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Preference of neuromuscular patients regarding equipment for daytime mouthpiece ventilation: a randomized cross-over study

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Michel Toussaint: designed research/study, performed and coordinated the research/study, collected the data, wrote the paper

Michelle Chatwin: co-designed the study, improved the English wording, co-wrote the initial paper and revisions

Stijn Verhulst: co-designed research/study, supervised the research/study especially regarding the methods

Gregory Reychler: analyzed the data, performed the statistics, co-wrote the tables with Michel Toussaint

Disclosure Statement

The following material was provided by Philips Respironics for the duration of the study: 3 Trilogy100; 20 tubing for mouthpiece ventilation; 10 arm support for mouthpiece. Philips Respironics did not play a role in the design nor in the data analysis in the present study. They did not read the text and did not ask to make changes.

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ABSTRACT

BACKGROUND:

Patients with neuromuscular disorders (NMDs) are likely to develop respiratory failure which requires noninvasive ventilation (NIV). Ventilation via a mouthpiece (MPV) is an option to offer daytime NIV.

OBJECTIVES:

To determine the preferred equipment for MPV by patients with NMDs.

METHODS:

Two MPV equipment sets were compared in 20 patients with NMDs. Set 1, consisted of a non-dedicated ventilator for MPV (PB560, Covidien) with a plastic angled mouthpiece. Set 2, consisted of a dedicated MPV ventilator (Trilogy 100, Philips

Respironics) without back-up rate and kiss trigger combined with a silicone straw mouthpiece. The Borg dyspnea score, ventilator free time, transcutaneous oxygen saturation (SpO2) and carbon dioxide tension ($TcCO_2$) were recorded with and without MPV. Patient perception was assessed by a 17-items list.

RESULTS:

$TcCO_2$ measurements and total perception score were not different between the two MPV sets. Dyspnea score was lower with the non-dedicated versus dedicated equipment, 1 (0.5) vs 3 (1-6), $p<0.01$. All patients with a ventilator free time lower than 6 hours preferred a set backup rate rather than a kiss trigger. Sixty five percent of patients preferred the commercial arm support and 55% preferred the plastic angled mouthpiece.

CONCLUSIONS:

Dedicated and non-dedicated MPV equipment are deemed effective and comfortable. Individualization of arm support and mouthpiece is advised to ensure success of MPV. A ventilator free time lower than 6 hours seems to be a useful indicator to *a priori* set a back-up rate rather than a rate at zero associated to the kiss trigger.

Keywords: noninvasive ventilation, mouthpiece ventilation, daytime ventilation, neuromuscular disorder, MPV

INTRODUCTION

Patients affected by neuromuscular disorders (NMDs) are characterized by variable muscle weakness depending on the severity and speed of disease progression. Weak respiratory muscles eventually lead initially to hypoventilation during sleep (1). At this stage, nocturnal noninvasive ventilation (NIV) is offered. NIV effectively reverses the nocturnal hypoventilation (2). However, respiratory muscle strength decreases with disease progression and subsequently diurnal ventilatory support is required (3). Despite effective nocturnal NIV around 3-5% of patients with NMDs will need daytime ventilatory support (4). With general improvements in the care of NMD's, patients live longer and the proportion of patients using mouthpiece ventilation (MPV) is expected to increase.

The choice of material for daytime ventilation are unclear, published reports recommend using noninvasive interfaces in those "ventilator dependent" patients requiring 24/7 NIV support (5-9). An elegant and promising option consists in alternating noninvasive interfaces such as nasal or full-face masks at night, and nasal mask and or mouthpiece during daytime activities according to patient preference.

The popularity of MPV for daytime use has increased over the 10 past years (10). Individualized combination of devices and accessories for patients is suggested for the successfully application of MPV (10). MPV can be used as an alternative to tracheostomy and is associated with a reduction of respiratory complications (11). In patient using 24/7 NIV in France, 90% are using a mouthpiece as an interface in the day (12). Ventilators with a dedicated MPV mode, software and accessories have been developed by manufactures to improve access for patients to MPV (13). The advantage of these ventilators with regard to efficacy and patient preference remains unclear. Patient preference regarding the material for NIV is deemed as essential to ensure its success (14).

We compared two sets of equipment for MPV in patients with NMDs. Set 1; consisted of a non-dedicated MPV ventilator with plastic angled mouthpiece and custom-made tubing support that has previously been reported as effective in terms of blood gas improvement (15, 16), ease to use (17, 18), decreased dyspnea and respiratory muscle fatigue (3, 19). Set 2; consisted of a ventilator with a dedicated

MPV mode with specific software, silicone straw mouthpiece and commercially available tubing support. The performance of ventilators with or without MPV dedicated software was recently investigated in a bench study. However, this study did no test the ventilators directly on patients (20). The objective of the present study was to determine whether a dedicated or non-dedicated ventilator set up was preferred by patients with NMDs using MPV.

Aims

The primary outcome was to compare oxygen saturation (SpO_2) and transcutaneous carbon dioxide ($TcCO_2$) blood gas measurements. Secondary outcome measures included: Borg dyspnea scale, subject perception and preference for the two experimental sets for the delivery of MPV.

MATERIALS AND METHODS

Patients

All individuals affected by NMDs attending the Centre for Home Mechanical Ventilation of Inkendaal Rehabilitation Hospital between 2015 and 2018 using nocturnal NIV were considered for study inclusion. All subjects used Volume-Assisted Pressure Control mode (VAPC) at night via a Covidien Puritan Bennett PB560 ventilator (Covidien, Mansfield, USA). Patients already using MPV before study inclusion all used the PB560 for daytime MPV.

Inclusion criteria: evening Borg dyspnea scale score higher than 2.5 out of 10 highlighting an increased workload on inspiratory muscles during the daytime was considered as an inclusion criterion for patients not using MPV. Patients already using MPV were also candidates for study inclusion.

Exclusion criteria: ineffective NIV during sleep as assessed by the measurement of 5 consecutive minutes of TcCO2>49mmHg (21), uncontrolled mouth leak with MPV assessed as the inability of patients to sip air from the mouthpiece, acute respiratory

infection during the trial period. The presence of learning difficulties was not an exclusion.

The current study was registered (ClinicalTrials.gov Identifier: NCT03867721) and approved by the ethics committee in Inkendaal (# 2014-WMT-001). Subjects written informed consent prior to study inclusion.

Study design

In the present randomized cross-over study subjects acted as their own control during a scheduled 6-monthly hospital admission to the Centre for Home Mechanical Ventilation in Inkendaal, we measured overnight $TcCO_2$ and SpO_2. Subjects were then randomized by flipping a coin to which experimental set they would start with. $TcCO_2$ and SpO_2 measurements were tested during a 1-hour session with subjects seated in their wheelchair and breathing via MPV on two separate afternoons over a 48-hour period.

Equipment for MPV

The two experimental set ups are shown in Figure 1. Each set included a different ventilator, tubing support and mouthpiece. Both ventilators were set to volume assisted control (VAC) mode according to the patient preference reported in a previous study (19).

Set 1; consisted of a non-dedicated (NON-DED) ventilator for MPV (PB560) using an active valve circuit. The trigger was set to a high sensitivity. The PB560 was combined with a local custom-made tubing support in thermo-formable plastic U-piece placed on the patient shoulders (figure 1 A) described in a previous report (15). The mouthpiece consisted in a 22mm white angled hard plastic mouthpiece (Philips Respironics; Murrysville, USA). The initial backup rate in the NON-DED equipment was copied from nighttime values and patients had the opportunity to modify the rate according to their comfort. Our group has previously reported the use of non-dedicated MPV ventilators and custom-made arm MPV support with a plastic angle

mouthpiece is safe and effective in a 10-year observational study of 42 patients affected by Duchenne Muscular Dystrophy (15).

Set 2; consisted of MPV dedicated ventilator (DED) (Trilogy 100, Philips Respironics; Murrysville, USA) combined with its tubing support, a kiss trigger without a back-up rate, and a silicone straw mouthpiece but. All disconnection alarms were switched to off. This set included a single passive open circuit without exhalation valve.

As opposed to set 1, in which patients need to actively inhale to trigger an inspiratory cycle, the kiss trigger does not require an active inhalation. Instead, patients need to interrupt the constant flow, either by pursing their lips around the mouthpiece or by touching the mouthpiece with their cheeks or tongue. Any flow disruption induces initiation of an inspiratory cycle, even when the rate is set at zero cycles/minute. The kiss trigger is therefore thought as a sensitive flow detection system.

The tubing support was a commercially available flexible tube support system attached via a clamp to the patient's wheelchair (Phillips Respironics, Murrysville, USA) (Figure 1 B). Similar VAC mode, tidal volumes and inspiratory times were used in both equipment's set ups to facilitate comparison. Trials were a succession of intermittent disconnections and reconnections to the mouthpiece. All subjects were encouraged to maintain a tight seal around the mouthpiece according to their breathing comfort.

Measurements

Day 1

Day 1; consisted of measurements and the characteristics of subjects spontaneously breathing prior to the trials on days 2 and 3. Measurements of forced vital capacity (FVC), maximum inspiratory (MIP) and expiratory pressures (MEP) were measured in seated position as per ATS/ERS guidelines (22) via a heated Fleisch no. 2 pneumotachometer (Metabo, Lausanne, Switzerland). Breathing comfort "breathlessness" was evaluated on the Borg dyspnea scale in the evening. Evening Borg score > 2.5 in Duchenne muscular dystrophy was suggested as a marker of increased work of breathing and reduced endurance of respiratory muscles. It was therefore considered by our group as an indication for daytime ventilatory support as

an extension of nocturnal ventilation (3). Baseline SpO_2 and $TcCO_2$ were recorded self-ventilating at the end of the afternoon via an ear clip connected to a Sentec monitoring (SenTec AG, Therwil, Swizerland) (23). Subjects reported spontaneous breathing time defined as the time of comfortable breathing without the support of NIV during the daytime. Subjects already using MPV were allowed to reconnect to MPV when spontaneous breathing was deemed uncomfortable. The time when patients decided to reconnect to MPV corresponded to the end of spontaneous breathing time. We finally measured the maximal active mouth opening (space between upper and lower teeth). Patients received their normal nasal nocturnal ventilation during nights 1 and 2. During night 1, SpO_2 and $TcCO_2$ were recorded continuously by Sentec to evaluate the effectiveness of nocturnal ventilation.

Days 2 and 3

Trials with MPV occurred in the afternoon. On each day $TcCO_2$ and SpO_2 was measured. We recorded the maximal $TcCO_2$ and minimal SpO_2 values obtained during the MPV trials (24). Subjects evaluated breathing comfort on the Borg dyspnea scale at the end of each experimental MPV set up. A seventeen-item score for patient perception were assessed with a Likert scale ranging from 0 to 5 (0 = maximal dissatisfaction, 5 = maximal satisfaction). This was completed during each experimental trial. Subjects were invited to rate the following: ventilator intuitiveness; appearance; easiness to manage the backup rate; easiness of the disconnection alarms; feeling of security; ability to rest respiratory muscles; easiness to eat, to drink and to speak. We also asked subject to rate the arm support with regards to easiness, appearance, effectiveness, feeling of security and the mouthpiece with regards to ability to prevent orthodontic deformities, easiness to engage or disengage, appearance, effectiveness. At the end of the 2 days subjects were asked their preference for the non-dedicated (set 1) or dedicated set up (set 2).

Data analysis

Data was tested for normality with Kolmogorov-Smirnov test, data is reported as mean (± SD) for normal distribution, or median (Minimum-Maximum) for abnormal

distribution (SPSS 25.0, IBM Software, USA). Comparisons between groups were performed by unpaired Student "T" test or Wilcoxon test depending on the normality of the distribution. $P < 0.05$ was considered as significant.

RESULTS

During the study period, 178 patients were seen for their routine 6-month control of nocturnal NIV. Twenty subjects met inclusion criteria and were enrolled in the study. See Table 1 for subject demographics (2 children and 18 adults; 20 males: 17 Duchenne Muscular Dystrophy, 2 congenital dystrophies and 1 Pompe disease). On day 1, evening Borg dyspnea score was 4.2 (SD: 1.5) in patients new to MPV and evening Borg score was 7.5 (SD:2.1) in experienced MPV users who were asked to disconnect from MPV for a maximum of 30 minutes. Daytime baseline spontaneous breathing SpO2 was 94.8 (85-98) %; TcCO2 was 45.5 (28-65) mmHg; spontaneous respiratory rate: 22 (13-45) cycles/min. Subjects scored on a 5 point Likert score for eating was 3/5 (0-4) points, score for drinking, 4/5 (0-5) points, score for speaking, 3/5 (1-5) points.

The effect of NON-DED versus DED ventilator settings on blood gas measurements, Borg dyspnea scale measurement and patient's perception are reported in Table 2. Subjects scored lower on The Borg dyspnea scale with the NON-DED equipment. There was no difference between $TcCO_2$ measurements and total perception score for the two equipment sets (Table 2).

See Figure 2 for subject preference for MPV experimental set up according to their ability for have ventilator free-time. No MPV users with a spontaneous breathing free-time lower than 6 hours preferred the DED experiment set up (backup rate at zero and kiss trigger) (Figure 2A). In subjects with a spontaneous breathing free-time greater than 6 hours, there was no difference in preference between NON-DED and DED equipment set up. Sixty-five percent preferred the DED flexible arm support (Figure 2B) and 55% preferred the plastic angled mouthpiece (Figure 2C). The mouth opening had no impact on the preferred mouthpiece (Figure 2D).

See Table 3 for patient perception of the three components of MPV equipment. The NON-DED experimental set (with backup rate) was deemed easier, more intuitive,

easier in controlling the rate, easier to managing leaks and it gave a better feeling of safety and relieving respiratory muscles than the DED experimental set (without backup rate). The DED ventilator was deemed easier in managing disconnection alarms. The DED arm support was easier to use, more convenient and gave a greater feeling of security than the NON-DED custom-made support. There were few differences regarding the preferred mouthpiece.

DISCUSSION

This is the first study to investigate the preference of patients with NMDs regarding the equipment for MPV. We compared dedicated (DED) versus non-dedicated (NON-DED) MPV equipment. The NON-DED set included a PB560 ventilator with a set backup rate while the DED set included a Trilogy 100 ventilator with an on-demand kiss trigger and no backup rate. In the present study we showed both equipment sets were deemed effective at delivering MPV, both experimental set ups had the same tidal volumes and inspiratory times. The set respiratory rate was higher on the NON-DED ventilator compared to the DED ventilator where the patients triggered the breath. Despite no difference between both set ups in controlling oxygen and carbon dioxide levels the NON-DED ventilator relieved the sensation of dyspnea to a greater extent that the DED ventilator. The explanation for this is that the patients on the DED ventilator had to interrupt the flow to trigger the breath and this is more fatigue inducing than synchronizing with a set backup rate. Importantly, transient SpO_2 desaturation and hypercapnia may occur with MPV during activities of daily living such as eating or watching TV. In these situations, patients do not experience an unpleasant sensation (24). In the present study, however, we did not observe SpO2 desaturations and hypercapnia with MPV, probably because our subjects were not performing activities of daily living, which may have caused distraction and underuse of their MPV.

Significance of Findings

Improvement in dyspnea in the present study were larger than the minimal clinically important difference (1 point) with both equipment sets (25). Also dyspnea was

higher when subjects used DED MPV equipment with the kiss-trigger. Subjects with little spontaneous breathing time preferred a fixed rate as they did not need to continuously concentrate on triggering the ventilator. However, when questioned about this, they told us that they can use the kiss trigger for a short period of time as it is sensitive and easy to use.

We found that subjects who were not able to trigger inspiration with the NON-DED ventilator via tubing with an active exhalation valve synchronized their breathing to the set rate on the NON-DED ventilator. Our data are therefore transitional to clinical practice as clinicians can use this information to set a backup rate if patients are unable to use MPV with a kiss-trigger.

Differences in dyspnea improvements can be explained by a lower respiratory rate with the DED ventilator causing slight air hunger. Dyspnea can also be explained by the characteristics of the Trilogy ventilator. The Trilogy has difficulty in ensuring a stable tidal volume in MPV mode. This is because the requirements of ventilators for nasal mask nocturnal ventilation are not the same as for daytime MPV.

According to the patient needs, MPV during the daytime is a succession of connections to MPV and disconnections from MPV in awake patients (17,24). During connections to MPV, little or no air leak around the mouth occurs. This represents the “no leak condition”. Lips are pursed around the mouthpiece and ventilation is effective. During disconnections from MPV, air leaks are observed and compensated by the ventilator. This is the “leak condition”. Lips are not pursed and ventilation is ineffective. The timing of the disconnections and reconnections during MPV is decided by the patients and allow activities such as speaking or swallowing. Patients manage leaks by adjusting the tightness of their lips around the mouthpiece and the less dependent patients may disengage the mouthpiece from their mouth when they do not require ventilatory support.

During these sequences of disconnections and reconnections to MPV, the challenge for the ventilators consists in the instantaneous production of a preset tidal volume at the precise time when the patients reconnects to MPV. Ogna et al reported the Trilogy ventilator had difficulty providing the right volume immediately after reconnection to MPV (20). They simulated the clinical picture of intermittent MPV in a bench study (20). They found that the PB560 ventilator stabilized the volume during

disconnections and reconnections to MPV. The Trilogy 100 performed less well in targeting the volume during the leak condition. In particular, several cycles were required before there was stabilization of the preset volume immediately after reconnection to MPV. However, Ogna et al., investigated the volume-controlled settings (VC-CMV) with tidal volumes at 500 and 1000 mL (20). It is likely that setting a higher tidal volume with the Trilogy ventilator would help to further reduce dyspnea and decrease $TcCO_2$ in our study.

The consequence of not receiving a stable volume means that patients cannot fully rely on the volume they expect to receive from the device. Patients reconnect to the ventilator as they need air, if the ventilator does not provide the volume they expect, they will feel uncomfortable. It may take several cycles before receiving the right volume of air. Patients can also receive a breath in to improve swallowing function or can breath stack to increase inspiratory volumes and improve cough. All of this is challenging when patients reconnect to MPV with the Trilogy ventilator. One solution for these issues is to set a higher volume with the Trilogy. More in general, if patients experience breathlessness on a DED MPV, increased tidal volume should be considered or a set respiratory rate rather than using a kiss trigger.

We found no difference between the preferred mouthpiece. One hypothesis might be that silicone straws are preferred when the mouth opening is smaller, but our data does not support this. Subjects reported silicone straws have the potential to reduce the risk of dental deformities. Subjects preferred the commercially available Philips arm support. Only one third of patients still preferred the customized arm support placed on the shoulders despite this being what they were used to. These findings confirm the need for testing different equipment's to tailor to the individual MPV equipment (10).

Limitations of the study

There are limitations in the present study. These include that there was a small number of subjects included. Therefore, this does not allow definitive conclusions on the best MPV equipment. Also 8 of the 20 subjects were already using the NON-DED MPV setup at study inclusion and were therefore familiar with this experimental setup. We acknowledge that this means some of them were using MPV for a long

time and their experience with the NON-DED equipment could affect the conclusion of the present study by preferring the equipment they used and knew. However, subjects showed interest for the DED equipment and 7 out of the 8 stated they would be able to use it. Interestingly, one of those experienced MPV users even chose for the DED equipment.

Another limitation is the short time in which each MPV setup was tested. It was also tested during quite activities. The present study did not assess MPV during daily activities and therefore comparison cannot be made for subjects who use the equipment in real life conditions. Notwithstanding the measurements being made during quiet activities we showed that both MPV setups were safe and effective in all patients except those who were unable to use the kiss trigger on the DED ventilator.

We did not compare pressure versus volume cycled modes. Although pressure cycled modes are mainly used for nighttime ventilation there may be a role for setting these in MPV. Future studies should investigate the reasons why pressure cycled modes are less popular than the volume modes for MPV. Finally, recently dedicated MPV modes designed by other manufacturers deserve further investigation.

Based on comments made by subjects on MPV equipment set ups (online supplements 1 and 2), the DED ventilator was deemed as less intuitive than the NON-DED ventilator. A limitation of the present study is that patients were used to the ventilator from the NON-DED set as it was their nighttime ventilator. However, supplement 2 highlights that patients were able to use both experimental sets but choose the backup rate when their spontaneous breathing time was less than 6 hours. No preference between equipment's was seen when the spontaneous breathing time was greater than 6 hours. We suggest that this limit of spontaneous breathing time at 6 hours differentiates between those patients who feel comfortable with a kiss trigger and those patients preferring a backup rate. Therefore, future studies are warranted to confirm whether the Trilogy ventilator with a backup rate is comparable for comfort in subjects with a spontaneous breathing time of less than 6 hours.

Despite these limitations, our study highlights the need to tailor MPV and the equipment for it to the individual.

In conclusion we found that subject preferences are individualized and not related to either experimental set up. Dedicated and non-dedicated MPV accessories were effective and deemed comfortable by MPV users. New MPV users with little dependence on the ventilator preferred the kiss trigger while patients with a spontaneous breathing time of less than 6 hours preferred a set backup rate. The comfort of ventilation is likely to be related to the ability of the ventilators to stabilize tidal volumes. MPV is typically performed with leak ventilation. Ventilators should therefore be able to adapt to leaks that occur with regular disconnections and reconnections to the mouthpiece. Individualization of pieces such as the arm support and mouthpiece is advised to ensure the success of MPV.

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Table 1: Characteristics of Subjects

	Experienced MPV users	New MPV users
N	8	12
Age (years old)	34.2 (5.7)	25 (8.5)
BMI (kg/m^2)	18.3 (4.9)	19.8 (7.9)
Years with NIV (years)	16 (5.8)	5.2 (4.1)
Years with MPV (years)	8.6 (5.1)	0
Time NIV/24h (hours)	23.6 (22-24)	13.4 (10-15)
Spontaneous breathing time (hours)	1.6 (0.1-6)	6 (0.2-10)
FVC (mL)	342.5 (136.9)	608.8 (206.9)
PCF (L/min)	60.3 (39.7)	150.5 (45.6)
MIP (cmH_2O)	9.3 (4.8)	20.6 (7.6)
MEP (cmH_20)	11.9 (4.9)	25.2 (10.1)
Mouth opening (cm)	2.3 (0.7)	3.2 (1.1)

Values are presented as mean (±SD) or median (Min-Max)

MPV: mouthpiece ventilation, Number (N), body mass index (BMI), noninvasive ventilation (NIV), mouthpiece ventilation (MPV), forced vital capacity (FVC), peak cough flow (PCF), maximum inspiratory pressure (MIP): maximum expiratory pressure (MEP)

Table 2: Comparison of non-dedicated (NON-DED) *versus* dedicated (DED) MPV equipment: impact on ventilator settings, blood gases and subject perception

		NON-DED PB560 active tubing with backup rate Angled plastic MPV	DED Trilogy passive tubing rate set to zero (kiss trigger) Silicone straw MPV	p value
Settings	Mode	VAC	VAC	
	Tidal volume (mL)	594 (157.1)	594 (157.1)	
	Actual respiratory rate (cycles/min)	21,5 (13-28)	17,5 (14-21)	0.002 *
	Inspiratory time (seconds)	1.2 (1.1-1.7)	1.2 (1.1-1.7)	0.102
Blood gas	SpO_2 minimum (%)	96 (95-99)	96 (93-98)	0.454
	TcCO2 maximum (mmHg)	37.9 (6.4)	39.6 (6.7)	0.092
Perception	Borg dyspnea score (0 to10 points)	1 (0-5)	3 (1-6)	0.004 *
	Total perception score (0 to 75 points)	66.3 (45-72.5)	63.7 (41-76)	0.463

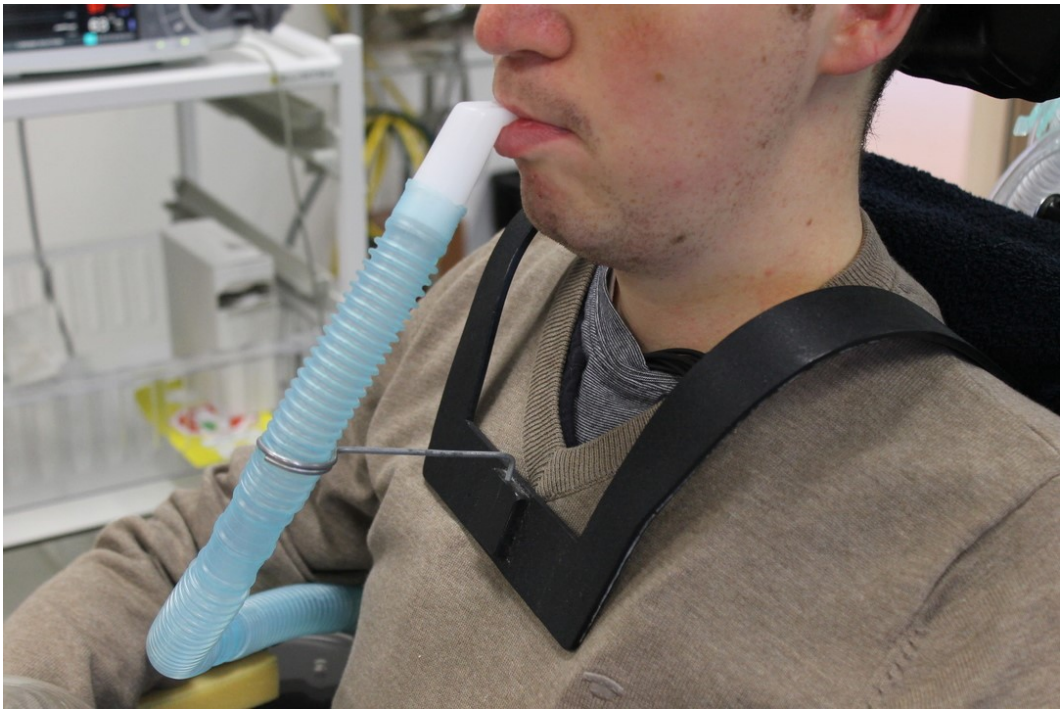
Volume assist control (VAC),

* $p<0.05$ between NON-DED et DED equipment

Table 3: Patient perception for mouthpiece ventilation (MPV) arm support

		NON DED	DED	p value
MPV ventilator	Easy-intuitive	4 (2-5)	3 (1-5)	0.019*
	Appearance	4 (3-5)	3.5 (1-5)	0.09
	Easiness to manage the respiratory rate	5 (3-5)	3 (1-5)	0.005*
	Easiness to manage disconnection alarms	4 (3-5)	5 (3-5)	0.026*
	Feeling of security	4.8 (3-5)	5 (3-5)	0.026*
	Able to rest respiratory muscles	4 (2-5)	3 (2-5)	0.024*
	Easiness to eat	3.8 (1-5)	3.5 (1-5)	0.645
	Easiness to drink	4 (1-5)	4 (1-5)	0.204
	Easiness to speak	4 (2-5)	4 (1-5)	0.503
MPV arm support	Easiness	3.5 (0-5)	5 (2-5)	0.016*
	Appearance	3 (0-5)	3,5 (2-5)	0.246
	Convenience / easy to manage	4 (0-5)	4,3 (3-5)	0.008*
	Feeling of security	3,6 (1.1)	4,5 (0.6)	0.009*
MPV mouthpiece	Avoidance of orthodontic deformities	3 (1-5)	5 (2-5)	0.001*
	Easiness to engage/disengage	3.8 (2-5)	4 (1-5)	0.797
	Appearance	3 (1-4)	3(1-4)	0.194
	Effectiveness	4 (1-5)	4 (1-5)	0.714
Whole equipment	Total perception score	66.3 (45-72.5)	63.7 (41-76)	0.463

Non-dedicated mouthpiece ventilator (NON-DED), dedicated mouthpiece ventilator (DED). Zero = very bad, 5= very good. Total perception score is the total of individual scores out of 85 points. * = $p<0.05$



crj_13118_f1a.jpg

crj_13118_f1b.png

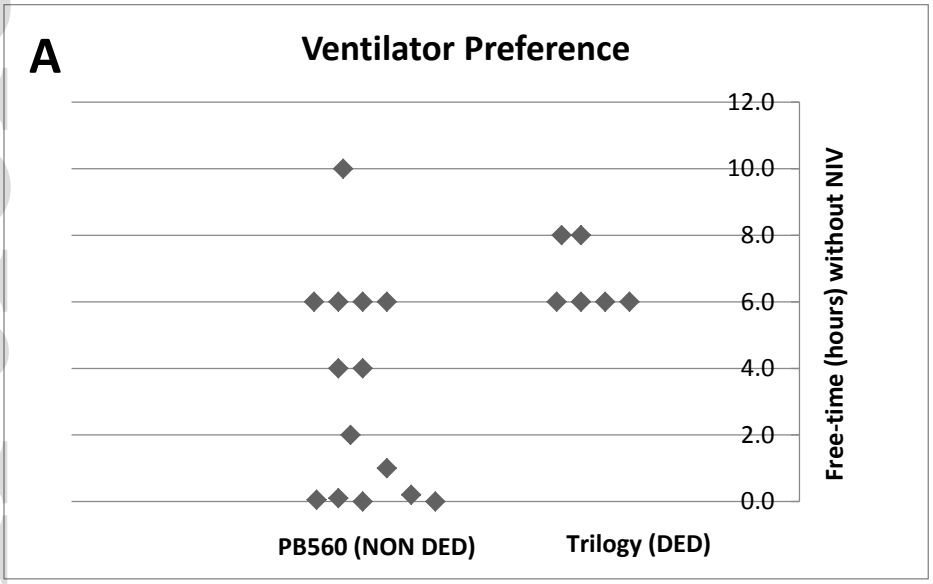


Figure 2A: This Figure shows the subjects preferred ventilator according to their spontaneous breathing time

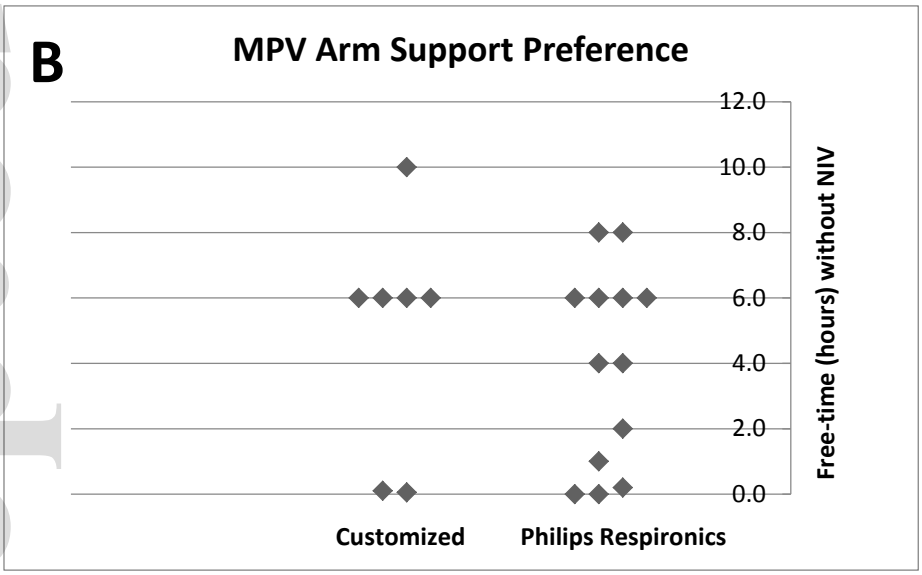


Figure 2B: This Figure shows the subjects preferred arm support (customized arm or commercial Philips Respironics) for MPV according to their spontaneous breathing time

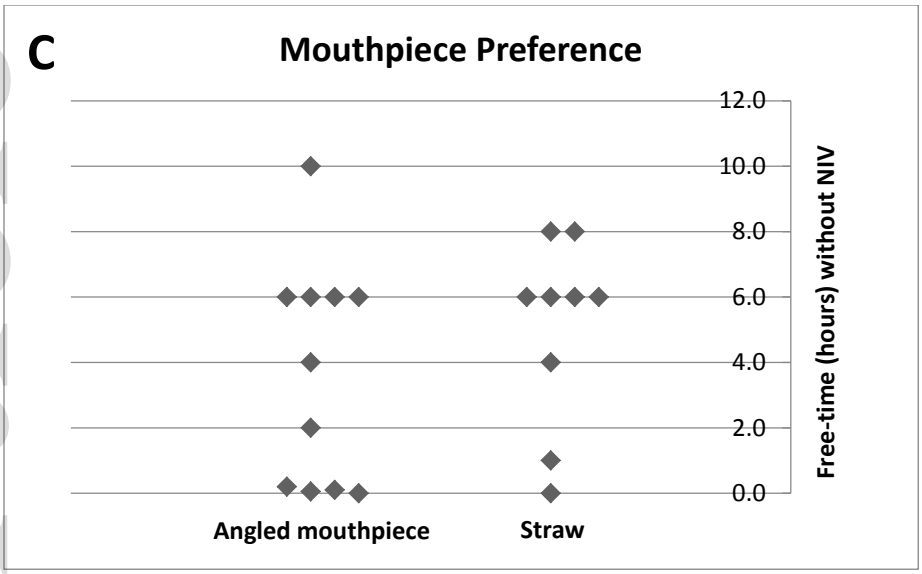


Figure 2C: This Figure shows the preferred mouthpiece (straw mouthpiece or angled mouthpiece) according to the subjects spontaneous breathing time

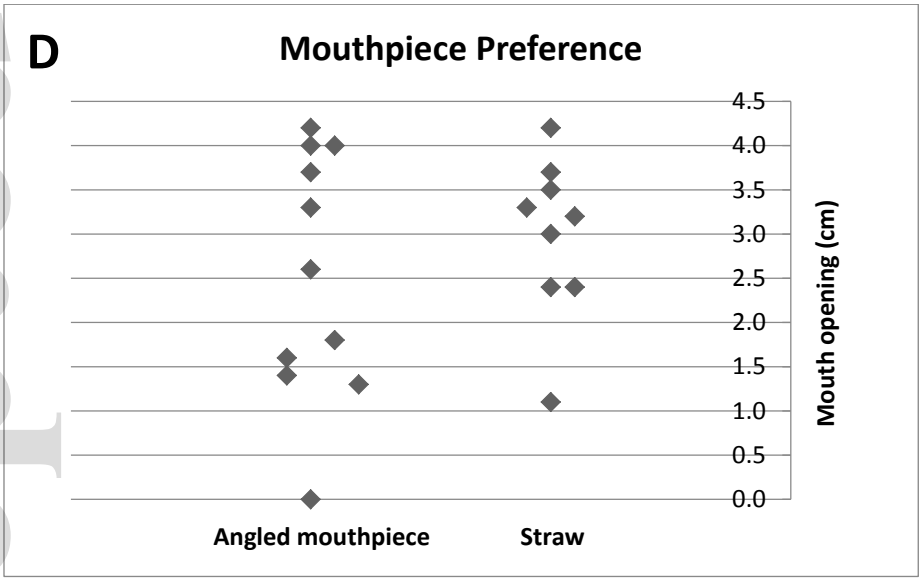


Figure 2D: This Figure shows the subjects preferred mouthpiece according to the subjects mouth opening measured in cm