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PATIENT-VENTILATOR ASYNCHRONY IN A TRAUMATICALLY INJURED POPULATION

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Short Title: Asynchrony in Trauma Patients

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ABSTRACT

Introduction: Prolonged mechanical ventilation, increased length of hospital stay, and a lower rate of home discharge have been reported with patient-ventilator asynchrony in medical patients. Though commonly encountered, asynchrony is poorly defined within a traumatically injured population.

Methods: Mechanically ventilated trauma patients at an urban, level I center were enrolled. Breath waveforms were recorded over 30 minutes within the first 48 hours following intubation. Asynchronous breaths were defined as ineffective patient triggering, double triggering, short cycle breaths, and long cycle breaths. Asynchronous patients were defined as having asynchrony in ≥10% of total breaths. Demographic, injury, sedation/delirium scores, clinical and discharge outcomes were prospectively collected.

Results: 35 patients were enrolled. Median age was 47 years, 77.1% male, 28.6% with penetrating injuries, 16% with a history of COPD, median ISS of 22 (IQR 17-27), and a median chest AIS of 2 (IQR 0-6). 15,445 breaths were analyzed. Asynchrony was present in 25.7% of patients. No statistical differences between asynchronous and non-asynchronous patients were found for age, sex, injury mechanism, COPD history, delirium/sedation scores, PaO2/FiO2 ratios, PEEP, blood gas values, sedative, narcotic and haloperidol use. Asynchronous patients more commonly used synchronized intermittent mandatory ventilation (SIMV) (100% vs. 38.5%; p=0.002) and took lower median spontaneous breaths per minute (4 (IQR 3-8) vs. 12 (IQR 9-14); p=0.007). SIMV with set respiratory rates ≥10 breaths per minute were associated with increased asynchrony rates (85.7% vs. 25.0%, p=0.02). We found no difference in ventilator days, ICU and hospital lengths of stay, % discharged home, or mortality between asynchronous and non-asynchronous patients.

Conclusions: Ventilator asynchrony is common in trauma patients. It may be associated with SIMV with a set respiratory rate ≥10 breaths per minute, though not with increased duration of mechanical ventilation, length of stay, or discharge disposition.

Key Words: Mechanical ventilation, asynchrony, trauma, critical care

INTRODUCTION

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Patient-ventilator asynchrony is a common occurrence in critically ill intensive care unit (ICU) patients. Asynchrony can be defined as a mismatch between the patient's ventilator needs and the ventilator settings and operating characteristics (1-5). Studies have shown that asynchrony may be associated with a longer duration of mechanical ventilation, due to ineffective weaning, resulting in increased ICU and hospital length of stay and poor outcomes (1,6).

Asynchrony has been evaluated in a number of studies utilizing review of the pressure, volume and flow waveforms from the mechanical ventilator (1-5). This technique has limitations which include the ability to visualize the waveforms on a variety of different ventilators with different display resolutions, reliance on the internal measurement systems of the ventilator, and lack of traditional esophageal pressure monitoring. Nonetheless, previous work has demonstrated the validity of ventilator waveforms evaluation compared to esophageal pressure monitoring for the detection of missed triggers and asynchrony (1). Additionally, these waveforms are commonly utilized by the clinical staff to both detect and alleviate asynchrony at the bedside of patients experiencing respiratory distress.

Traumatically injured patients differ greatly from previously investigated populations by virtue of lower ages with resultant decreased comorbities; nonetheless, bedside clinicians encounter asynchrony. To date, there have been no prospective studies of asynchrony in trauma patients thus the application of previous conclusions made in medical patients appear to be speculative. We conducted a prospective study to determine the frequency and characteristics of asynchrony in a traumatically injured patient population. We hypothesize that asynchrony is present in trauma patients though the characteristics and implications upon outcomes are different than the published data in populations of medically ill patients.

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METHODS

Patient Population

All traumatically injured patients in the surgical intensive care unit (ICU) of the University Hospital that had spontaneous respiratory efforts within 48-hours of initiation of mechanical ventilation were eligible for study inclusion. The University Hospital of the University of Cincinnati is an adult American College of Surgeons-verified Level I trauma center that serves 1.8 million people in southwestern Ohio, northern Kentucky and southeastern Indiana. The hospital is a 693-bed facility with over 100 critical care beds, 34 of which are dedicated to injured and critically ill surgical patients. Exclusion criteria for study participation were age < 18 years old, patients without spontaneous respirations due to injury, sedation, or chemical paralysis, patients with air leaks in the ventilator circuit such to preclude accurate data collection of pressure-time, flow-time and tidal volume-time waveforms, and use of a ventilator other than the Draeger Evita XL (Draeger Medical, Telford, PA). The presence or absence of asynchrony was not a criterion for study inclusion. Ventilator-patient waveforms were not collected before study participation. The Institutional Review Board of the University of Cincinnati approved the study with informed consent obtained from the patients legally authorized representative. This study was registered with ClinicalTrials.gov with an identifier of NCT01049958.

Data Acquisition

Real time pressure, flow, and volume waveforms generated by the patient were acquired and recorded over 30 minutes by a laptop computer connected to the RS 232 output port of the

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ventilator for those patients that met inclusion criteria. Recordings were done once per patient during the first 48-hours of ventilator initiation with none of the patients having a tracheostomy. Ventilator settings were determined by the clinicians caring for the patient and were not manipulated during the recording period. Respiratory therapists provided usual care during the period of recording with all patients having a heat moisture exchanger (HME). Recordings were performed by study personal during periods in which healthcare delivery did not preclude investigation. Waveforms were analyzed at a later date utilizing Vent View software (Vent View, Draeger Medical, Telford, PA).

Asynchrony Criteria

Asynchronous breaths included ineffective triggered breaths, double-triggered breaths, as well as short cycle breaths and prolonged cycle breaths (1, 8). Ineffective triggering was defined as a simultaneous decrease in airway pressure and an increase in airflow without an assisted breath (a wasted patient effort) (Figure1). Double-triggered breaths occur when the ventilator inspiratory time is shorter than the patient's inspiratory time in turn causing the incomplete patient effort of the first cycle to trigger a second ventilator breath (Figure 2). Short cycle breaths were defined as a cycle in which the inspiratory time is less than half the mean set inspiratory time (Figure 3). Prolonged cycle breaths describe breaths in which the inspiratory time is more than double the mean set inspiratory time (Figure 4). A unique asynchronous breath type was identified during the study and labeled as ventilator breath stacking during synchronized intermittent mandatory ventilation (SIMV). This ventilator breath stacking was defined as breaths in which a mandatory breath was delivered during the inspiratory phase of a spontaneous breath (with or without pressure support) (Figure 5).

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Individual patient pressure, flow, and volume recorded waveforms were reviewed simultaneously by two investigators blinded to demographic and outcome data. A third investigator was utilized in circumstances of non-agreement with agreement between all evaluators necessary before classifications as an asynchronous event occurred. The total breaths, including non-asynchronous and asynchronous breaths (ineffective triggered, double-triggered, short cycle, prolonged cycle and ventilator breath stacking) were calculated for each patient. The asynchrony index (AI) was calculated by dividing the number of asynchronous breaths by the number of asynchronous and non-asynchronous breaths (Asynchrony Index = Number of Asynchronous Events /Total Number of Breaths.) Patients with an AI ≥ 10% were defined as asynchronous (1,8).

Patient Characteristics

Patient demographics including age, gender, mechanism of traumatic injury, Injury Severity Score (ISS) and individual Chest Abbreviated Injury Scores (chest AIS), smoking history and history of chronic obstructive pulmonary disease (COPD) were recorded (9). Ventilator settings and arterial blood gas values prior to the initiation of the recording period were noted. The assessment of sedation level and the presence of delirium was performed by bedside ICU nurses versed in the utilization of the Richmond Agitation and Sedation Score (RASS) and the Confusion Assessment Method in the ICU (CAM-ICU) in adherence to a previously published ICU sedation protocol (10, 11, 12). The protocolized scoring of pain by the visual analog score, sedation by the RASS and delirium by the CAM-ICU occurs on an every 8-hour basis or when a change in behavior necessitates an intervention. Predetermined bolus dosing of sedative and/or analgesic medications occurs first in response to objective score changes with an increase in hourly rates of these same mediations if bolus therapy fails. The treatment of delirium with haloperidol occurs only via bolus therapy though the frequency of therapy may increase if subjective increases in delirium are present. Propofol and fentanyl are utilized as the sedative and analgesic medications of choice within the first 72 hours after intubation. Both RASS and CAM-ICU scores were recorded immediately prior to waveform recording. The amount of fentanyl (mcg/kg), propofol (mg/kg) and haloperidol (mg) for the previous 24 hours and 1 hour prior to recording were documented.

Data Analysis

The primary outcome was determined to be the number of ventilator days utilized between patients with AI ≥ 10% vs. those with AI <10%. Secondary outcomes of ICU length of stay (LOS), hospital LOS, proportion of patients discharged home, and mortality were analyzed between the AI groups.

Continuous data (non-normally distributed) were summarized using medians [interquartile ranges], while categorical data were summarized using frequencies and percents. Continuous data were compared between groups using Wilcoxon rank-sum tests. Categorical data were compared using exact x^2 chi-square tests. All tests were two-sided and $p \leq 0.05$ were considered statistically significance. Analysis was carried out using SAS 9.2 (SAS Institute, Inc., Carey, NC).

RESULTS

A total of 70 trauma patients were screened with 35 being ineligible (20 without spontaneous respirations, 12 in which consent could not be obtained and 3 refused participation)

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and 35 enrolled in the study (Figure 6). Patients were studied for 30 minutes each yielding a total of 15,445 breath waveforms for analysis. None of the patients enrolled experienced hemodynamic instability or required inotropic and/or vasopressor pharmacotherapy during waveform collection. Twenty-six patients (74.3%) had an AI < 10%, and 9 (25.7%) had an AI ≥ 10%. Demographics of the two cohorts are presented in Table 1. No statistical difference was seen in median age, ISS, and chest AIS. There was no difference in the proportion of male patients, the rate of penetrating injuries, history of smoking or COPD between the groups. Arterial blood gas analyses between the cohorts lacked a difference in regards to pH, PaO_2/FIO_2 ratios, $PaCO_2$, and bicarbonate levels at the commencement of waveform analysis (Table 1).

When ventilator characteristics were analyzed, patients with an AI ≥ 10% had a statistically greater proportion of synchronized intermittent mandatory ventilation (volume control) with pressure support ventilation (SIMV + PSV) use (100% vs. 38.5%, $p = 0.0015$) with a resultant higher median set rate of ventilator breaths per minute (12 [8, 14] vs. 0 [0, 6], $p < 0.0001$) and lower median rate of spontaneous breaths per minute (4 [3, 8] vs. 12 [9, 14], $p = 0.02$; Table 2). SIMV + PSV with a set respiratory rate of ≥ 10 breaths per minute was significantly more prevalent in the AI ≥ 10% cohort (85.7% vs. 14.3%, $p = 0.02$).

The sedation levels, delirium rates, analgesic, sedative and haloperidol use were evaluated between the cohorts. The proportion of patients with a RASS between +1 to -1 and rate of positive CAM-ICU evaluations at the time of waveform collection was similar between those with < 10% AI and ≥ 10% AI (Table 2). No difference was found between the groups for the use of propofol (mg/kg), fentanyl (mcg/kg), and haloperidol (mg) in the previous hour and 24 hours before waveform recordings were performed. No haloperidol was provided to any patient up to one hour immediately prior to recording.

Breath characteristics were analyzed for both AI cohorts (Table 3). The ≥ 10% AI cohort had 10,896 total breaths of which 1,184 were asynchronous while the < 10% AI group had a total of 4,549 breaths, 235 were asynchronous. A statistically different pattern of asynchronous types were seen between the groups ($p < 0.01$) with the ≥ 10% AI cohort having more prolonged cycle breaths (54.7% vs. 11.5%) and less ventilator breath stacking (26.2% vs. 54.9%) compared to those without group asynchrony. Since ventilator breath stacking was not among previously described asynchrony breath types, secondary statistical analysis was performed excluding these breath types. With this breath exclusion, the proportion of asynchrony within the cohort did not significantly differ.

Patients with an AI ≥ 10% failed to demonstrate a significant outcome difference (Table 4). Ventilator days, ICU LOS, hospital LOS, the proportion of patients discharged home and mortality were similar between the cohorts. The inclusion of long cycle and short cycle breaths as an asynchronous subtype may have altered outcome interpretation therefore secondary analyses were performed removing these episodes. Without the inclusion of these breaths, 29 patients were found to have < 10% AI and 6 patients had ≥ 10% AI. Demographic and arterial blood gas data were not statistically different between the AI groups. Ventilator settings and proportion of those with SIMV with a ventilator rate ≥ 10 was not different between AI types though the patients' respiratory rate became non-significant. The amount of fentanyl and propofol, RASS and CAM-ICU scores were not statistically different as well. The proportion of asynchronous breath types were statistically different ($p < 0.001$) between those with < 10% and ≥ 10% AI. Ventilator breath stacking was the majority of the asynchronous breaths in the < 10%

cohort (59.7%) while missed/ineffective trigger breaths made up the majority in those with ≥ 10% AI (43.8%). There was no statistically significant outcome difference demonstrated in regards to ventilator days, ICU LOS, hospital LOS, proportion discharged home and mortality seen between AI groups when long cycle and short cycle asynchronies were removed.

DISCUSSION

In this study, we investigated the complex interaction of mechanical ventilation with a traumatically injured population so to clarify the presence, etiology and outcomes from patient-ventilator asynchrony. We demonstrated that approximately a quarter of traumatically injured patients exhibit ventilator asynchrony (AI ≥ 10%) and that these patients have an associated greater utilization of SIMV + PSV with a set rate ≥ 10 breaths per minute. Unique to this work is the finding of ventilator breath stacking, a mandatory breath delivered during the inspiratory phase of a spontaneous breath, as an additional asynchronous breath type. Nonetheless, the presence of asynchrony was not associated with prolonged mechanical ventilation, ICU LOS, hospital LOS, or mortality in this population. It is noteworthy that while ineffective triggers are the most commonly identified asynchrony in medical patients, missed triggers were relatively uncommon in our study. This is likely due to the presence of chronic lung disease and air-trapping in prior studies which complicate triggering in the medical patient. In a number of our patients, intrinsic positive end expiratory pressure (PEEPi) was present, but in the absence of dynamic hyperinflation and respiratory muscle dysfunction, did not result in missed triggers.

Patient-ventilator asynchrony is a common problem encountered in critical care platforms and is associated with poor outcomes. Chao et al. demonstrated in 174 chronically

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ventilator dependent patients that those with ineffective triggered breaths required a longer duration of mechanical ventilation (70 vs. 33 days) and lower rate of eventual liberation (16% vs. 57%) (6). Further work by Thille et al. reaffirmed an association of prolonged mechanical ventilation with an AI ≥ 10% (median duration 25 vs. 9 days) as well as describing a higher rate of tracheostomy (33% vs. 4%) (1). However, Chao et al analysis was performed in older critically ill medical populations (69-75 years old) with 45% having the diagnosis of COPD while the work of Thille et al was performed in ICU patients with a quarter having COPD. Ineffective triggering/missed triggering breaths are the most common (85-88%) asynchronous breaths recorded in previous medical studies (1,8). These breaths are associated with PEEPi resulting from large tidal volumes and the continuation of mechanical inspiration during patient defined expiration (3,4,13). Patients with COPD have a higher rate of ineffective triggering as pressure support levels increase because higher patient generated pressures are required to overcome the PEEPi associated with hyperinflation and shortened expiratory time (3,6,7,14,15,16).

Little is known about patient-ventilator asynchrony in a traumatically injured patient population. In comparison to a medically ill population, our study trauma population is younger (median 47 years) with a resultant decreased rate of COPD (16.1%). Even with these inherent differences, the proportion of asynchronous patients (25.7%) is comparable to previous studies even in the presence of light sedation goals with delirium monitoring and treatment (1,8). Our patient population exhibited unique proportions of asynchrony breath types. With a decreased rate of COPD in this population, ineffective triggering occurred infrequently (10.1%) as a proportion of asynchronous breaths while prolonged cycle breaths (54.7%) were the most common asynchronous breath type in those with ≥ 10% AI.

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Upon further examination of the prolonged cycle breaths, we discovered that in the ≥ 10% AI group, one patient had 75% of the total of this breath type. Additionally, this patient had the highest set ventilator rate in SIMV than any other patient in the study which is an associated risk factor for high asynchrony. In light of this finding, re-analysis of asynchronous breath type proportions excluding this patient was performed. With this data excluded, the difference in prolonged cycle breaths between the low (< 10% AI) and high asynchrony groups (≥ 10% AI) was still statistically significant ($p < 0.01$) but only comprised 23.3% of the total asynchronous breaths instead of 54.7% as shown in Table 3. Nonetheless, prolonged cycle breaths are still a significant source of asynchronous breaths in the trauma patient population.

Unique to this study was the identification of what we termed ventilator breath stacking. This occurs when a mandatory breath is delivered during the inspiratory phase of a spontaneous breath. This phenomenon occurred during mandatory ventilator breaths in SIMV using the dual control feature (Auto Flow) on the Drager XL ventilator. When this feature is activated, the software measures dynamic respiratory system compliance on a breath-to-breath basis and calculates the pressure required to reach the target tidal volume on the next mandatory breath. Functionally, this mode is pressure limited but uses a feedback loop to target an inspired tidal volume. The breath type is pressure controlled with decelerating flow. By definition, the ventilator algorithm synchronizes the SIMV mandatory breaths with the patient's spontaneous breaths to eliminate stacking a mandatory breath on top of a spontaneous one, resulting in a delivered volume much larger than set. We observed that in the presence of Auto Flow, synchronization of the mandatory breath and patient effort was not always obtained. Even though the mandatory breath is delivered on top of the spontaneous breath, since the breaths are pressure limited, over-inflation might be avoided. Though the delivered tidal volume is not

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affected, this phenomenon increases inspiratory time which is often longer than neural inspiratory time of spontaneous breaths and may result in asynchrony.

Our study has several limitations. Though the use of ventilator waveforms have been previously validated, this study did not utilize esophageal pressure monitoring for the determination of triggering events. As such, an inherent lack of sensitivity for detection may exist. Even with a predetermined window (first 48 hours after intubation) for waveform recording performed over 30 minutes, periods of asynchrony could be missed thus underestimating the prevalence of this phenomenon in our population. Furthermore, recordings were occurred during daytime hours and thus might have omitted asynchronous periods that occurred during the night when interruptions in sleep by normal ICU care may account for periods of agitation and/or delirium. Though not statistically significant, a trend towards RASS scores outside of -1 to +1 was associated with those with a higher asynchrony index. The smaller sample size of this study may have contributed to false conclusions in regards to sedation differences between the groups. We used the Drager XL ventilator exclusively for this study due to its compatibility with the recording software. We assume that other ICU ventilators would produce similar patient-ventilator interactions using the same modes. Finally, this study was conducted in a single institution with 35 trauma patients using various modes of mechanical ventilation. Our study may not have the power to find an outcome difference between the two groups, therefore a larger cohort of trauma patients with uniformity in regards to mechanical ventilation mode over multiple institutions may support alternative findings. Future work may focus on a larger population of trauma patients compared both internally and externally to both surgical and non-surgical cohorts.

CONCLUSIONS

In this current work, patient-ventilator asynchrony is common in mechanically ventilated traumatically injured patients. However, associations between groups with high asynchrony and negative outcomes including ventilator days, ICU and hospital LOS, and mortality could not be made. The most common ventilator mode associated with high asynchrony in our patient population was SIMV with set respiratory rate ≥ 10 bpm. While ineffective efforts have represented as much as 85% of asynchronous breaths in medical patients, this was not observed in this cohort of surgical patients. Careful matching of the appropriate ventilator mode(s) and settings to the patient's ventilatory needs may help minimize asynchrony and improve patient comfort.

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FIGURE LEGENDS

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Figure 1. Missed/ineffective trigger characterized by a decrease in airway pressure and an increase in airflow without an assisted breath. Ventilator settings were PSV Δ 10 cm H_2O over 5 cm H_2O PEEP.

Figure 2. Double triggering is the result of the ventilator inspiratory time being shorter than the patient's inspiratory time causing the incomplete patient effort of the first cycle to trigger a second ventilator breath. Ventilator settings were SIMV + PSV Δ 10 cm H_2O over 5 cm H_2O PEEP, with a set respiratory rate of 12 breaths/min. Mandatory breaths are adaptive pressure breaths (autoflow).

Figure 3. Short cycle breaths have an inspiratory time that is less than half the mean inspiratory time. Ventilator settings were PSV Δ 10 cm H_2O over 5 cm H_2O PEEP.

Figure 4. Prolonged cycle breaths occur when the ventilator's inspiratory time is more than double the patient's inspiratory time. Ventilator settings were PSV Δ 10 cm H_2O over 5 cm H_2O PEEP.

Figure 5. Ventilator breath stacking occurs when a mandatory breath was delivered during the inspiratory phase of a spontaneous breath. Ventilator settings were SIMV + PSV (with autoflow) Δ 10 cm H_2O over 5 cm H_2O PEEP with a set respiratory rate of 12 breaths/min. Mandatory breaths are adaptive pressure breaths (autoflow).

Figure 6. Flow diagram of the enrollment process.

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	< 10% AI (n = 26)	**≥ 10% AI (n = 9)**	**p-Value**
Demographics			
Age	45 (33, 59)	48 (40, 58)	0.79
Male	80.8%	66.7%	0.39
Penetrating Injury	30.8%	22.2%	0.62
ISS	21 (17, 29)	22 (21, 25)	0.82
Chest AIS	2.5 (0, 8)	2 (0, 3)	0.63
History of Smoking	43.5%	16.7%	0.23
History of COPD	16.7%	14.3%	0.88
Arterial Blood Gas			
pH	7.38 (7.35, 7.42)	7.41 (7.32, 7.44)	0.97
PaO2/FiO2 Ratio	283 (254, 350)	395 (200, 468)	0.57
PaCO2	43 (38, 47)	38 (35, 43)	0.14
Bicarbonate	25 (22, 27)	23 (23, 26)	0.34

Table 1. Demographics and Arterial Blood Gas on Evaluation

All values medians (interquartile ranges) unless otherwise specified, $p < 0.05$ considered significant
AI, asynchrony index; ISS, Injury Severity Scale; AIS, Abbreviated Injury Scale; COPD, Chronic Obstructive Pulmonary Disease

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	< 10% AI (n = 26)	≥ 10%AI (n=9)	p-Value
Ventilator			
SIMV + PSV	38.5%	100%	0.0015
Tidal Volume (mL)	600 (550, 600)	550 (550, 600)	0.63
Inspiratory Time (sec)	1.15 (0.9, 1.25)	1.2 (0.9, 1.2)	0.86
PIP (cm H_2O)	22 (16.5, 25)	19 (17, 26)	0.94
Pressure Support (cm H_2O)	10 (10, 10)	10 (10, 10)	0.48
PEEP (cm H_2O)	5 (5, 8)	5 (5, 5)	0.46
Ventilator Rate (BPM)	0 (0, 6)	12 (8, 14)	< 0.0001
Patient Rate (BPM)	12 (9, 14)	4 (3, 8)	0.007
SIMV with Vent Rate ≥ 10 (BPM)	14.3%	85.7%	0.02
Sedation/Delirium			
Fentanyl previous hour (mcg/kg)	1.01 (0.45, 1.35)	1.00 (0, 1.25)	0.51
Fentanyl previous 24 hours (mcg/kg)	13.8 (6.8, 29.7)	16.0 (2.9, 21.2)	0.61
Propofol previous hour (mg/kg)	1.35 (0, 2.4)	0.30 (0, 1.5)	0.29
Propofol previous 24 hours (mg/kg)	20.5 (5.2, 41.6)	10.6 (9.5, 20.9)	0.35
RASS of +1 to -1	61.5%	33.3%	0.31
CAM-ICU Positive	33.3%	40.0%	0.78

Table 2. Ventilator Settings, Sedation and Rate of Delirium on Evaluation

All values medians (inter-quartile ranges) unless otherwise specified, $p < 0.05$ considered significant
AI, asynchrony index; SIMV, synchronized intermittent mandatory ventilation; PSV, pressure support ventilation; PIP, peak inspiratory pressure
BPM, breaths per minute; RASS, Richmond Agitation Sedation Scale; CAM-ICU, Confusion Assessment Method for the ICU

	< 10% AI n = 26	≥ 10% AI (n = 9)	p-Value
Total Number of Breaths	4549	10,896	
Total Number of Asynchronous Breaths	235	1,184	
Asynchronous Breath Type			< 0.01
Missed/Ineffective Trigger	32 (13.6%)	120 (10.1%)	
Double Trigger	41 (17.4%)	107 (9.0%)	
Short Cycle	6 (2.6%)	0 (0.0%)	
Long Cycle	27 (11.5%)	647 (54.7%)	
Ventilator Breath Stacking	129 (54.9%)	310 (26.2%)	

Table 3. Proportion of asynchronous breath types by AI cohorts

$p < 0.05$ considered significant
AI = asynchrony index

Outcomes			
Ventilator Days	7 (3, 14)	9 (4, 22)	0.42
ICU LOS (days)	11 (6, 18)	13 (8, 26)	0.28
Hospital LOS (days)	17 (11, 24)	22 (10, 27)	0.46
Discharged Home	38.5%	11.1%	0.13
Mortality	3.9%	11.1%	0.42

Table 4. Outcomes

All values medians (inter-quartile ranges) unless otherwise specified, $p < 0.05$ considered significant
AI, asynchrony index; LOS, length of stay

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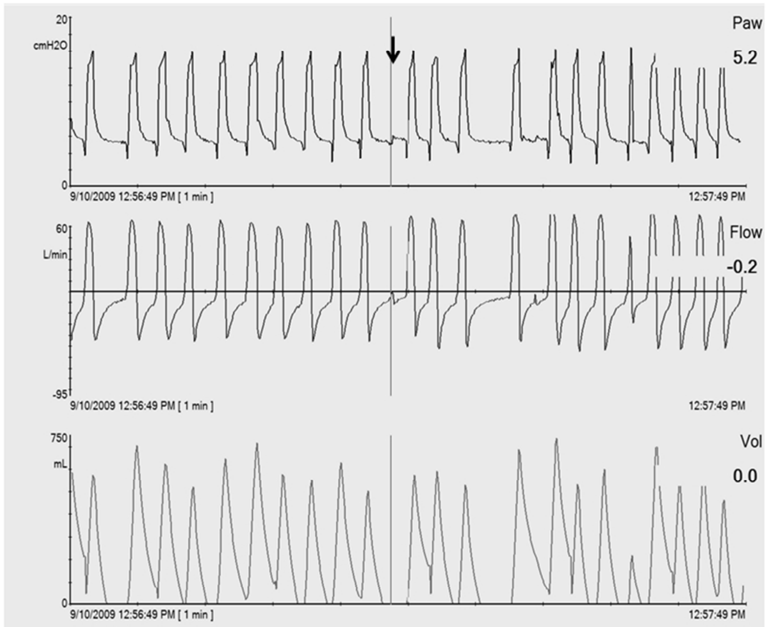

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Figure 2

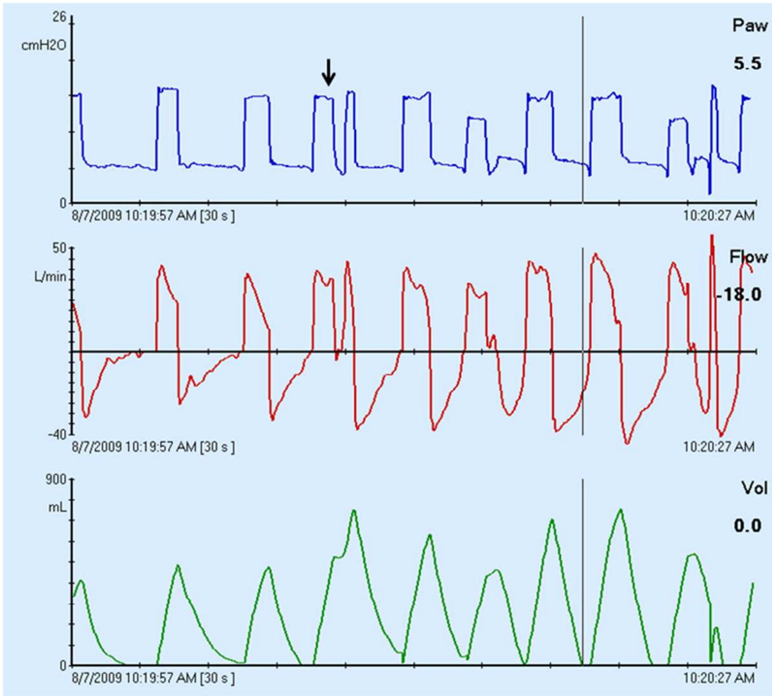

Figure 2
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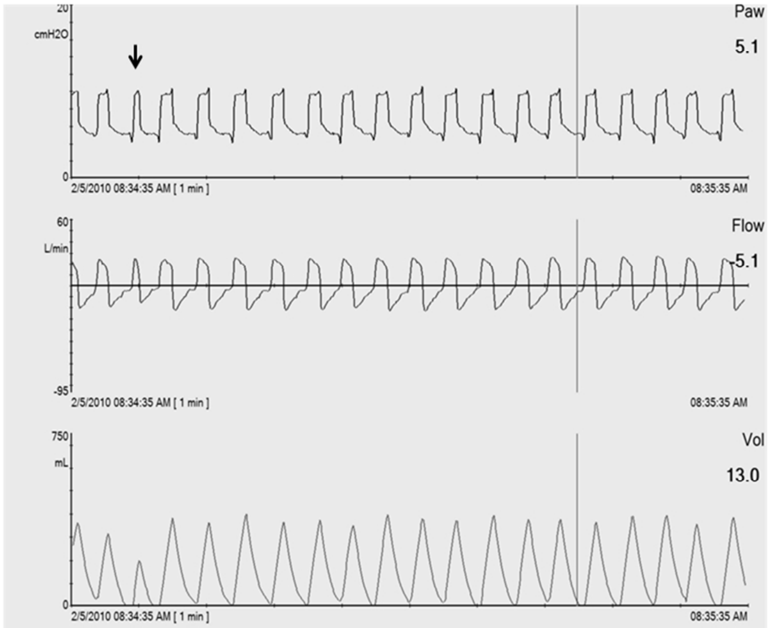

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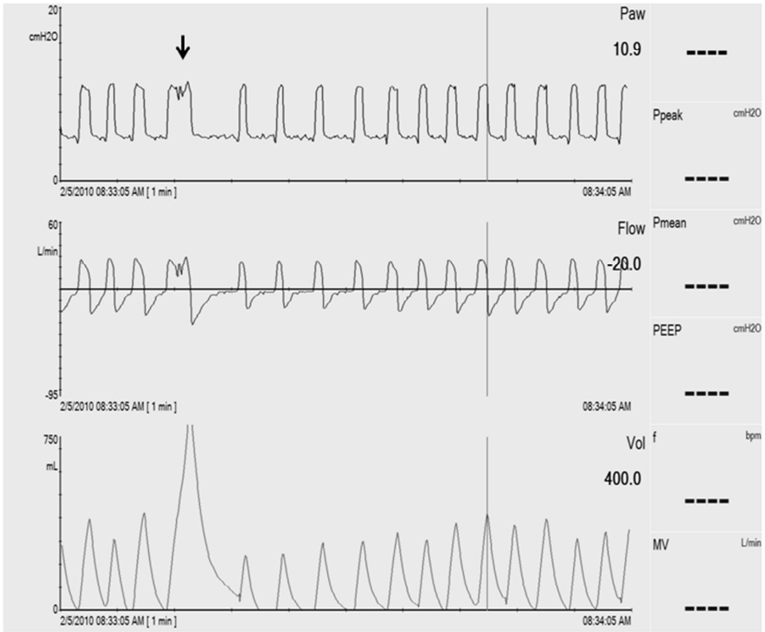

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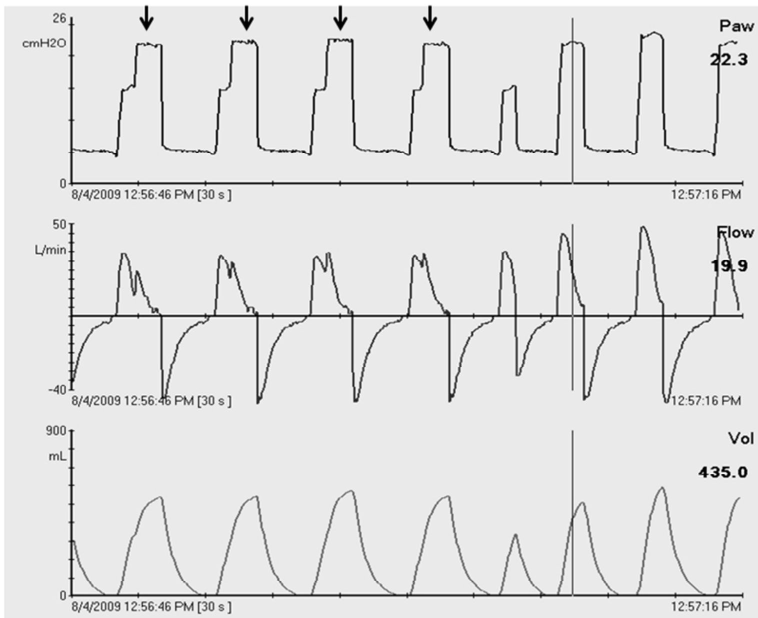

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