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# 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

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Abstract

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

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

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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.[1] A phenomenon common to the experience of these patients, but not highly recognized by clinicians, is the development of patient ventilator dyssynchrony (PVD).[2-5] In fact, Thille et al.[6] found that 25% of ventilated patients exhibit dyssynchronous ventilator interaction. Sassoon and Foster[7] 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,[8,9] 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.[10-14] However, achieving synchrony is a daunting task and inappropriately high levels of sedation have been shown to prolong the duration of MV,[15] increase the need for diagnostic testing to determine responsiveness,[16] and increase the occurrence of one type of PVD, Ineffective Trigger.[17]

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,[2] cardiovascular compromise,[2] patient discomfort,[18-20] anxiety/fear,[18] impairment of sleep quality,[21] prolonged mechanical ventilation,[22] and possible diaphragmatic injury.[7;23] 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,[16-22] but there are few classification systems that objectify PVD. In addition, Thille et al.[9] and other studies[6;17;22] 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.[19] 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


1. Tobin MJ, Laghi F, Jubran A. Respiratory muscle dysfunction in mechanically-ventilated patients. Molecular Cell Biochemistry 1998;179:87-98.

2. Dick CR, Sassoon CS. Patient-ventilator interactions. Clinical Chest Medicine 1996;17:423-38.

3. Nava S, Bruschi C, Fracchia C, Braschi A, Rubini F. Patient-ventilator interaction and inspiratory effort during pressure support ventilation in patients with different pathologies. The European Respiratory Journal 1997;10:177-83.

4. Tobin MJ, Jubran A, Laghi F. Patient-ventilator interaction. American Journal of Respiratory Critical Care Medicine 2001;163:1059-63.

5. Branson RD. Functional principles of positive pressure ventilators: implications for patient-ventilator interaction. Respiratory Care Clinics of North America 2005;11:119-45.

6. Thille AW, Rodriguez P, Cabello B, Lellouche F, Brochard L. Patient-ventilator asynchrony during assisted mechanical ventilation. Intensive Care Medicine. 2006;32:1515-22.

7. Sassoon CS, Foster GT. Patient-ventilator asynchrony. Current Opinion in Critical Care 2001;7:28-33.

8. Kirby RR. Improving ventilator-patient interaction: reduction of flow dyssynchrony. Critical Care Medicine 1997;25:1630.

9. Navalesi P, Costa R. New modes of mechanical ventilation: proportional assist ventilation, neurally adjusted ventilatory assist, and fractal ventilation. Current Opinion in Critical Care 2003;9:51-58.

10. Sessler CN. Comfort and distress in the ICU: scope of the problem. Seminars in Respiratory and Critical Care Medicine 2001;22:111-14.

11. Jacobi J, Fraser GL, Coursin DB, Riker RR, Fontaine D, Wittbrodt ET *et al.* Clinical practice guidelines for the sustained use of sedatives and analgesics in the critically ill adult. Critical Care Medicine 2002;30:119-41.

12. Rhoney DH, Murry KR. National survey of the use of sedating drugs, neuromuscular blocking agents, and reversal agents in the intensive care unit. Journal of Intensive Care Medicine 2003;18:139-45.

13. Blanchard AR. Sedation and analgesia in intensive care. Medications attenuate stress response in critical illness. Postgraduate Medicine. 2002;111:59-4, 67.

14. Tufano R. Analgesia and sedation in intensive care: a progress report. Minerva Anestesiology 2003;69:735-37.

15. Kollef MH, Levy NT, Ahrens TS, Schaiff R, Prentice D, Sherman G. The use of continuous i.v. sedation is associated with prolongation of mechanical ventilation. Chest 1998;114:541-48.

16. Kress JP, Pohlman AS, O'Connor MF, Hall JB. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. New England Journal of Medicine 2000;342:1471-77.

17. de WM, Pedram S, Best AM, Epstein SK. Observational study of patient-ventilator asynchrony and relationship to sedation level. Journal of Critical Care 2009;24:74-80.

18. Bergbom-Engberg I, Haljamae H. Assessment of patients' experience of discomforts during respirator therapy. Critical Care Medicine 1989;17:1068-72.

19. Jubran A, Van de Graaff WB, Tobin MJ. Variability of patient-ventilator interaction with pressure support ventilation in patients with chronic obstructive pulmonary disease. American Journal of Respiratory and Critical Care Medicine 1995;152:129-36.

20. Manning HL, Molinary EJ, Leiter JC. Effect of inspiratory flow rate on respiratory sensation and pattern of breathing. American Journal of Respiratory and Critical Care Medicine 1995;151:751-57.

21. Reishtein JL. Sleep in mechanically ventilated patients. Critical Care Nursing Clinics of North America 2005;17:251-55.

22. Chao DC, Scheinhorn DJ, Stearn-Hassenpflug M. Patient-ventilator trigger asynchrony in prolonged mechanical ventilation. Chest 1997;112:1592-99.

23. Kondili E, Prinianakis G, Georgopoulos D. Patient-ventilator interaction. British Journal of Anaesthesia 2003;91:106-19.

24. Vitacca M, Bianchi L, Zanotti E, Vianello A, Barbano L, Porta R *et al.* Assessment of physiologic variables and subjective comfort under different levels of pressure support ventilation. Chest 2004;126:851-59.