2010

Patient Ventilator Dyssynchrony: Types, Frequency and Patterns in Critically Ill Adults

Karen Mellott
Virginia Commonwealth University

Follow this and additional works at: https://scholarscompass.vcu.edu/etd

Part of the Nursing Commons

© The Author

Downloaded from
https://scholarscompass.vcu.edu/etd/2084

This Dissertation is brought to you for free and open access by the Graduate School at VCU Scholars Compass. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of VCU Scholars Compass. For more information, please contact libcompass@vcu.edu.
PATIENT VENTILATOR DYSSYNCHRONY: TYPES, FREQUENCY AND PATTERNS IN CRITICALLY ILL ADULTS

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

by

Karen Gwen Mellott
B.S., Nursing, Pennsylvania State University, 1983
M.S., Nursing, Virginia Commonwealth University, 1991

Director: Mary Jo Grap, Ph.D., RN, ACNP, FAAN
Professor, Adult Health And Nursing Systems
School of Nursing

Virginia Commonwealth University
Richmond, Virginia
April 2010
Acknowledgment

My journey has been filled with wonderful people God placed into my professional and personal life. First, I thank God above, from whom all gifts and blessings flow. I also thank my parents Lloyd and Lucille Mellott, my brother and sister-in-law, Kevin and Carol Mellott for their unwavering love and support. Their steadfast presence in my life always brought me home, even though I was many miles from them.

As a master’s student and research assistant of Dr. Mary Jo Grap it was hard not to become interested in research. Her passion for clinically applicable research to improve the care and outcomes of mechanically ventilated adults is contagious. She truly has been an awe-inspiring force and anchor during my entire graduate education at VCU. She always believed in me and my potential and her outstanding mentorship helped to make this dissertation a reality. I have been extremely fortunate to be mentored by her exceptional wisdom, experience, kind spirit, positive attitude, patience, and character throughout my graduate education.

I also express sincere thanks to my distinguished dissertation committee members, Dr. Cindy Munro, Dr. Curtis Sessler and Dr. Paul Wetzel. Each member is truly an extraordinary mentor who provided guidance, intellectual stimulation and encouragement. Their steadfast faith in my work has always been present and expressed. I add heart-felt thanks to Dr. Jessica McKinney Ketchum and Dr. Jon O. Nilsestuen. Dr. Ketchum’s guidance and assistance with data management and Dr. Nilsestuen’s expertise in waveform interpretation and patient care were extremely valuable and centered at the core of this dissertation.

Also I thank my friends who leave precious memories and an outlook for future good times together. I am ever grateful for their hearts of laughter, love, kindness, generosity, strength, and encouragement. All of them are true gems that shine in the night. I also thank the research grant staff of the VCU School of Nursing. They were knowledgeable, supportive and helpful in learning the grant process and contributed to my success. I also give thanks to the supportive staff at Noldus, Inc for their assistance with the Observer XT software. Tiffany Mayton was an exceptionally gifted problem solver and software expert.
I express gratitude for the financial support of the National Institute of Nursing Research and National Research Service Award (F31- NR009623); Virginia Commonwealth University School of Nursing; the Gamma Omega Chapter of Sigma Theta Tau International Honor Society of Nursing; and the Honor Society of Phi Kappa Phi. In addition, I thank Phillips, Respironics who donated the noninvasive cardiac output monitor for use in this work.

Without the generous support of these wonderful people and organizations, I could not have completed this work.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgment</td>
<td>ii</td>
</tr>
<tr>
<td>List of Tables</td>
<td>vii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>viii</td>
</tr>
<tr>
<td>Abstract</td>
<td>ix</td>
</tr>
<tr>
<td>Chapters</td>
<td></td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Patient ventilator dyssynchrony: clinical significance and implica-</td>
<td>9</td>
</tr>
<tr>
<td>tions for practice (manuscript)</td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td>10</td>
</tr>
<tr>
<td>Factors affecting Patient Ventilator Interaction</td>
<td>11</td>
</tr>
<tr>
<td>Patient related factors</td>
<td>11</td>
</tr>
<tr>
<td>Respiratory center output</td>
<td>11</td>
</tr>
<tr>
<td>Respiratory system mechanics</td>
<td>15</td>
</tr>
<tr>
<td>Patient disease states and conditions</td>
<td>17</td>
</tr>
<tr>
<td>Artificial airway in place</td>
<td>17</td>
</tr>
<tr>
<td>Ventilator related factors</td>
<td>18</td>
</tr>
<tr>
<td>Ventilator triggering</td>
<td>18</td>
</tr>
<tr>
<td>Newer ventilator modes to improve ventilator triggering</td>
<td>19</td>
</tr>
<tr>
<td>Ventilator cycling off</td>
<td>20</td>
</tr>
<tr>
<td>Premature termination</td>
<td>20</td>
</tr>
<tr>
<td>Delayed termination</td>
<td>21</td>
</tr>
<tr>
<td>Prevalence of Patient Ventilator Dyssynchrony (PVD)</td>
<td>22</td>
</tr>
<tr>
<td>Consequences of PVD</td>
<td>23</td>
</tr>
<tr>
<td>Measurement/Identification of PVD</td>
<td>24</td>
</tr>
<tr>
<td>Types of dyssynchrony and contributing factors</td>
<td>24</td>
</tr>
<tr>
<td>Trigger Dyssynchrony</td>
<td>25</td>
</tr>
<tr>
<td>Flow Dyssynchrony</td>
<td>27</td>
</tr>
<tr>
<td>Termination Dyssynchrony</td>
<td>28</td>
</tr>
<tr>
<td>Expiratory Dyssynchrony</td>
<td>29</td>
</tr>
<tr>
<td>Manifestation and measures of PVD</td>
<td>29</td>
</tr>
<tr>
<td>Nursing implications for improving the phenomena of PVD</td>
<td>31</td>
</tr>
<tr>
<td>Monitoring of PVD</td>
<td>31</td>
</tr>
</tbody>
</table>
3. Patient ventilator dyssynchrony: types, frequency and patterns in critically ill adults (manuscript) ........................................ 45
   Background ........................................................................ 45
   Method ............................................................................... 47
   Design and Sample ............................................................. 47
   Measurement of Key Variables ............................................ 48
   Patient Ventilator Dysynchrony (PVD) .................................. 48
   PVD Types .......................................................................... 48
   PVD Frequency .................................................................... 56
   PVD Patterns ....................................................................... 56
   Level of Sedation .................................................................. 58
   Subject Descriptive Data ...................................................... 58
   Procedure ............................................................................ 59
   Data Collection Procedure .................................................. 59
   Data Analysis ........................................................................ 59
   Results ................................................................................ 60
   Characteristics of Sample .................................................... 60
   Patient Ventilator Dyssynchrony ......................................... 63
   PVD Types .......................................................................... 63
   Variability in PVD Types ..................................................... 63
   Unexpected PVD Types ....................................................... 65
   PVD Frequency .................................................................... 66
   PVD Patterns ....................................................................... 67
   Level of Sedation .................................................................. 71
   Discussion ............................................................................ 71
   Subjects / Sample ................................................................. 71
   PVD Types .......................................................................... 72
   PVD Frequency .................................................................... 74
   PVD Patterns ....................................................................... 75
   Level of Sedation and PVD ................................................... 76
   Limitations ............................................................................ 76
   Conclusions .......................................................................... 77
   Acknowledgements ................................................................ 79
   References ........................................................................... 80
Appendix .........................................................................................................................86
  A. Ventilation Data Collection Tool .........................................................86
Vita ..........................................................................................................................88
List of Tables

Chapter 1 (none)

Chapter 2

Table 1: Patient- and ventilator- related factors that affect patient-ventilator interaction.........................................................................................................................................................12
Table 2: Receptors and their effect on autonomic respiratory drive ..................16
Table 3: Phases of an assisted ventilated breath associated with patient-ventilator dyssynchrony.........................................................................................................................................................25
Table 4: Markers of patient-ventilator dyssynchrony ........................................31
Table 5: Identification, causes, and collaborative interventions for patient-ventilator dyssynchrony.........................................................................................................................................................36
Table 6: List of potential research questions for the future direction of nursing research on patient-ventilator dyssynchrony .................................................................38

Chapter 3

Table 1: Characteristics of sample and major variables (n= 27) .........................62
Table 2: Breath types (Total ventilated breaths of sample, n= 43,758) ...............64
Table 3: PVD Breath Categories(% for n= 27 subjects) ....................................67
Table 4: State Lag Analysis, Frequency for Premature Termination and Delayed Termination .................................................................................................................................69
Table 5: Time lag- Frequency Matrix for Premature Termination to Multiple Triggers and Delayed Termination to Ineffective Triggers.................................70
List of Figures

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Figure Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 1</td>
<td>(none)</td>
<td></td>
</tr>
<tr>
<td>Chapter 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Figure 1: Trigger dyssynchrony, Double trigger</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Figure 2: Trigger dyssynchrony, Ineffective effort</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Figure 3: Flow dyssynchrony</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Figure 4: Termination dyssynchrony</td>
<td>29</td>
</tr>
<tr>
<td>Chapter 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Figure 1: Waveform Categories used for Coding and Data Analysis</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Figure 2: Subject Variation in Dyssynchrony by Breath Category</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Figure 3: Patterns of PVD Associations</td>
<td>68</td>
</tr>
</tbody>
</table>
Abstract

PATIENT VENTILATOR DYSYNCHRONY: TYPES, FREQUENCY, PATTERNS IN THE CRITICALLY ILL

By Karen Gwen Mellott Ph.D., R.N.

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

Virginia Commonwealth University, 2010

Major Director: Mary Jo Grap, Ph.D., RN, ACNP, FAAN
Professor, Adult Health, School of Nursing

Patient ventilator dyssynchrony (PVD) occurs frequently, but little is known about the types, frequency and patterns of PVD for longer than 30 minutes. Deeper levels of sedation are associated with PVD. Evaluation of ventilator graphics and the ability to identify PVD should assist clinicians to optimize patient ventilator interactions and promote earlier interventions. The purpose of this study was to identify the different types, frequency and patterns of PVD in critically ill adults and determine the effect of sedation level on PVD. Thirty medical and surgical ICU adult patients were enrolled; 27 were used for analysis. Pressure/time and flow/time waveform data were collected using the Noninvasive Cardiac Output monitor for up to 90 minutes per subject. Blinded waveform analysis was performed. Sedation level was measured every 20 minutes. A
Dyssynchrony Index (DI) and PVD Type Indices were used to describe PVD frequency. Lag analysis was used to detect associated patterns of PVD. PVD occurred during all phases of ventilated breaths and during each of the ventilatory modes used. Heretofore undocumented dyssynchrony in the form of patient gasp PVD, active triggers and combined PVDs were found. The most common type of PVD was Ineffective Trigger (63%), followed by Premature Termination-Flow (17%), Premature Termination (9%), Multiple Trigger (1%), Flow (0.87%) and Delayed Termination (0.09%). The overall frequency of dyssynchronous breaths in the sample was 23% of total breaths analyzed, however 93% of subjects experienced at least one incident of PVD. The overall median DI (Interquartile Range [IQR]) was 4% (1% - 9%) with Ineffective Trigger Index having the highest median index (1.78%). The high DI group (6 subjects, 22%) had a DI (IQR) of 61% (42% - 85%). Seventy seven percent of subjects experienced multiple types of PVD. Premature Termination was followed by Multiple Triggers starting at 3 seconds, but Delayed Termination was followed by Ineffective Triggers, starting at 30 seconds. Clinicians need to recognize PVD, since this is a critical step in evaluating patient ventilator interaction and providing subsequent intervention. PVD interpretation is complex requiring clinicians to clearly understand the operational function of ventilator modes and waveform alterations that occur.
CHAPTER 1. INTRODUCTION

Fifty percent of Intensive Care Unit (ICU) patients receive mechanical ventilation. A phenomenon common to the experience of these patients, but not highly recognized by clinicians, is the development of patient ventilator dyssynchrony (PVD). In fact, Thille et al. found that 25% of ventilated patients exhibit dyssynchronous ventilator interaction. Sassoon and Foster define PVD as a mismatch between patient (neural) and ventilator assisted breaths (phase asynchrony), as well as the inability of the ventilator’s flow delivery to match the patient’s flow demand (flow asynchrony). A common term used to describe this phenomenon in practice is the elusive phrase, “fighting the ventilator”; however, there are few empirical studies which elaborate on the bio-behavioral markers to identify PVD in ICU patients.

Physicians and researchers have worked to improve patient-ventilator interactions for two decades, yet optimal patient-ventilator interaction has still not been achieved. Often, the use of sedation is required to increase the client’s tolerance of the endotracheal tube, reduce anxiety, facilitate sleep, and improve synchronization with the ventilator. However, achieving synchrony is a daunting task and inappropriately high levels of sedation have been shown to prolong the duration of MV, increase the need for diagnostic testing to determine responsiveness, and increase the occurrence of one type of PVD, Ineffective Trigger.
There are complex and varied patient-related and ventilator-related factors which influence the patient-technology interface and possible interventions to improve PVD are based on these complex relationships. In the meantime, PVD persists, and contributes to possible complications. PVD can result in adverse clinical outcomes including hypoxemia, cardiovascular compromise, patient discomfort, anxiety/fear, impairment of sleep quality, prolonged mechanical ventilation, and possible diaphragmatic injury. Given this data, a literature review with regard to the factors contributing to PVD; the manifestations, measurement, types and causes of PVD; nursing implications; and future directions for nursing research is presented (Chapter 2).

Since recognition is underappreciated and PVD complications are serious, optimizing the patient ventilator interaction begins with identification of PVD types, frequency and patterns. Once clinicians can recognize PVD, onsite interventions can be initiated to improve the patient ventilator interaction and reduce risk from dyssynchronous patient-ventilator related complications. PVD has been detected by a variety of measures, but there are few classification systems that objectify PVD. In addition, Thille et al. and other studies have identified the occurrence of PVD during short periods of time (≤ 30 minutes) using morphological and mathematical definitions, however, very little is documented about the types, frequency, traits and characteristics of PVD over longer periods of time in critically ill medical and surgical adult patients. Since clinicians work with patients over extended time periods, an
investigation into the frequency, types and patterns of PVD over time is presented in Chapter 3.

A descriptive, prospective and cross-sectional design was initiated to explore the presence of PVD in mechanically ventilated, adult medical and surgical ICU subjects up to a 90 minute period of time. The specific aims of this proposed research were to: (a) identify the types, frequency and patterns of PVD over time; and (b) determine the effect of sedation level on PVD. Thirty subjects were consented and enrolled, with 27 available for data analysis. To identify PVD types, frequency and patterns, airway pressure/time and flow/time waveform analysis was conducted based on an expert classification system by Nilsestuen and Hargett, 2005. The pressure and flow waveforms were obtained using the Non-Invasive Cardiac Output (NICO) Cardiopulmonary Management system (Respironics®, Model 7300, Wallingford, CT). The pressure and flow signals collected from the NICO were sent to a data acquisition system (MP 150 Data Acquisition System®, Biopac Systems Inc, Goleta, CA). The MP 150 sampled, synchronized, amplified, time stamped and stored data until downloaded for later analysis.

Waveforms were coded through a software package called the Observer XT 8.0 (Noldus, Inc). A breath by breath interpretation was completed during each subject's observed time period by the principle investigator (PI) (KGM). These breaths were then independently validated with expert consultation. As new dyssynchronous breath types emerged from the data, they were given a descriptive indicator, operational definition
and added to the coding scheme for complete and thorough coding and documentation longitudinally.

Patient ventilator dyssynchrony was found in both medical and surgical subjects and during each of the ventilator modes included in this study. Ninety three percent of subjects experienced at least one type of PVD, however 77% of all breaths (n= 43,758 breaths) in the sample were normal. The most common PVD was Ineffective Trigger, followed by Premature Termination, Undocumented, Multiple Triggers, Flow PVD and Delayed Termination. Heretofore, previously Undocumented PVDs were found, such as active triggers, combinations of PVD during different phases of the same ventilated breath and new variant forms of Flow PVD and Delayed Termination PVD (e.g. Patient Gasp PVD and Resisting Ventilation). For the 27 subjects, the median Dyssynchrony Index (IQR) for the sample was 4% (1% - 9%). There were 6 subjects (22%) who experienced a clinically significant level of PVD (DI ≥ 10%, defined by Vitacca et al.24); in this group the median DI (IQR) was 61% (42% - 85%). Both predictor PVD types were followed by response PVD types, however at a low occurrence rate. Level of sedation did not affect the DI (F (1, 25)= 1.33, p= 0.26). In addition, there was no significant relationship between level of sedation (awake or deep sedation) and PVD type index (Ineffective Trigger Index) using ANOVA (F (1,25)= 0.005, p= 0.94).

This study contributes new knowledge to the identification of PVD in medical and surgical ICU patient populations and during all studied modes of mechanical ventilation. In fact, new types of PVD were found and combinations of PVD can occur. This evidence should alert clinicians to the possibilities that PVD is recognizable, may occur
in undocumented forms and may be generated from a variety of patient or ventilator related issues for clinical evaluation and treatment.

Reference List


