Patrick Mburugu
CHAIR, JKUAT ISERC



 JKUAT is ISO 9001:2015 and ISO 14001:2015 certified
Setting Trends in Higher Education, Research, Innovation and Entrepreneurship

Appendix XI: NACOSTI Research Permit

Appendix 11: NACOSTI Research Permit 1


REPUBLIC OF KENYA


NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 796358 Date of Issue: 16/August/2023

RESEARCH LICENSE



This is to Certify that Mr. Mark Lewu Ngu of Jomo Kenyatta University of Agriculture and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Machakos on the topic: TWO LEVELS OF NEGATIVE PRESSURE IN OPEN TRACHEAL SUCTIONING AND THEIR EFFECT ON CARDIO-RESPIRATORY INDICES AND CARE OUTCOMES AMONG PATIENTS IN CRITICAL CARE UNIT AT MACHAKOS LEVEL FIVE HOSPITAL for the period ending : 16/August/2024.

License No: NACOSTI/P/23/28497

796358
Applicant Identification Number


Director General
NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY &
INNOVATION

Verification QR Code



NOTE: This is a computer generated License. To verify the authenticity of this document,
Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix XII: Research Approval and Appointment of supervisors

Appendix 12: Research Proposal Approval and Appointment of Supervisors



**JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY**

OFFICE OF THE DIRECTOR, GRADUATE SCHOOL
P.O. BOX 62000, 00200 • NAIROBI • KENYA • TEL: (007) 5870001-4 • Email: director@jku.ac.ke

REF: JKU/2/11/ HSN411-0015/2022 19TH SEPTEMBER, 2023

MARK LEWA NGUI
C/o SON
JKUAT

Dear, Mark

RE: APPROVAL OF RESEARCH PROPOSAL AND APPOINTMENT OF SUPERVISORS

Kindly note that your PhD: research proposal entitled: "TWO LEVELS OF NEGATIVE PRESSURE IN OPEN TRACHEAL SUCTIONING AND THEIR EFFECT ON CARDIO-RESPIRATORY INDICES AND CARE OUTCOMES AMONG PATIENTS IN CRITICAL CARE UNIT AT MACHAKOS LEVEL FIVE HOSPITAL." has been approved. The following are your approved supervisors:-

1. Dr. Mwangi Elijah Githinji
2. Dr. Mutisya Kyalo
3. Dr. Fatuma Aden Afley

Please be advised that you are expected to publish your research outputs in quality and indexed journals.

Yours sincerely, 

PROF. LOSENGE TUROOP
DIRECTOR, GRADUATE SCHOOL
Copy to: Dean, SON



JKUAT is ISO 9001:2015 and ISO 14001:2015 Certified
Setting Trends in Higher Education, Research, Innovation and Entrepreneurship

Appendix XIII: Machakos County Research Authorization

Appendix 13: Machakos County Authority 1



REPUBLIC OF KENYA
COUNTY GOVERNMENT OF MACHAKOS
DEPARTMENT OF HEALTH
Office of the County Director of Medical Services

Telephone: +254-44-20246
Fax: 254-44-20655

Highway
P.O. Box 2574-90100
Machakos, Kenya

Ref No: MKS/DHES/RSCH/VOLI/317
Date: 29/9/2023

Dear Mark Lewa Ngini,

RE: LETTER OF AUTHORIZATION FOR CONDUCTING PROPOSED RESEARCH

The Department of Health and Emergency Services, Machakos County is keen to collaborate in your study titled, **"Two Levels of Negative Pressure in Open Tracheal Sectioning and Their Effect on Cardio-respiratory Indices and Care Outcomes Among Patients in Critical Care Unit at Machakos"**.

Level Five Hospital"

Note is taken of the letter of Ethical clearance from JKUAT Institutional Scientific and Ethical Review Unit, REF: JKU/ISERC/02316/0914, for the approval period 13th July 2023 to 12th July 2024 as well as the Research License from the National Commission for Science, Technology & Innovation number NACOSTI/P/23/28497 for the period ending 16th August 2024.

You are hereby authorized to proceed with the research in Machakos County and urged to share the findings with the Department of Health and Emergency Services, Machakos County, through this email: research.dhes@gmail.com

Sincerely,

Dr. Sharon Mwani
County Director Medical Services & Research
Machakos County



Cc:
County Executive Committee Member – Health
Chief Officer – Medical Services & Public Health
County Research Committee

Appendix XIV: Renewal of JKUAT ISERC Approval

Appendix 14: ISERC 2



JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
P.O BOX 62000(00200) NAIROBI, Tel: (067) 58700001-4
(Office of the Deputy Vice Chancellor, Research Production and Extension Division)
JKUAT INSTITUTIONAL SCIENTIFIC AND ETHICAL REVIEW COMMITTEE

REF: JKU/2/4/8968 Date: 6th June, 2024

MARK LEWA NGUI
SCHOOL OF NURSING

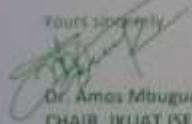
Dear Mr Ngui

RE: TWO LEVELS OF NEGATIVE PRESSURE IN OPEN TRACHEAL SUCTIONING AND THEIR EFFECT ON CARDIO-RESPIRATORY INDICES AND CARE OUTCOMES AMONG PATIENTS IN CRITICAL CARE UNIT AT MACHAKOS LEVEL 5 HOSPITAL

This is to inform you that JKUAT Institutional Scientific and Ethical Review Committee has reviewed and approved your request to renew your above research proposal. This renewal is subject to the terms and conditions of your earlier approval JKU/ISERC/02316/0914 dated 13th July 2023. The approval period is 13th July 2024 to 12th July, 2025. This approval is subject to compliance with the following requirements;

- Only approved documents including (informed consents, study instruments, MTA) will be used
- All changes including (amendments, deviations, and violations) are submitted for review and approval by JKUAT ISERC
- Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to JKUAT ISERC within 72 hours of notification
- Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to JKUAT ISERC within 72 hours
- Clearance for export of biological specimens must be obtained from relevant institutions.
- Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- Submission of an executive summary report within 90 days upon completion of the study to JKUAT ISERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://onlinacosti.go.ke> and also obtain other clearances needed.

Yours sincerely,

Dr. Amos Mbugua
CHAIR, JKUAT ISERC



 JKUAT is ISO 9001:2015 and ISO 14001:2015 certified

Setting Trends in Higher Education, Research, Innovation and Entrepreneurship

Appendix XV: Renewal of NACOSTI Research Permit

Appendix 15: NACOSTI Research Permit 2


REPUBLIC OF KENYA


NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 712910 Date of Issue: 24/July/2024

RESEARCH LICENSE



This is to Certify that Mr., Mark Lewa Ngui of Jomo Kenyatta University of Agriculture and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Machakos on the topic: TWO LEVELS OF NEGATIVE PRESSURE IN OPEN TRACHEAL SUCTIONING AND THEIR EFFECT ON CARDIO-RESPIRATORY INDICES AND CARE OUTCOMES AMONG PATIENTS IN CRITICAL CARE UNIT AT MACHAKOS LEVEL FIVE HOSPITAL for the period ending : 24/July/2025.

License No: NACOSTI/P/24/37702

712910
Applicant Identification Number


Director General
NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY &
INNOVATION

Verification QR Code



NOTE: This is a computer generated License. To verify the authenticity of this document,
Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix XVI: Renewal of Machakos County Authorization

Appendix 16: Machakos County Authority 2



REPUBLIC OF KENYA
COUNTY GOVERNMENT OF MACHAKOS
DEPARTMENT OF HEALTH
Office of the County Director of Medical Services

Telephone: +254-44-20246
Fax: 254-44-20655
Email: research.dhcs@gmail.com

Machakos Highway
P.O. Box 2574-90100
Machakos, Kenya

Ref No. MKS/DMS/RESEARCH APPROVALS/2024/30 6th September 2024

Dear Mr. Mark Ngũi,

RE: LETTER OF AUTHORIZATION FOR CONDUCTING PROPOSED RESEARCH

The Department of Health Services, Machakos County, is keen to collaborate in your study titled, **"Two Levels of Negative Pressure in Open Tracheal Suctioning and their Effect on Cardio-Respiratory Indices and Care Outcomes among Patients in Critical Care Unit at Machakos Level Five Hospital."**

Note is taken of the letter of Ethical Clearance from JKUAT ISERC: JKU/2/4/896B for the approval period 13th July 2024 to 12th July 2025 as well as the Research License from the National Commission for Science, Technology & Innovation number NACOSTI/P/24/37702 for the period ending 24th July 2025.

You are hereby authorized to proceed with your research at Machakos Level 5 hospital ICU and urged to share the findings with the Department of Health, Machakos County, through the Email: research.dhcs@gmail.com

Sincerely,



Dr. Sharon Mwani
County Research Coordinator
Deputy Director Medical Services
Machakos County

CC:
County Executive Committee Member - Health
Chief Officer - Medical Services & Public Health
All Directors
Medical Superintendent Level 5 Hospital

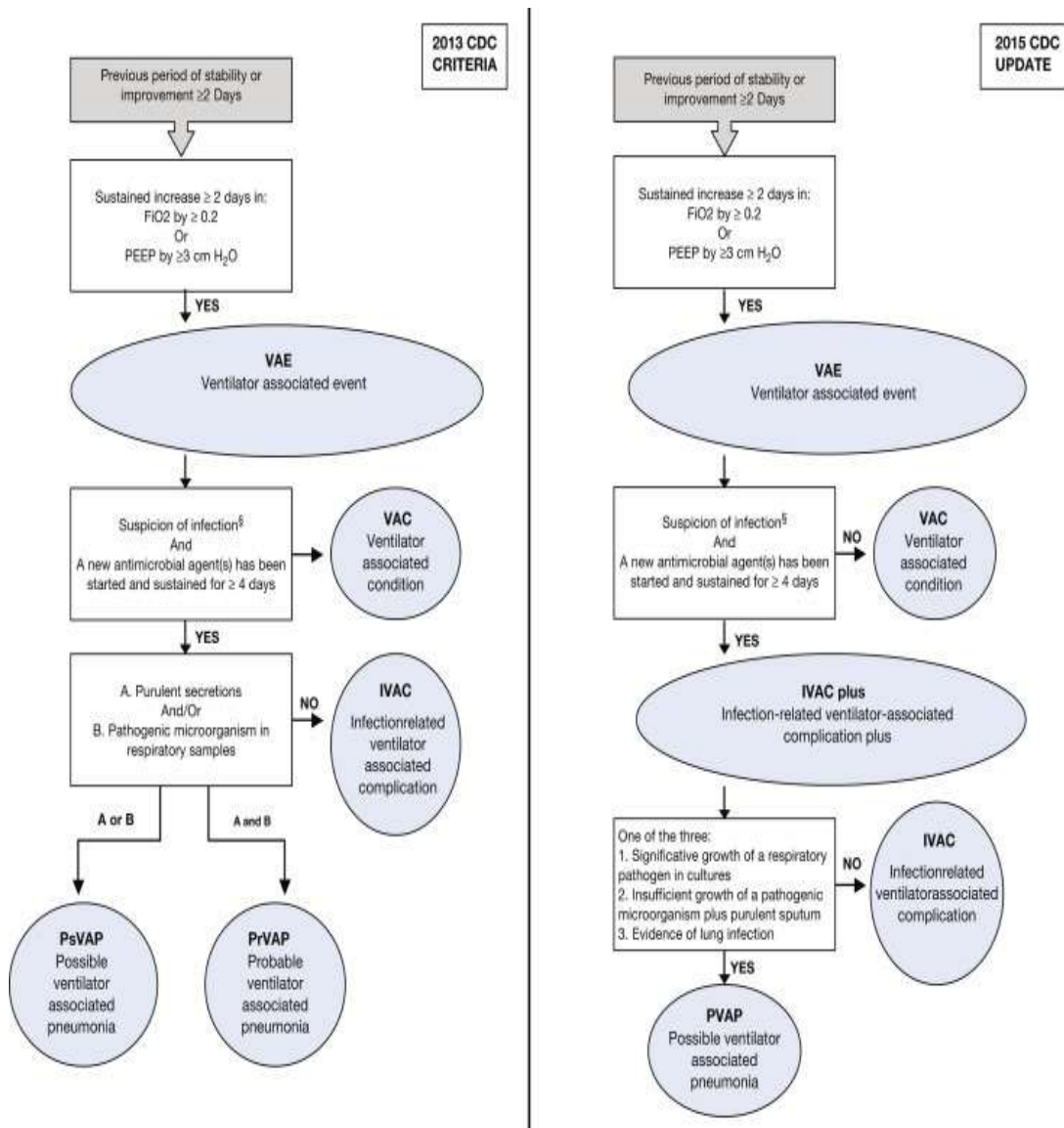
Appendix XVII: Research Budget

Tabulated below is the budget for the research project at Machakos level 5 hospital Intensive Care Unit.

The data collection process took 12 months.

SNO	ITEM	UNIT COST (Kshs.)	QTY	TOTAL COST (Kshs.)
	JKUAT Scientific & Ethical Committee Fees	5,000	2 (2 nd =2000/=)	7,000.00
	NACOSTI Permit Fees	2,000/=	2	4,000.00
	Machakos County Research Fee	5,000/=	2	10,000.00
	Research assistants' stipend	1500/= per month per person	24 for 12 months	432,000.00
	Research assistant training per diem	4000/= snacks per day	2 days	8,000.00
	Data management expert (Bio-statistician) consultation	30,000/=	1	30,000.00
	Stationery (foolscap papers, notebooks, pens)	900/=	10 reams	11,500.00
		50/=	30 note books	
		25/=	40 pens	
	Tracheal Tube Cuff Manometer	35,000.00	1	35,000.00
	Telephone, Internet services	5000/=	12 months	60,000.00
	Printing/photocopying	5/= per page	5000 pages	25,000.00
	Binding services	8 book copies	1100/-	8,800.00
	Publication Fees	35,000.00		35,000.00
	Contingency			35,000.00
	Total (Kshs.)			701,300.00

Appendix XVIII: Ventilator Associated Event Algorithm



ADOPTED FROM

Peña-López Y, Ramírez-Estrada S, Rello J. (2019). Ventilator-Associated Events: Definitions and Uses. Reference Module in Biomedical Sciences.