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Comparison of Pressure-, Flow-, and NAVA-Triggering in Pediatric and Neonatal Ventilatory Care

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Summary. Objective: To compare conventional trigger modes (pressure and flow trigger) to neurally adjusted ventilatory assist (NAVA), a novel sensing technique, and to observe the patient-ventilator interactions during these modes. Methods: In this prospective, crossover comparison study in tertiary care pediatric and neonatal intensive care unit, 18 patients (age from 30 weeks of postconceptional age to 16 years) needing mechanical ventilation were randomized. Three patients were excluded from the analysis because of problems in data collection. Patients were ventilated with three different trigger modes (pressure, flow, NAVA), for 10 min each. Patients were randomly allocated to six groups according to the order of trigger modes used. Results: The primary end point was the time in asynchrony between the patient and the ventilator. Secondary end points were peak and mean airway pressures (MAP), breathing frequency, tidal volume (TV), and vital parameters during each trigger mode. The proportion of time in asynchrony was significantly shorter in the NAVA group (8.8%) than in the pressure (33.4%) and flow (30.8%) groups ($P < 0.001$ for both). In the NAVA group, the peak inspiratory pressure was 2 to 1.9 cmH_2O lower than in the pressure and flow groups, respectively ($P < 0.05$ for both) and the breathing frequency was 10 breaths/min higher than in the pressure group ($P = 0.001$). There was a tendency toward a lower MAP ($P = 0.047$) but the mean TV was about the same (6.4–6.8 ml/kg) in all three groups ($P = 0.55$). There were no differences in oxygen saturation or vital parameters between the groups. Conclusion: NAVA offers a novel way of sensing patients' spontaneous breathing and significantly improves short-term patient-ventilator synchrony in a pediatric population. **Pediatr Pulmonol. 2012; 47:76–83.** © 2011 Wiley Periodicals, Inc.

Key words: mechanical ventilation; neurally adjusted ventilatory assist; asynchrony; diaphragm electrical activity; patient-ventilator interaction.

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INTRODUCTION

Mechanical ventilation may induce lung injury, especially when high tidal volumes (TV) are used.[1,2] Patient-ventilator asynchrony may prolong the need for mechanical ventilation and cause weaning difficulties.[3,4] Small TVs and the assistance of the patient's own breathing are considered to have a major role in preventing these problems.[1,4,5] Attempt to improve patient-ventilator synchrony is in line with this ideology.[4]

The recognition of patient's breathing has traditionally been done by sensing the changes in airway pressure or flow. In pediatric patients, the sensing and hence assisting the patients' own breathing may be technically difficult because of small TVs and a high respiratory rate. Moreover, in neonates, the ventilatory system often remains open because of an air leak from an uncuffed intubation tube making proper sensing even more difficult. When pressure or flow sensors are either over or under sensitive, support of spontaneous ventilatory modes becomes impracticable. Ventilatory modes with more controlled breaths are therefore widely used in children despite their theoretical disadvantages. As a consequence, children often adapt poorly to the ventilator and may need high

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doses of sedation.[6,7] This in turn weakens their spontaneous breathing and may prolong the need for ventilatory assist. Proper sensing of the child's own breathing could improve their ventilatory care markedly.

Neurally adjusted ventilatory assist (NAVA) is a new sensing and assisting mode independent of airway pressures and flow. NAVA technology is based on the recognition of the electrical activity of the patient's diaphragm (Edi), which is recorded via a specially modified naso/orogastric tube with a sensor and isolated from other electrical signals.[8] NAVA operates on a ''first served first'' basis with neural and pneumatic triggers, i.e. whichever appears first will be assisted. However, right of the appearance of the Edi signal it overtakes the rest of the breathing cycle. Edi can be used to determine the time and the amount of assistance given by the ventilator.[8] In addition, Edi offers a novel way to observe patients attempting to breathe, which renders analyzing patient-ventilator interactions easier.

In the current trial, our aim was to compare the conventional trigger modes (pressure and flow trigger) with assist-control ventilation to NAVA in their ability to achieve synchrony between the patient and the ventilator in a pediatric population. We used Edi as a sign of the patient's active inspiration and expiration (nerve cell excitation/relaxation before/after muscle contraction in the diaphragm) and evaluated the synchrony of ventilatory assist based on this information. We also monitored the airway pressures as well as frequencies and TVs and measured the oxygen saturation and blood gas values during the trial.

MATERIALS AND METHODS

The children were recruited from those needing mechanical ventilation from 30 weeks of postconceptional age to 16 years of age treated at the pediatric intensive care unit (PICU) or neonatal intensive care unit (NICU) at Oulu University Hospital, Finland. Children for whom the positioning of naso- or orogastric tube was not possible were excluded from the study. Critically ill patients with a severe respiratory, hemodynamic or bleeding disorder and patients needing high frequency oscillation ventilation were also excluded. All patients were studied during the weaning phase of the mechanical ventilation. The patients were recruited from February to May 2009.

Results from a study published in 2004 were used in estimating the sample size.[9] In that study, asynchrony was found to be present in $53.4 \pm 26.2\%$ of the total breath duration during every mandatory breath.[9] We considered a clinically significant decrease in the proportion of asynchrony to be 50%. With an $\alpha = 0.05$ and power of 0.8, we needed 15 children in this cross-over study. To ensure this number in the final analysis, 18 patients were recruited (Table 1).

The Ethical Committee of the North Bothnian Health care District approved the study protocol. Written informed consent was obtained from a parent or legal guardian before performing any procedures for the study. Twenty-one eligible patients were screened, but a lack of an available NAVA-ventilator meant that three of them were not randomized. One patient was extubated in the middle of recording and thus dropped out;

TABLE 1— Patient Characteristics

N	Gender	Age	Diagnosis	Earlier ventilation mode	Group	Notes
1	F	10.8 years	Post op. analgesia, mental retardation	PRVC	NPF	Drop out (extubated)
2	M	2 months	Cystic lung malformation, post op.	PC	NFP	
3	F	1 month	RSV-bronchiolitis	PC	PFN	
4	M	2.6 years	Esophagitis, post op.	PRVC	FNP	Drop out (data collection error)
5	M	13.8 years	Scoliosis, post op.	PRVC	PNF	
6	M	10 months	Pneumonia l.a.	PRVC	FPN	
7	F	3.8 years	Pneumonia Cockayne sdr,	PRVC	PNF	
8	F	9 hr	RDS Prematurity (h33 + 0),	PC	NPF	Low Edi >100 sec in both flow and pressure trigger
9	F	13.2 years	Scoliosis, post op. Spastic tetraplegy	PRVC	FPN	Low Edi >100 sec in pressure trigger
10	M	4 months	RSV-bronchiolitis	PRVC	NFP	
11	F	1 month	Facial nevus, post op.	PRVC	FNP	
12	F	3 weeks	Aortic anomaly, post op.	PRVC	PFN	
13	M	4 hr	Prematurity (h34 + 5)	PC	FPN	
14	M	9 hr	RDS Prematurity (h35 + 2),	PC	PFN	Autotriggering +5→+2
15	M	9 hr	RDS Prematurity (h30 + 1),	PC	PNF	Autotriggering +5→+1
16	M	3 months	Cranioplasty, post op. Sdr Apert	PRVC	NFP	Low Edi > 100 sec in both flow and pressure trigger
17	F	8.3 years	Acute appendicitis and peritonitis	PRVC	FNP	Drop out (data collection error)
18	M	43 hr	Neonatal sepsis	PC	NPF	Low Edi > 100 sec in flow trigger

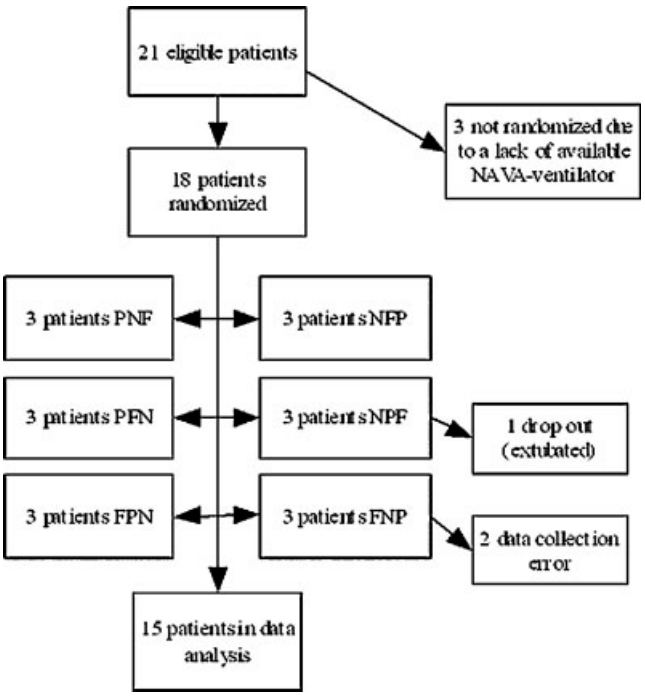

Fig 1. Study design.

i.e. seventeen patients went through the protocol. With two patients (numbers 4 and 17) there was an error in data collection, recordings not clearly indicating the time labels, and these patients were left out, leaving 15 children in the final analysis (Fig. 1).

The patients were randomly allocated into six groups according to the order of trigger modes used. Groups were NPF, NFP, PNF, PFN, FNP, FPN, N = NAVA, F = flow trigger, *P* = pressure trigger (Fig. 1). We used a crossover setting, in which each patient was ventilated by using three different trigger modes (F, P, N) for 10 min each, without wash-out periods in between. All the other ventilator settings remained the same as existed, and were selected on clinical grounds individually for each patient. Data were recorded from the ventilator with a specifically designed software program (NAVA-tracker, Maquet Nordic, Solna, Sweden). In addition, we obtained the data on blood gas values, blood pressure, heart rate, and oxygen saturation. Most parameters were monitored continuously and blood was drawn at the start, before every change in trigger mode and at the end. Sedative and pain medications were not altered during the recordings.

All patients were ventilated by Servo-i ventilator Version 4.00 (Maquet Nordic, Solna, Sweden). A nasogastric tube with rings of electrodes mounted in the wall (Edi- catheter) was inserted. In order to standardize the Edi signal, manufacturer provides six different sizes of Edi catheters. For newborns weighting 0.5–1.5 kg there are 6Fr/49 cm catheters and for those weighting 1.5–2.0 kg 6Fr/50 cm catheters. In older children the length only defines the size of the catheter: for 45–85 cm 8Fr/100 cm, 75–160 cm 12Fr/125 cm and >140 cm either 16Fr/125 cm or 8Fr/125 cm. The optimal position of the catheter was set individually by following the manufacturer's instructions. There are four pairs of electrodes in the Edi catheter and the goal is to get two pairs on each side of the diaphragm. The ventilator receives not only the Edi signal but also the ECG signal which is visualized in the ventilator screen from each of the four pairs of electrodes. When the catheter is in right position, i.e. two pairs of electrodes are above and two below the diaphragm, the voltages of the P-wave and QRS complex in the ECG signal are highest in the curve from the uppermost pair of electrodes and diminishes downwards, i.e. in the curves more distant from heart. Additionally, the program show blue color marks on those ECG curves, which detect the strongest Edi signal. These blue marks should appear in the two curves in the middle on the ventilator screen.

Data collection was started when a regular continuous Edi-signal was obtained. The trigger mode for the ventilator was changed between flow- (+5), pressure- (−2), and Edi-trigger (0.5 μV) in the order determined by randomization. These flow and pressure trigger settings are the ones routinely used in our institute and in fact, flow (+5) is the trigger level commonly preset in the ventilator by manufacturer and automatically used if not changed during the treatment. In two neonates who had an air leak from loose tubes, the flow trigger (+5) launched auto triggering with continuously increasing PEEP, and thus the recordings were done with flow triggers (+1) and (+2) (Table 1). The ventilation mode was pressure controlled (PC) or NAVA for newborns and pressure regulated volume controlled (PRVC) or NAVA for children over 3 months of age. Pressure controlled ventilation is commonly used for neonates, since volume controlled ventilation has many inaccuracies with small TVs.[10] When using PC, the peak inspiratory pressure (PIP) was adjusted to aim at 5–7 ml/kg TVs, resulting in practically similar minute ventilation as in PRVC.

The data collected with the NAVA-tracker were analyzed by using a specially designed program (graphical user interface [GUI] running in Matlab [MathWorks, Inc], Tuomo Ylinen, Finland), which illustrates pressure-, flow-, and Edi-signal curves in one picture frame (Fig. 2). During active inspiration, the Edi-signal increases as a sign of nerve cell activation (neural inspiratory time) which is then followed by muscle contraction.[9] We considered that the inspiration started when there was a rise in the Edi-signal to 0.5 μV or higher from the minimal level (Fig. 2). The Edi-signal can be detected at the level of 0.1–0.3 μV, but it is difficult to isolate it from the electrical noise from other tissues.

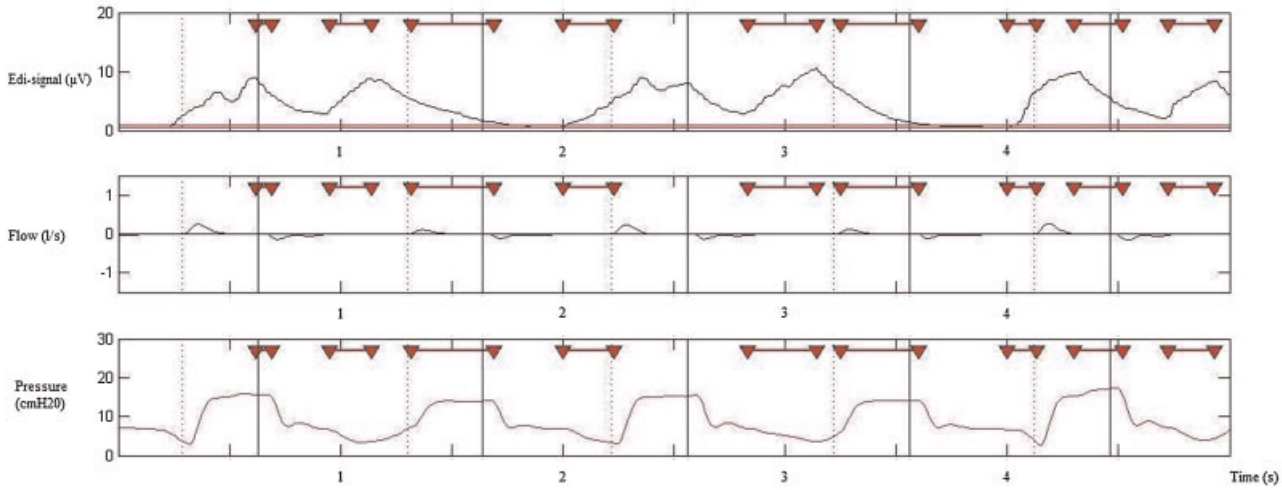

Fig 2. 5 sec clip from patient's No 15 data during pressure triggering. GUI view illustrates pressure-, flow-, and Edi-signal curves in one picture frame. During active inspiration, Edi-signal increases as a sign of nerve cell activation (Neural inspiratory time), and decreases during exhalation. The two parallel horizontal lines in the Edi-curve illustrate 0.5 μV increase. Synchrony is present, when ventilator supports patient's inspiration (increasing Edi simultaneously with high or increasing airway pressure) and is not resisting the expiration (decreasing Edi simultaneously with decreasing or absent pressure support). Asynchrony is considered to be present when the support given by ventilator is not simultaneous with Edi-signal increase. Time in asynchrony is marked in the figure by lines between the arrowheads.

Thus an Edi-level rise to 0.5 μV has commonly been used to indicate the start of inspiration.[9,11] Expiration was considered to begin at the moment when the Edi-signal started to suppress. The exact time points for trigger mode change were verified from the data collected by NAVA tracker.

The definition of synchrony required either:

1 Simultaneous Inspiration (Increasing Edi-Signal >0.5 μV) And Increasing Or Steady High Pressure Given By The Ventilator.
2 Simultaneous Expiration (Constantly Decreasing Edi-Signal From The Maximum Level) And Decreasing Pressure Support By The Ventilator.

Asynchrony was considered to be present when directions of these parameters were opposed, i.e.,

1 No pressure increase during Edi increase.
2 Pressure increase/high pressure while the Edi-signal demonstrated either a decreasing trend as during expiration or no change between the two breaths (Fig. 2).

During absence of Edi-signal asynchrony could not be measured by using this definition. Thus, when analyzing the curves, non-physiological periods of ''Edi silent time'' (defined as time exceeding five previous breaths) were left out. Absent Edi, i.e. lack of spontaneuous breathing, may be related to immaturity, oversedation, or ventilatory overassistance. Whatever is the reason for absent Edi, the role of ventilator in these occasions is to keep the patient alive. Thus, the time when ventilator is properly delivering controlled breaths during silent Edi, could be interpreted as synchrony as well. Therefore, we analyzed the data also by including this time in synchrony.

Statistical Analysis

The effect of trigger mode order and differences in variable means between trigger modes were tested by repeated measures analysis of variance. When sphericity was violated, degrees of freedom were corrected by the Greenhouse-Geisser correction. The Bonferroni adjustment was used for post hoc pairwise comparisons. Data were analyzed using the PASW Statistics 18 software.

RESULTS

The time in asynchrony in the NAVA group was 58.4/664 sec (8.8%) while in P group it was 206/619 sec (33.4%), and F group 168/537 sec (30.8%), i.e. NAVA decreased the time in asynchrony by 74 or 66%, respectively ($P < 0.001$ for both) (Table 2). This difference remained significant even when the low Edi-signal time was interpreted as synchrony ($P < 0.001$) (Table 2). By visual evaluation from the GUI-curves (Fig. 2), NAVA was more accurate in both initiation and termination of the ventilatory support for each breath cycle (data not shown).

TABLE 2— The Effect of Trigger Mode in Patient-Ventilator Interaction

	Pressure trigger	Flow trigger	NAVA	ANOVA P[1]	Pressure vs. Flow Mean difference (95% CI), P	Pressure vs. NAVA Mean difference (95% CI), P	Flow vs. NAVA Mean difference (95% CI), P
Follow-up time (sec)							
Mean	678	622	674				
Range	592–931	545–930	541–978	0.223			
Low Edi-signal[2] (sec)							
Mean	58.5	85.1	10				
Range	0–267	0–529	0–66	0.077[3]			
Low Edi-signal (%)							
Mean	8.1	12.2	1.3		−4.2 (−14–5.7)	6.7 (0.9–12.6)	10.9 (−1.6–23.5)
Range	0–29	0–57	0–8	0.036[3]	$P = 0.802$	$P = 0.023$	$P = 0.100$
SD	10.2	18.5	2.8				
Asynchrony (%)							
Mean	33.4	30.8	8.8		2.6 (−4.7–10.0)	24.6 (15.2–34.0)	22.0 (14.9–29.0)
Range	10–57	16–48	4–15	<0.001	$P = 1.000$	$P < 0.001$	$P < 0.001$
SD	12.6	8.2	3.3				
Asynchrony (%) (Low Edi interpreted as synchrony)							
Mean	31.4	27.5	8.7		3.8 (−4.2–11.8)	22.7 (12.7–32.6)	18.9 (10.3–27.4)
Range	7–57	8–48	4–15	<0.001	$P = 0.644$	$P = 0.000$	$P = 0.000$
SD	13.6	8.2	3.2				
Edi min (μV)							
Mean	0.03	0.03	0.04				
Range	0–0.20	0–0.22	0–0.22	0.660[3]			
Edi max (μV)							
Mean	22.8	22.0	28.8				
Range	2.4–51.9	4.0–53.2	3.1–79.6	0.139			
Peak inspiratory pressure (cmH_2O)							
Mean	14.5	14.4	12.5		0.1 (−0.8–1.0)	2.0 (0.02–3.99)	1.9 (0.01–3.76)
Range	8–26	9–26	9–20	0.012[3]	$P = 1.000$	$P = 0.048$	$P = 0.049$
SD	4.4	4.2	3.5				
Mean airway pressure (cmH_2O)							
Mean	8.4	8.7	7.7		−0.3 (−1.2–0.7)	0.7 (−0.4–1.8)	0.9 (0–1.9)
Range	6–12	6–11	6–11	0.047	$P = 1.000$	$P = 0.379$	$P = 0.051$
SD	1.7	1.4	1.7				
Positive end- expiratory pressure (cmH_2O)							
Mean	5.2	5.8	5.5				
Range	4–11	4–12	3–10	0.055			
Tidal volume (ml/kg)							
Mean	6.8	6.4	6.4				
Range	4.6–11.0	4.4–11.4	2.7–13.1	0.550[3]			
Frequency (/min)							
Mean	34.8	39.5	44.5		−4.8 (−9.8–0.3)	−9.7 (−15.6–−3.8)	−4.9 (−12.6–2.7)
Range	17–62	18–78	21–77	0.001	$P = 0.068$	$P = 0.001$	$P = 0.311$
SD	11.8	16.6	17.8				
pH							
Mean	7.4	7.4	7.4				
Range	7.27–7.43	7.26–7.43	7.23–7.44	0.213[3]			
CO_2 (kPa)							
Mean	5.4	5.4	5.5				
Range	4.2–6.9	3.9–7.8	4.0–7.0	0.693[3]			
O_2 (kPa)							
Mean	10.5	11.0	10.2				
Range	6.2–15.3	6.5–15.0	6.4–13.7	0.167[3]			
SaO_2 (%)							
Mean	96.7	97.1	96.9				
Range	90–100	88–100	90–100	0.518[3]			

[1]Repeated measures analysis of variance.
[2]Electrical activity of diaphragm (Edi).
[3]Greenhouse-Geisser corrected.

In the NAVA group, the PIP was 2.0 to 1.9 cmH_2O lower than the in the P and F groups, respectively ($P < 0.05$ for both) and the breathing frequency was 10 breaths/min higher than in the P group ($P = 0.001$) (Table 2). There was a tendency toward a lower mean airway pressure (MAP) in the NAVA group than in the other two groups ($P = 0.047$), but the mean TV was about the same (6.4–6.8 ml/kg) in all three groups ($P = 0.55$) (Table 2).

Proportion of time with absent Edi was lower in NAVA group (1.3%), than in P (8.1%), and F groups (12.2%), respectively, the difference being statistically significant between the NAVA and P groups ($P = 0.023$) but not between the NAVA and F groups ($P = 0.10$) (Table 2). Four (21%) patients altogether had long periods (over 100 sec/600 sec) without an Edi-signal, one in P, one in F, and two both in the P and F groups compared to none in NAVA group (Table 1). In two patients (9 and 16), the low Edi was associated with deep sedation in the postoperative period, and in the other two newborn infants (8 and 18) with probable over-assistance followed by the start of controlled ventilation leading to hyperventilation (aBCO_2 4.10 kPa) in patient 8 (Table 1).

The mean oxygen saturation, arterial pH, pCO_2, and pO_2 levels were similar in each group (Table 2) and there were no adverse events during the study.

DISCUSSION

NAVA significantly improved short-term patient-ventilator synchrony. The decrease in time in asynchrony was 74 to 66% compared to traditional pediatric triggering and ventilation modes. The advantage of this mode was seen both in more accurate triggering of assist at inspiration and more precise termination of assist during exhalation. NAVA resulted in lower PIP and a higher ventilation rate, but TVs and vital parameters remained the same. Our findings are in line with animal and human studies in which NAVA has improved synchrony and lowered airway pressures in comparison to traditional ventilation.[11–14] A recent study in children compared NAVA with pressure support ventilation with pneumatic trigger, finding similarly that NAVA was associated with improved synchrony and lower PIP.[15] In their study Breatnach et al. compared pneumatic trigger to neural triggering during NAVA mode, using information of proportion of breaths triggered and cycled off by neural trigger versus pneumatic trigger.[15] They concluded that delivery of faster triggering and cycling off resulted in superior synchrony.[15] In the current study we analyzed the synchronization of respiratory cycle in more details including not only the active breaths but also the time between the breaths. In the study of Breatnach et al. all patients were treated and followed first with PSV and then with NAVA and no randomization or cross-back phase was used.[15] Pneumatic trigger -1cmH_2O was used compared to our two different pneumatic trigger levels.[15] Despite of these methodological differences both studies emphasize the positive effect of neural triggering on synchrony when compared to traditional pneumatic triggering.

Inappropriate sensing and triggering reduces the applicability of traditional supportive ventilation modes in children. The problems in pressure and flow triggering are particularly apparent when TVs are small — sometimes only a few milliliters. Since it is technically challenging to detect such small airflows and pressures properly, especially when breathing frequencies are high; controlled modes are widely used on children despite their theoretical disadvantages. In the current study, we chose two commonly used assist-control ventilation modes, PC and PRVC, with pressure and flow trigger levels recommended for children. Not surprisingly, the asynchronous time was very high with both techniques, the child and the ventilator not coinciding approximately one-third of the time. In the study by Beck et al. [9], this proportion was even higher (53%), but they studied synchrony only during mandatory breaths.

Edi-signal is a novel way of supporting and monitoring the patient's own breathing. In NAVA technology, Edi guides both the timing of the ventilatory assist and the amount of gas given; i.e., the patient may choose whether to have a deep or a shallow breath. With any ventilatory mode, the Edi-signal can be used as a monitoring tool. By monitoring Edi during traditional ventilation we observed several hazardous or possibly detrimental episodes which were not easily identified by other ventilatory parameters or clinical signs: First, there was a marked latency after diaphragm contraction before any flow or pressure change was detected and supported both in pressure and flow triggered PC and PRVC modes. Secondly, in two neonates in PC with flow trigger who had an air leak from loose tubes, the leak launched auto triggering without any signs of active breathing in the Edi curve. Thirdly, we observed the traditional pediatric ventilation modes being constantly associated with impaired spontaneous breathing drive. During the pressure and volume triggered assist-control modes 8.1–12.2% of time spent in ventilator there were no signs of spontaneous breathing compared to 1.3% of time during the NAVA. Our results suggest that especially pressure triggered ventilation in newborns may be harmful to spontaneous breathing either being too laborious or the assistance coming too late. These problems in traditional sensing and assisting techniques will evidently lead to increased need of controlled ventilation and sedation.

There are still some limitations in the NAVA technology, most of which derive from the Edi-signal

processing. In order to isolate the Edi from the electrical noise in the area, most importantly the ECG, signals must be filtered. Since other signals sometimes conceal Edi, it cannot always be reliably detected even when the patients have actually started to breathe and the flow or pressure trigger start to override. On these occasions, the Edi-signal appears only after the ventilatory support has been launched, but even then, when detected properly, it overtakes the control of the support. The Edi level of 0.5 μV used in the current study has frequently been recommended as the trigger level but it may be set individually. The other technical compromise causing asynchrony in NAVA is the preset level for the termination of the pressure support. The Servo-i with NAVA has been set to terminate the support when Edi has decreased to 70% of its highest peak, inducing a small proportion of asynchrony into every breathing cycle. Allowance for individual setting of termination could improve the synchrony even more. In the light of these limitations, the measured proportion of time in asynchrony with NAVA in this study (8.8%) was acceptable and comparable to that found in adults (7%).[12]

There were some limitations in our study. First, our study population was small and the follow-up short. The applicability of our results is thus limited and we cannot draw any long-term conclusions. Secondly, we wanted to compare a current sensing and ventilatory practice to the NAVA technique. We ended up comparing two assist-control ventilation modes (PC and PRVC) with fixed inspiratory time to NAVA which is an assisting mode and inspiratory time differ from breath to breath. This methodological difference between assisting and assist-control ventilation may explain some of the findings. Still we clearly demonstrated the superiority of Edi-signal based sensing to pressure or flow based sensing. We thus believe that our results are applicable to any type of ventilatory assist using the same sensing techniques. This interpretation was supported by a recent study comparing the NAVA to pressure support with a pressure trigger yielding similar results.[15] Thirdly, the value of Edi increase of 0.5 μV chosen for launching pressure support in the NAVA group was the same as the definition of the start of inspiration in our study. This favors NAVA in comparison to other modes. This definition, however, is the best available and much more precise than any earlier pressure or flow based measure and should thus be used. In fact, there are no such definitions of synchrony that do not rely on the sensing techniques somehow.[15] Fourth, a wash-out period would have been needed to avoid any carry-over effect from previous ventilatory modes. However, there is no ventilatory mode, which would have neutral effect on spontaneous breathing drive and thus a real wash-out cannot be expected during invasive ventilation. In addition, these neonatal and pediatric patients were in a weaning phase of their ventilatory care and the time expected to extubation was only an hour or less. Thus we considered prolongation of ventilation and sedation merely for research purposes unethical. By using randomization for the order of trigger mode we wanted to diminish carry-over effect but, as the sample size was small, some effect may remain. For example, we frequently saw a decrease in Edi-signal immediately after the change from NAVA to PC or PRVC. This is logical, since asynchronous support for any reason decreases the patients' instinct drive to breathe.[9]

In conclusion, asynchrony was less often observed when neurally adjusted ventilator assist was used when compared to pressure and/or flow triggered assist-control ventilation. In addition, NAVA resulted in slightly lower airway pressures while delivering equal TVs. Whether this is of clinical importance needs further research.

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