Original Article

The Efficacy of "Do It Yourself" High Flow Nasal Cannula, DIY HFNC

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Objective: High flow nasal cannula (HFNC) plays role in many indications of oxygen therapy. Unfortunately, in middle income with a developing country like Thailand, HFNC is totally imported and high cost. For this whole reason, we would like to conduct DIY HFNC for comparing the efficacy with the standard marketing machine (Airvo-2).

Materials and Methods: The present study was an experimental study. The DIY HFNC was generated from our many medical equipment. Targeted gas flow and fractional oxygen (FiO_2) were calculated by gas concentration stoichiometry formula. The efficacy of DIY HFNC was measured gas flow, FiO_2 compared with the standard machine.

Results: Testing DIY HFNC when set-flow of 30 liters/min (L/m) and set-FiO_2 in the range of 30 to 60% show achieved-flow in the range of 29.30 to 34.48 L/m (relative different (Δ) -2.33 to 14.93%), achieved-FiO_2 as 30.60, 41.80, 52.50 and 60.50% (Δ2, 4.50, 5 and 0.83%, respectively). The next set-flow of 40 L/m and set-FiO_2 in the range of 40 to 60% show achieved-flow in the range of 42.28 to 45.25 L/m (Δ10.70 to 13.13%), achieved-FiO_2 as 41.50, 51.50 and 60.50% (Δ3.75, 3 and 0.83%, respectively). The next set-flow of 50 L/m and set-FiO_2 at 60% show achieved-flow as 57.09 L/m (Δ14.18%), achieved-FiO_2 as 60.10% (Δ0.17%). The last set-flow of 60 L/m and set-FiO_2 at 60% show achieved-flow as 68.98 L/m (Δ14.97%), achieved-FiO_2 as 63% (Δ5%). All usage periods give the same measure values.

Conclusion: The DIY HFNC shows the efficacy nearby the standard machine in gas flow range of 30 to 60 L/m and FiO_2 range of 30 to 60%.

Keywords: High flow nasal cannula (HFNC); Do it by yourself (DIY)

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High Flow Nasal Cannulas (HFNC) has become an increasingly popular instrument in the treatment of acute respiratory failure type 1[1-3] and is able to prevent reintubation in high-risk and low-risk patients after weaning ventilator and removing breathing tube[4,5]. In addition, after outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-COV2)[6], HFNC is used in the treatment of hypoxemia and reduces requirement of endotracheal intubation[7]. This is because HFNC has higher effective functions than low flow oxygen system such as oxygen masks, oxygen mask with bag, and oxygen cannula. Special features of HFNC include: 1) Heat humidified which provides humidity and controls air temperature, promote mucus secretion[8] and clearing of patient's airways; 2) Reduce work of breathing and lessen fatigue during respiratory failure; 3) Positive end expired pressure (PEEP) and alleviation of atelectasis symptom; 4) Relieve respiratory dead space[9,10]. Due to these superior features, presently, HFNCs are more widely used. However, for Thailand, which is an upper middle-income country, hospitals have difficulties in accessing the HFNC because it has to be imported and cannot be produced by domestic manufacturer. In addition, the prices are high between 5,975 to 7,469 USD per unit. Therefore, the researcher tried to assemble a HFNC with medical

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Figure 1. Standard heat humidifier (MR850, Fisher and Paykel Healthcare) from unused ventilator.

Figure 2. Auto feed chamber and corrugated tube for one-way air/oxygen blended air passages.

Figure 4. Ambient air flow meter with capacity of 15 liters per minute, total 2 units.

Figure 3. Oxygen flow meter with capacity of 15 liters per minute, total 2 units.

Figure 5. Oxygen extension tubes, total 4 units.

equipment available in hospitals as prototype for use in hospitals that lacked the equipment, and we aimed to study efficacy and cost of DIY HFNC.

Materials and Methods

This research is based on experimental study by assembling HFNC with available materials and equipment and to study the efficacy of the oxygen concentration ratio and air/oxygen blended air flow rate.

1) Assembling methods for DIY HFNC is as follows:

1.1 Attach the heat humidifier with corrugated tube;

1.2 Fit the 4 T-shaped air tube connectors;

1.3 Cover the end of T-shaped air tube connectors with ventilation tube cap;

1.4 Connect two-way oxygen pipe separator to the oxygen dispenser and connect 2 oxygen flow meters with capacity of 15 liters per minute;

1.5 Connect two-way air pipe separator to the air dispenser and connect 2 ambient air flow meters with capacity of 15 liters per minute;

1.6 Connect the 2 ambient air flow meters to the T-shaped air tube connectors with oxygen extension tubes;

1.7 Connect the 2 oxygen flow meters to the T-shaped air tube connectors with oxygen extension tubes;

1.8 Connect nasal prong to corrugated tube.

2) Calculate the air/oxygen blended air flow rate and the required oxygen concentration ratio using the following formula:

$$C_1V_1+C_2V_2 = C_\Sigma V_\Sigma$$

Whereas C_1 is oxygen concentration ratio of 100% from the oxygen pipeline

V_1 is oxygen flow rate from the supply tube

C_2 is oxygen concentration ratio of 20% from the

Figure 6. Two-way oxygen pipe separator, total 1 unit.

Figure 7. Two-way air pipe separator, total 1 unit.

Figure 8. T-shaped air tube connectors, total 4 units.

Figure 9. M-sized Nasal prong of Spiro Med Co., Ltd.

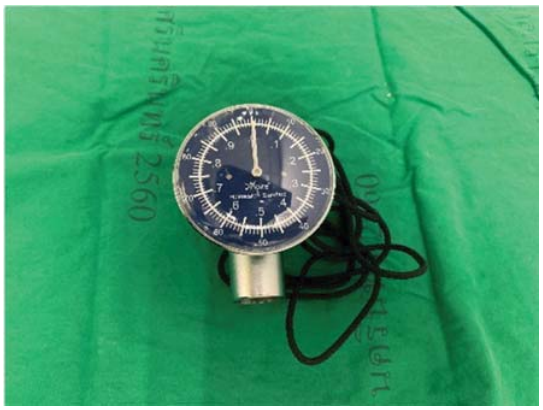

Figure 10. Wright spirometer.

Figure 11. Oxygen concentration content tester, CY-12C.

Figure 12. Ventilation tube cap, total 1 unit.

Figure 13. Shows completely assembled DIY HFNC.

ambient air pipeline

V_2 is the ambient air flow rate

C_Σ is fraction of inspired oxygen (FiO_2)

V_Σ is total flow rate

Set the blended air flow rate at 30, 40, 50 and 60 liters per minute and the oxygen concentration ratio at 30, 40, 50 and 60 percent for calculation of oxygen flow rate from the supply tube and ambient air flow rate. When the abovementioned variables are applied in the formula, results of the calculation are as Table 1.

3) Adjust the oxygen and ambient air flow rate according to the above table.

4) Test performance by using oxygen concentration content tester and wright spirometer, by measuring the flow rate and the oxygen concentration ratio at each level of blended gas.

Research results

From the calculation table of blended air flow rate and oxygen concentration ratio, the study can only be conducted on each type of gas with flow rate of not more than 30 liters per minute. It was because ambient air flow meter could measure maximum capacity of 15 liters per minute, thus, when using two-way air tubing separator, the total measurable gas flow rate of each type of gas was only 30 liters per minute. The research results showed that, at all usage periods, the study results were similar. When the specified blended set-flow was 30 liters per minute, with required oxygen concentration ratio of 30%, the achieved-flow was 32.30 liters per minute (14.10% relative different from the standard HFNC) and achieved-FiO_2 was 30.60% (2% relative different from the standard HFNC). When set-FiO_2 increased to 40%, the achieved- flow was 32.96 liters per minute (9.87% relative different from the standard HFNC) and achieved-FiO_2 was 41.80% (4.50% relative different from the standard HFNC). When set-FiO_2 increased to 50%, the achieved-flow was 34.48 liters per minute (14.93% relative different from the standard HFNC) and achieved- FiO_2 was 52.50% (5% relative different from the standard HFNC). When set-FiO_2 increased to 60%, the achieved- flow was 29.30 liters per minute (-2.33% relative different from the standard HFNC) and achieved-FiO_2 was 60.50% (0.83% relative different from the standard HFNC).

When set-flow was 40 liters per minute, with required set-FiO_2 of 40%, the achieved- flow was 44.28 liters per minute (10.70% relative different from the standard HFNC) and the achieved-FiO_2 was 42.50% (6.25% relative different from the standard HFNC). When set-FiO_2 increased to 50%, the achieved-flow was 45.02 liters per minute (12.55% relative different from the standard HFNC) and achieved-FiO_2 was 51.50% (3% relative different from the standard HFNC). When set-FiO_2 increased to 60%, the achieved- flow was 45.25 liters per minute (13.13% relative different from the standard HFNC) and achieved-FiO_2 was 60.50% (0.83% relative different from the standard HFNC).

When set-flow was 50 liters per minute, with required set-FiO_2 of 60%, the achieved-flow was 57.09 liters per minute (14.18% relative different from the standard HFNC) and achieved-FiO_2 was 60.10% (0.17% relative different from the readings of standard HFNC).

When set-flow was 60 liters per minute, with required of set-FiO_2 60%, the achieved- flow was 68.98 liters per minute (14.97% relative different from the standard

Table 1. Illustrates results of DIY HFNC performance test

Set flow	Set-FiO_2	Oxygen flow setting	Air flow setting	The usage period is immediately 24, 48 and 72 hours*			
				Achieve-flow (relative difference)		Achieve-FiO_2 (relative difference)	
30	30	3.75	26.25	34.23	14.10	30.60	2.00
	40	7.50	22.50	32.96	9.87	41.80	4.50
	50	11.25	18.75	34.48	14.93	52.50	5.00
	60	15	15	29.30	-2.33	60.50	0.83
40	30	5	35	**			
	40	10	30	44.28	10.70	41.50	3.75
	50	15	25	45.02	12.55	51.50	3.00
	60	20	20	45.25	13.13	60.50	0.83
50	30	6.25	43.75	**			
	40	12.50	37.50	**			
	50	18.75	31.25	**			
	60	25	25	57.09	14.18	60.10	0.17
60	30	7.50	52.50	**			
	40	15	45	**			
	50	22.50	37.50	**			
	60	30	30	68.98	14.97	63.00	5.00

* Performance tests provided the same values for all immediate usage period of 24, 48 and 72 hours
** The tests were not performed because the air flow rates were not exceeding 30 liters per minute

Table 2. Illustrates cost breakdowns of DIY HFNC

No.	Description	Quantity	Unit price (USD)	Total price (USD)
1	Standard heat humidifier (MR850, Fisher and Paykel Healthcare)	1	2,540	2,540
2	Auto feed chamber	1	18	18
3	Corrugated tube for one-way air/oxygen blended air passages	1	54	54
4	Oxygen flow meter with capacity of 15 liters per minute	2	39	78
5	Ambient air flow meter with capacity of 15 liters per minute	2	39	78
6	Oxygen extension tubes	4	1	4
7	Two-way oxygen tubing separator	1	233	233
8	Two-way air tubing separator	1	233	233
9	T-shaped air tube connectors (dis straight connector 22F)	4	2.5	10
10	M-sized Nasal prong of Spiro Med Co., Ltd.	1	30	30
11	Ventilation tube cap	1	1.2	1.2
Total				3,279.2

HFNC) and achieved- FiO_2 was 63% (5% relative different from the standard HFNC) (Table 1).

The costs of assembling DIY HFNC were 3,279.2 USD. Most of the components are permanent materials which can be reused. As a result, the recurring costs for using the machine consist of only consumable supplies, such as nasal prong, which costs 1,000 baht per time (Table 2). When comparing with costs of standard HFNC which are 6,064.37 to 7,580.47 USD, the DIY HFNC can save about 56.74 percent of expenses.

Discussion

The DIY HFNC offers similar performances as standard HFNC (over or less than 15 percent) in all blended

air flow rates. When the blended air flow rates increased from 30 liters per minute to 40, 50 and 60 liters per minute, it was found that the airflow rates tend to be higher in proportion to the higher flow rate. The reason could be due to each of the 4 oxygen flow meters and ambient air flow meters which have capacity of 15 liters per minute and accuracy of ±0.50 liters per minute. Therefore, most of the actual measured air flow rates were higher than the amount required. In addition, as the adjustment of capacity of 15 liters per minute of oxygen flow and ambient air flow meters were made manually, thus, there was possibility that the adjustment may be made higher than actual requirement.

As for the efficiency of oxygen concentration ratio of the blended pure oxygen and normal air, it was found that all the required oxygen concentration ratios were more than 5%, although the total air flow exceeded the limit in the range of -2.33% to 14.97%. This is because the oxygen flow and ambient air flow rates tend to be in the same proportion. Therefore, the required oxygen concentration ratios were not more than 5% when compared with standard HFNC.

For adult patients, no DIY HFNC has been used for clinical purpose. Nonetheless, DIY HFNCs have been used in the treatment for pediatric patients, and provided reliable performances[11]. This may be because high flow rate in children (15 to 20 liters per minute) is much lower than that in adults (>30 liters per minute). As a result, there is no excess air or oxygen supply than the prescribed rate when the rates were adjusted to be as high as the rates required in the research results which were applied in adults.

Our study had some limitations, including: A) If researchers would like to conduct study on all blended air flow rates and the required or higher oxygen concentration ratios such as oxygen concentration ratio of 100%, oxygen flow and ambient air flow meter with capacity of 70 liters per minute would be required. Nonetheless, the devices are still limited in most hospitals. B) If it is necessary to apply or promote the use of self-made HFNC, some hospitals, which do not have two-way air or oxygen tubing separator to supply air or oxygen with flow rate exceeds 15 liters per minute, can purchase the devices which would be cheaper than standard HFNC. Nonetheless, if the devices could not be found, operator may connect additional oxygen flow meter and ambient air flow meter with capacity of 15 liters per minute to obtain total air flow rate of 30 liters per minute, and the oxygen concentration ratio of 60 percent which are applicable. However, there are limitations that the required flow rate and oxygen ratio cannot be adjusted. C) Some equipment such as auto feed chamber, corrugated tube, and nasal prong are disposable. Decontamination with ethylene oxide is unsafe due to limit information on product stability.

Conclusion

The DIY HFNC shows the efficacy nearby the standard machine in gas flow range of 30 to 60 L/m and FiO_2 range of 30 to 60%.

What is already known on this topic?

Standard HFNC was generated based on the gas blending ratio between air and oxygen. The three properties which high flow, heat, and moist gas delivery are the main characteristics.

What this study adds?

When we know the ratio of air and oxygen by concentration stoichiometry formula calculation, we will achieve target blended gas flow and oxygen concentration. The DIY HFNC was generated by three main equipment including: 1) air source; 2) oxygen source; and 3) heat humidifier. The efficacy depends on the accuracy of the gas flow meter that releases air and oxygen flow including an un leakage system.

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Potential conflicts of interest

The authors declare no conflict of interest.

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