Dual High Flow Oxygen Therapy and CPAP ventilation in a Single Device for COVID-19

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ABSTRACT

High flow oxygen therapy (HFOT) and Continuous positive airway pressure (CPAP) could be considered the most important ventilatory therapies during the COVID-19 pandemic because of their frequency of use. There are many devices on the market which provide this type of ventilatory support, and these should be distinguished from one another by their efficacy, versatility, patient comfort, and hygiene. We evaluated the AquaVent FD140i from Armstrong Medical, which delivers both HFOT and CPAP, comparing it with a gold standard in the market: Fisher & Pykel; as well as their exchangeability of their humidifier and disposables. The results of this study allow to use the combination of both systems which can reduce consumable costs. Consequently, the AquaVent FD140i provides two potentially efficacious treatments to COVID-19 patients, while its long-life battery facilitates transfers for escalation and de-escalation of care.

INTRODUCTION

High flow oxygen therapy (HFOT) is a method of non-invasive oxygen delivery, in which humidified air-oxygen blends can be delivered at up to 60 L/min, and the fraction of inspired oxygen can be titrated up to 100% (Sharma et al., 2020). Continuous positive airway pressure (CPAP) delivers continuous positive airway pressures through either a face mask, a nasal mask or a helmet (Pinto & Sharma, 2020).

The role of HFOT and CPAP in the treatment of Coronavirus Disease 2019 (COVID-19) is incompletely characterised, since the identification of those patients who require intubation is a subject of ongoing controversy (Tobin et al., 2020). Some patients can be managed well with supplemental oxygen, although those with the most severe respiratory failure clearly require the insertion of an endotracheal tube (Tobin, 2020; Yao et al., 2020).

It has been postulated that COVID-19 comprises two main phenotypes, although this is the subject of ongoing controversy (Fowler et al., 2020; Gattinoni, Coppola, et al., 2020; Jain & Doyle, 2020). 'L', or 'non-ARDS', is characterised by high compliance and the loss of reactive hypoxic vasoconstriction, which can lead to a ventilation perfusion mismatch (Gattinoni, Coppola, et al., 2020; Jain & Doyle, 2020). The 'H', or 'ARDS', phenotype is characterised by pulmonary oedema which progresses to consolidation (Gattinoni, Coppola, et al., 2020; Jain & Doyle, 2020). The L phenotype may respond well to non-invasive ventilation, and the H phenotype to invasive ventilation, with high positive end-expiratory pressures and low tidal volumes (Gattinoni, Chiumello, et al., 2020).

Invasive and non-invasive ventilation carry with them different risks. The placement of an endotracheal tube allows control over a threatened or unstable airway, and permits the tight

regulation of oxygenation and ventilation (Tobin et al., 2012). However, the placement of the tube is associated with a wide range of potential complications (Higgs et al., 2018). Furthermore, as mechanical ventilation increases in duration, morbidity and mortality also increases (Kalanuria et al., 2014).

Non-invasive ventilation, such as HFOT and CPAP, avoids the risks associated with intubation. However, it has been suggested that non-invasive ventilation may lead to greater spread of COVID-19 to healthcare workers compared to invasive ventilation. This has not been borne out by a number of experimental and observational studies, although few have directly compared aerosol dispersal from HFOT and CPAP with invasive ventilation (Li et al., 2020). Nevertheless, a number of studies comparing aerosol dispersion from HFOT and CPAP with that from conventional oxygen therapy have shown no statistically significant increase in dispersal with these therapies (Iwashyna et al., 2020). Studies which attempt to quantify dispersal have found that it is limited to the patient's face and the CPAP mask or HFOT cannulae themselves (Kotoda et al., 2020).

The potential efficacy of HFOT in COVID-19 can be inferred from its efficacy in other severe viral respiratory illnesses like influenza A and H1N1 (Rello et al., 2012). Use of HFOT has led to lower progression to invasive ventilation compared with other forms of non-invasive oxygen therapy across a number of respiratory pathologies (Rochwerg et al., 2019). In COVID-19 patients, a number of recent studies have suggested that HFOT use is associated with a reduction in the rate of invasive mechanical ventilation and overall mortality in patients with moderate to severe hypoxaemic respiratory failure (Patel et al., 2020).

CPAP also has a substantial evidence base for its efficacy as a supportive treatment for patients in type 1 respiratory failure (Mas & Masip, 2014). Despite initial concerns regarding its use in COVID-19, early anecdotal experience has been favourable with newer guidelines now suggesting CPAP as an option for care (Ñamendys-Silva, 2020).

AIMS

- To evaluate the AquaVENT FD104i flow driver's potential benefits and utility in the COVID-19 pandemic.
- To evaluate the AquaVENT 2600A humidifier and circuits as potential adjuncts to the AquaVENT FD104i by testing airway and circuit temperatures with varying flow rate, and comparing them to industry gold standard from Fisher & Pykel.

THE AQUAVENT FD140i FLOW DRIVER

The AquaVENT FD140i is a dual therapy flow driver, that incorporates an external humidifier AquaVENT 2600A, which allows for patients to be switched between HFOT and CPAP quickly and simply. It can be used for adult, paediatric and neonatal patients. CPAP options include Facemask CPAP, Helmet CPAP and Bubble PAP.

The AquaVENT FD140i has six modes of use: CPAP, CPAP paediatric CPAP, CPAP Helmet, Bubble PAP, HFOT and POINT. It has a maximum CPAP flow rate of 140L/min, and a maximum HFOT flow rate of 70L/min. It has an integrated drug nebuliser. Anti-microbial hosing can be supplied. The internal battery maintains an hour charge, and has a low charge alarm. The alarm system has two-tier visual and aural alarms, and include pressure and apnoea alarms.

It has a 7-inch, high resolution multi-colour LCD touch-screen. Setting adjustments can be made in single digit increments for flow rate and FiO_2. A sensitive respiratory wave highlights patients' work of breathing and assists with setting optimal flow rates.

Delivering CPAP requires optimising flow to meet the patients peak inspiratory requirement which can be monitorised through the respiratory rate and the wave form represented on its screen allowing to evaluate patient's response to CPAP therapy.

Patients who require a treatment escalation from HFOT to CPAP, or those who are ready to wean from CPAP to HFOT, can have their treatment delivered through a single machine. This has attendant benefits in terms of patient comfort and reduced consumable costs. The long-life battery facilitates patient transfers, for example from a medical ward to an intensive care unit. In addition, the flow driver is quiet, with consequent benefits to patients and attending staff. Additionally, the AquaVENT 2600A can be used with a dedicated helmet CPAP mode with minimum flow of 40L to prevent CO2 rebreathing and it provides a barrier of protection for healthcare workers from COVID-19 aerolisation.

METHODS

A test was performed with two humidifiers, the AquaVENT 2600A and the Fisher Paykel MR850. Aquavent 2600A has two temperature modes displayed on screen, invasive, which delivers 40^{o}C at the end of the breathing circuit and, non-invasive, that delivers 34^{o}C at the end of the breathing circuit. This temperature monitoring allowed to counter check the measurements by the humidity - temperature instrument. The gas source was at 6 bar for medical and oxygen, setting a constant FiO_2 of 0.4%. The gas inflow was at 23^{o}C of temperature and for CPAP analysis a Positive End Expiratory Pressure (PEEP) of 10 cmH_2O was set. Ambient temperature was 22^{o}C (-1 to +2) at 30 – 50% humidity. Ambient air speed was less than 5 cm.s at 1 atmosphere. The stabilisation time of the devices was 60 minutes and the data collection point was done after 90 minutes. Humidity and temperature was measured with a DM509-TX-01 (Rense Instruments, Oosterhout, NL). The breathing circuits were Armstrong Medical REFs AMHO1509/008 and AMCKUK01240 and Fisher Paykel Healthcare RT202. Measures were taken three times, and the average recorded.

RESULTS

Temperature decrease with the heater F&P-MR850 takes place in a direct proportion to the increase of gas flow as shown in Table 1. This variation takes place above 40L of gas flow either at the airway or the chamber for both types of consumables. Temperature alarms are triggered over 70L in the airway or over 50L in the chamber. Difference between consumable temperatures is maximum at 40L with decrease of 1.0°C when using the Armstrong Airway and -0.3°C at flows of 90L in the airway or 40L in the chamber.

Table 1. Temperature/Gas Flow variation with Heater F&P-MR850

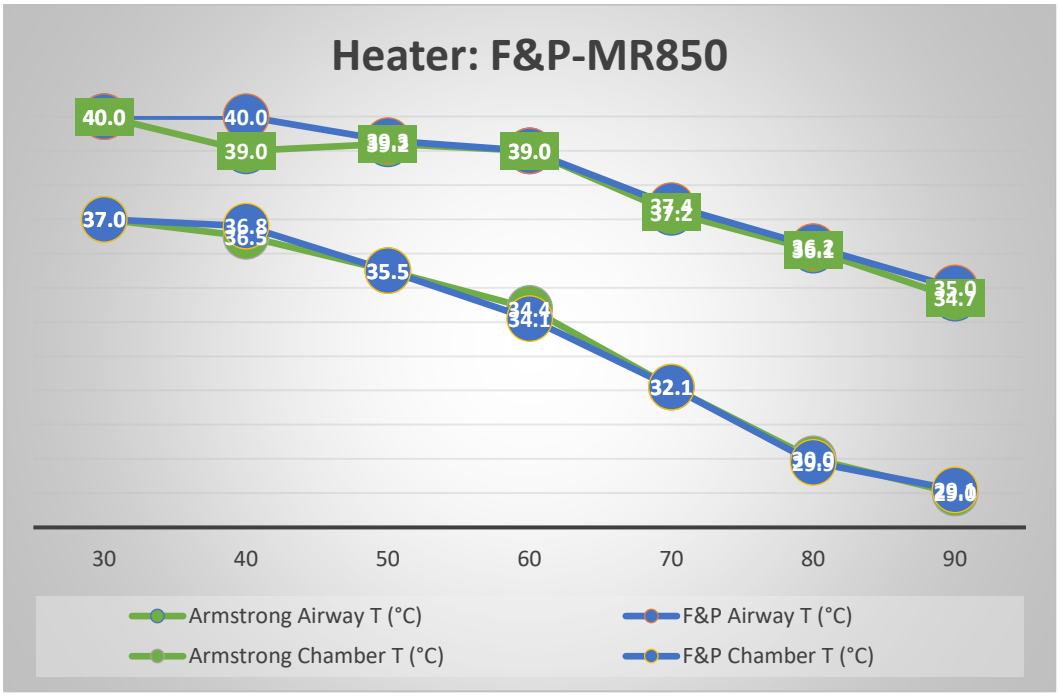
Heater: F&P-MR850	Gas Flow Rate (L/min)						
	30	40	50	60	70	80	90

Armstrong Airway T (°C)	40.0	39.0	39.2	39.0	37.2	36.1	34.7
F&P Airway T (°C)	40.0	40.0	39.3	39.0	37.4	36.2	35.0
Armstrong Chamber T(°C)	37.0	36.5	35.5	34.4	32.1	30.0	29.0
F&P Chamber T (°C)	37.0	36.8	35.5	34.1	32.1	29.9	29.1

Low Chamber Temperature Alarm
Low Airway Temperature Alarm

In the following graph (Graph 1) temperatures maintain an homogenous variation with the heater F&P-MR850 either in the airway circuit or the chamber.

Graph 1. Temperature/Gas Flow variation with Heater F&P-MR850



When the heater AquaVENT 2600 is used, the temperature decreases at high flows (90L) in the airway for the F&P Airway of -0.8°C, and -0.5°C in the F&P Chamber. There is a direct proportion of decrease based on the increase of flow, more stable than with the F&P-MR580 heater. Temperature alarms are triggered at flows of 80L in the airway or at 60L in the chamber; a difference of sensibility of 10L when compared with the heater F&P-MR850.

Table 2. Temperature/Gas Flow variation with Heater AquaVENT 2600

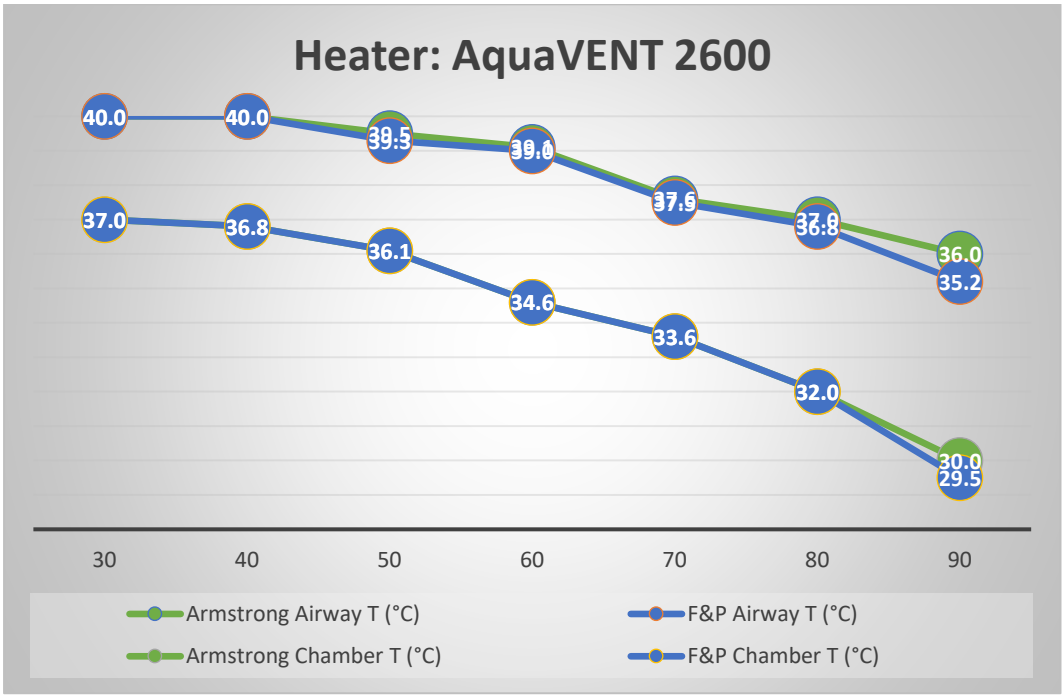
Heater: Armst 2600	**Gas Flow Rate (L/min)**						
	30	**40**	**50**	**60**	**70**	**80**	**90**
Armstrong Airway T (°C)	40.0	40.0	39.5	39.1	37.6	37.0	36.0
F&P Airway T (°C)	40.0	40.0	39.3	39.0	37.5	36.8	35.2

Armstrong Chamber T(°C)	37.0	36.8	36.1	34.6	33.6	32.0	30.0
F&P Chamber T (°C)	37.0	36.8	36.1	34.6	33.6	32.0	29.5

Low Chamber Temperature Alarm
Low Airway Temperature Alarm

This stability can be observed in the graph below (Graph 2) in with the lines of tendency become at a maximum dispersion of -0.8°C in the F&P Airway Circuit or -0.5°C for F&P chamber.

Graph 2. Temperature/Gas Flow variation with Heater AquaVENT 2600



DISCUSSION

These results appear to demonstrate that the two circuits are compatible with one another. The AquaVENT 2600A appears to be more temperature stable in high flows over 50L, maintaining temperatures closer to 40°C to higher flow rates. Consequently, alarms are not triggered as quickly, since the AquaVENT 2600A is better able to achieve the temperatures within the desired range. It may be the case that the Fischer and Paykel humidifier was not manufactured to work at flows greater than 50-60L, which are the maximum flows achievable with F&P device. Variations between both systems may be related to the geometry of the chamber or the kinetic forces in the circuit but, even at flows of 90L, optimal results appear to be obtained with the combination of the AquaVENT humidifier and Armstrong circuit.

CONCLUSIONS

Current evidence suggests that HFOT and CPAP are efficacious in the treatment of COVID-19. The advantage of dual therapy in one device plus and integrated nebuliser is that, apart from patient comfort, the patient may be able to remain connected to the device for longer periods, with consequent maintenance of oxygenation.

Dual therapy may also be associated with reduced healthcare costs. The ease of escalation and weaning with a single device may help reduce ICU length of stay, or potentially avoid admission. Consumable costs will also be lower. A single circuit may be used for both HFOT and CPAP, and potentially reduce therapy costs by up to 50%.

Consequently, the AquaVENT FD140i provides two potentially efficacious treatments to COVID-19 patients, while its long-life battery facilitates transfers for escalation and de-escalation of care. Furthermore, the AquaVENT 2600A compares well to an industry standard humidifier, with better temperature control at higher flow rates. This is particularly evident when paired with an Armstrong circuit, but humidifiers and circuits examined appeared to be compatible with one another.

In summary, the combination of AquaVENT FD140i, AquaVENT 2600A and Armstrong breathing circuit can be expected to be of therapeutic use in COVID-19.

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