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Analysis of Stability and Accuracy of Gas Flow in High Flow Nasal Cannula for COVID-19 Patients

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ABSTRACT In December 2019, the world was introduced to a new coronavirus called severe acute respiratory syndrome (COVID-19). In this case, the primary strategy proposed for COVID-19 patients including a supportive care using high-flow nasal oxygen therapy (HFNC) reported effective in improving oxygenation. Stability is the ability of a medical device to maintain its performance. Medical equipment must have stability to maintain its critical performance conditions over a certain time. Meanwhile, accuracy is the closeness of agreement between the value of a measuring quantity and the value of the actual quantity of the measuring quantity. The purpose of this study was to ensure that the readings of the HFNC device are accurate and stable so that it is safe and comfortable when used on patients. The development of the equipment used by the author added graphs to the TFT LCD to help monitor stable data in real time so that officers can monitor the stability of the flow and fraction of oxygen in the device. This study used Arduino Nano, GFS131 sensor, and Nextion TFT LCD to display the results. The test was carried out by comparing the setting value of the HFNC tool that appears on the TFT LCD with a gas flow analyzer with a measurement range of 20 LPM to 60 LPM for 5 times at each point. Based on the measurements on the gas flow analyzer, the HFNC module had an average error (%) of 6.40%, with an average uncertainty (Ua) of 0.05. The conclusion made from these results is that the calibrator module had a relative error (error value) that was still within the allowable tolerance limit, which is ±10%. Therefore, the tool was precise because of the small uncertainty and good stability of the stability test carried out within a certain time.

INDEX TERMS High Flow Nasal Canule, Stability, Accuracy, Oxygen, Flow

I. INTRODUCTION

In recent years, High Flow through Nasal Cannula (HFNC) has been introduced in clinical practice. HFNC delivers an oxygen mixture of heated moist air to the patient, with a range of inspired oxygen fraction (FiO2) from 21 to 100% and a flow of up to 60 L/min through a large perforated nasal cannula [1][2]. HFNC has several potential advantages for COVID-19 patients [3] [4][5]. First of all, HFNC provides heating (37◦C) and humidified air-oxygen mixture (44 mg/L) to the patient, which avoids injury to ciliary movement, reduces inflammatory response associated with dry and cold gas, damage to ciliary epithelial cells, and loss of airway water, as well as keeps the bronchial water content from being modified by secretions [6]. In addition, in vitro and clinical studies have shown that placing a simple surgical protective mask on patients significantly reduces the dispersion distance and levels of virus-infected bio-aerosols as far as 20 cm of the patient coughs [7]. Such surgical masks may be worn by patients who are oxygenated via a nasal cannula (standard nasal cannula or HFNC) but not if using a simple, non-rebreathing or Venturi oxygen mask. In this report, we described our recent experience with HFNC after it was widely accepted into practice in two major referral health centers, to include frequency of use and the efficacy and safety of HFNC compared with previous results with non-invasive respiratory support consisting of NCPAP [8] [9].

Medical equipment must have stability to maintain its critical performance conditions over a certain time. Meanwhile, accuracy is the closeness of agreement between the value of a measuring quantity and the value of the actual quantity of the measuring quantity [10][11]. In this case, medical devices with diagnostic or measurement (including monitoring) functions, where inaccuracies can have a significant adverse effect on the patient, shall be designed and manufactured in such a way as to provide adequate accuracy, precision, and stability for the intended purpose of the instrument [12]. Accuracy can be obtained only from correct calibration activities, while stability and reliability can be known from testing. On this basis, it is necessary to carry out regular testing and calibration of instruments. Testing is an activity to determine one or more characteristics of a material or instrument, so that the conformity between the characteristics and specifications can be ascertained [13], [14]. Meanwhile, calibration is an activity to determine the conventional truth of the appointment of measuring instruments and measuring materials [15].

In a previous study carried out in 2020, A. Agarwal made Measuring Instrument for Detecting Volume of Gas Usage Medical Oxygen as the Basis for Determining Tariffs [16]. This tool uses a flow sensor (hall effect) which can only measure a maximum flow of 20 LPM. In this case, the error obtained was quite large, which is 13.5%. Furthermore, Muhammad Khoshi'in created a Volume Counter and Usage Timer Oxygen [17] using the AWM5000 sensor which can only measure up to 20lpm. In this case, the tool had an accuracy of only 44%-66.4%, which was considered not good enough. In addition, A. Prakoso in 2018, made Design and Simulation of Automatic Control Valves for Gas Flowmeter Calibrator from Bell Prover [18] to measure gas flow rate at 250 – 1200 LPM. However, this study did not measure the flow rate of gases with low range as in oxygen flowmeter for the patient. Yunaifi Niswatul Firdaus then made Measuring Oxygen Concentration and Flow in the Ventilator [19] to measured oxygen levels and velocity oxygen flow with character LCD interface for displaying the readings. In this case, the researcher used the OCS 03F sensor. The accuracy value of the tool was considered good but can only measure the rate gas flow at 0 – 10 LPM measurement, while the response time according to sensor specifications was only 0.5 seconds. Furthermore, D. L. Grieco in 2021 carried out a study on Designing a Gas Flowmeter Calibrator Tool [20]. This tool has successfully measured the flow of oxygen gas using the MCS100A120 gas flow sensor. However, this tool was only able to measure the flow rate of oxygen 0 – 10 LPM and had a fairly large average error of -8.326% so it is not suitable for HFNC tools. In 2020, Meving Oktheresia Yolanda performed an analysis of the accuracy of calibration results in the design of a gas flowmeter calibrator using a TFT LCD. This tool also used the SMF4100 sensor. The tool had an advantage of already using a TFT LCD with an average error rate of 4.16%, but can only take measurements from 0-15 LPM so it is not suitable for HFNC devices with a high flow range.

In the market, HFNC is dominantly a factory-made tool with quite expensive prices due to imports [21]. In 2020, LIPI conducted research in the form of locally made HFNC equipment with a fairly cheap market price. This tool can provide a flow rate of 5-60 LPM and an oxygen fraction of 21-100% by utilizing jetflow with a character LCD display. Furthermore, an analytical review was conducted by Dante A. Suffredini and Michael G. Allison in 2021 on Reasons for Use of High-Flow Nasal Cannula for Certain Patients with Suspected or Confirmed Corona Virus-2 Infection Severe Acute Respiratory Syndrome which mentions the clinical use of HFNC must be monitored because if this tool is unstable and inaccurate, it can cause serious problems for patients [22].

HFNC tool module can display flow rate measurement results on the TFT LCD with a display of numbers and pictures so that it can facilitate monitoring of the stability of the output flow rate and oxygen fraction on the tool. The research found that the sensor errors applied to HFNC designs with different specifications [23]. The error factors can be in the forms of the sensor itself, proper data collection (no leaks when collecting data), the output of the amplifier circuit, and the accuracy of the conversion from Arduino. The stability performance test of this module was good because after a stability test has been carried out for a certain time, the displayed data results still show stability [24].

In the future, this research can be developed using other sensors or making a better analog conditioning signal. The module can use two graphic LCDs to make it easier for users to remotely monitor the stability with the IoT system since these devices are usually located in the infection room. The development of this device can also use automatic pulse oximetry settings for oxygen flow and fraction so that users do not need to enter the room to change the settings. Based on previous research, researchers wanted to analyze the accuracy and stability of flow in HFNC using the GFS131 sensor which can measure high flow rates [19]. The development of the equipment that the author used was in the forms of adding graphics to the TFT LCD to help monitor stable data in real time. With this development, it is hoped that it can help medical personnel monitor the flow rate and fraction of oxygen in the device. With the addition of this TFT LCD, the stability of the flow output and oxygen fraction of the device can also be obtained. This tool is expected to be more efficient, especially for developing domestic products so that they are not inferior to foreign products. The aim of this study was to ensure the accuracy and stability of HFNC readings so that they are safe and comfortable to be used on patients Accuracy and stability really need attention because they greatly affect the reliability of HFNC so it must be monitored to ensure that the patient support is working. The contribution of this study is as follows:

1. Development of the GFS131 sensor to measure high flow rates in HFNC
2. Use of a TFT LCD with a graphical output to monitor the HFNC output in real time
3. The device can facilitate monitoring of accuracy and stability of HFNC readings so that it is safe and comfortable when used on patients.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

The research data taken were oxygen flow rate came out from HFNC. The measurements were made 5 times in 5 point of measurement. After that, measurements were made using a comparison device, named gas flow analyzer.

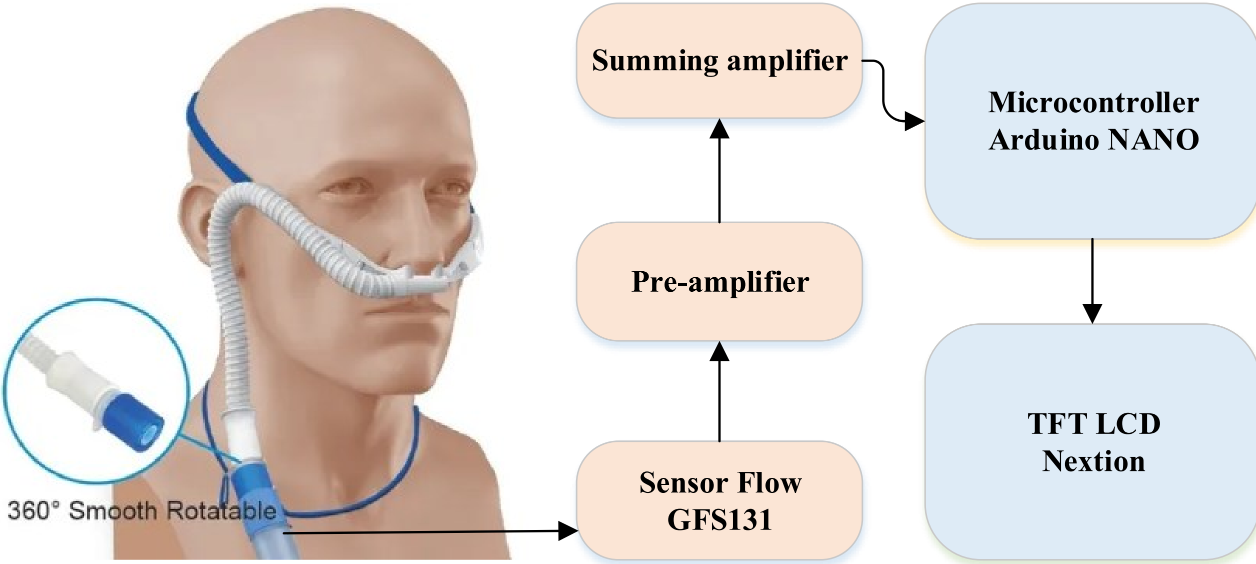

FIGURE 1. Block Diagram of Oxygen Flow Measurement to be given to the patient

1) MATERIALS AND TOOL

This study used the GFS-131 sensor to read the output oxygen flow rate on HFNC. Meanwhile, the component used was the Arduino Nano as a Microcontroller, GFS-131 as a sensor to read the output of HFNC, and TFT LCD to display the results in number and graphic.

2) EXPERIMENT

In this study, researchers compiled a module used for the data collection on HFNC. The researchers further analyzed the performance of high-range flow sensor in accordance with HFNC. The Analysis included the accuracy, stability, and repeatability of the GFS131 sensor on the HFNC device. The display output of HFNC is numeric with LPM and used a graph to make it easier for nurses to monitor and ensure the output of the tool is always stable.

B. Diagram Block and Flowchart

1. DIAGRAM BLOCK

FIGURE 1 shows the block diagram of this study, where the module getting the supply voltage turns on the circuit. When the sensor detects the flow rate, the sensor output voltage enters the differential amplifier circuit which conditions the analog signal to be more linear and get a voltage. This circuit further makes the input voltage to arduino higher than the sensor output so arduino can read it easily and have better resolution. The output from the analog signal conditioning goes to the Arduino at the ADC pin. This input is then converted into digital data and units of Liters Per Minutes which is further displayed on the TFT LCD with graphics. The screen displays the number from the LPM, while the graph shows a few seconds of gas flow and monitor its stability.

2. FLOWCHART

FIGURE 2. shows the flowchart of this study, when the module gets supply voltage from the battery or the power supply circuit, it will activate all circuits including GFS 131 sensors, the microcontroller Arduino and the TFT LCD Nextion [25]. Furthermore, the program initializes the TFT LCD. The next step is adjusting the flow rate by turning/opening the setting knob to required flow rate. If the user does not set the flow, it will wait to setting flow. If the user sets the flow rate, the flow is detected and reading data from the gas flow sensor. If sensor can read it, it will be displayed on the TFT LCD according to the gas flow setting on the flowmeter. If its not, it will try to read.

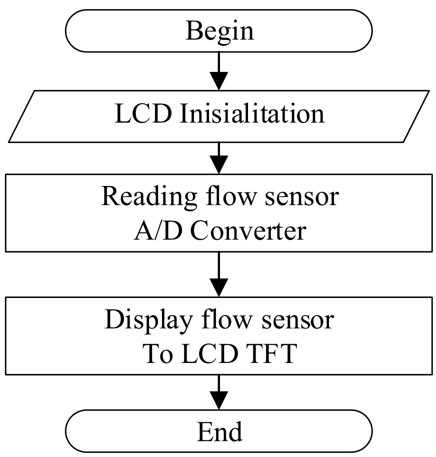

FIGURE. 2 Flowchart of Oxygen Flow Measurement to be given to the patient

III. RESULT

The testing of the HFNC module was carried out using a gas flow analyzer as the comparison tool. The gas flow rate in the HFNC was compared with the output of the gas flow analyzer

Gas flow rate measurement can be set from 0 LPM to 60 LPM with a resolution of 1 LPM. For the measurements, 5 measurement points were set, namely 20 to 60 LPM. The results of the gas measurement were recorded (five) 5 times at each measurement point. At the time of data collection, the measured room temperature was 24.7^{0}C.

1) GAS FLOW MEASUREMENT RESULTS

Table I shows the results of measuring the gas flow settings on the HFNC device with settings of 20, 30, 40, 50, and 60 LPM, with 5 data collection per point.

TABLE 1

Measurement of the gas flow retrieval HFNC

Setting Flow (HFNC) LPM	Calibrator (Gas Flow Analyzer) Measurement To- (LPM)				
	1	2	3	4	5
20	18.2	18.4	18.2	18.3	18.4
30	28.5	28.6	28.4	28.6	28.5
40	38	38.1	37.9	38	37.9
50	47.1	46.9	47	46.9	47.1
60	55.7	55.3	55.5	55.7	55.3

2) RESULTS OF DATA FLOW PROCESSING

The processing of the measurement data includes the average reading of the instrument, the standard deviation, the error value, and the measurement uncertainty of the acceptability set by the reference standard. In this case, Table 2 shows the results of the calculation of data readings and the results of processing gas flow rate data on the HFNC tool.

TABLE 2

Measurement of the Data Flow Processing HFNC

Setting Flow (LPM)	Average	Standard Deviation	Error (%)	Uncertainty (Ua)
20	18.30	0.10	8.50	0.04
30	28.52	0.08	4.93	0.04
40	37.98	0.08	5.05	0.04
50	47.00	0.10	6.00	0.04
60	55.50	0.20	7.50	0.09

Based on the data processing of comparison of the HFNC flowrate and gas flow analyzer, the error values on the table above the graph was obtained as below.

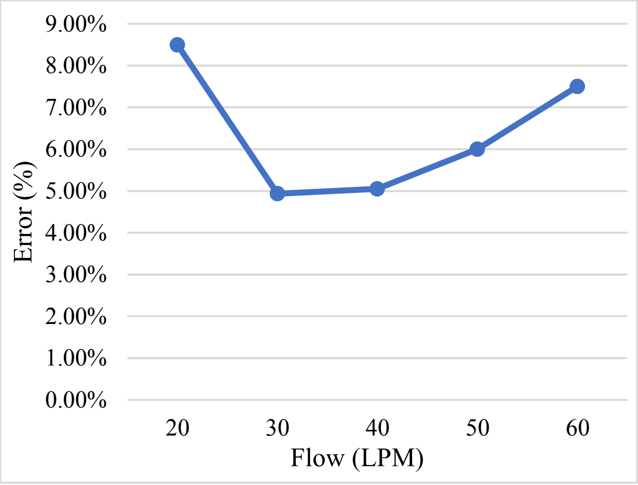

FIGURE. 3 Chart Measurement comparison of error values between points

FIGURE 3 shows a comparison of the error values between measurement points where the lowest error was at the 30 LPM measurement point by 4.93%. Meanwhile, the highest error was at the 20 LPM point by 8.5%. The reading of the GFS131 sensor was considered not good because according to the specifications of the accuracy value of the sensor, which was 4%. Meanwhile, the results of the readings made by the researcher had an error of more than 4%. Based on the data processing of comparison of the HFNC flowrate and gas flow analyzer, the measurement uncertainty (Ua) values on the table above the graph was obtained as below. FIGURE 4 The purpose of calculating measurement uncertainty was to provide an idea of the quality of the measurement. Measurement uncertainty describes doubts about the results of a measurement. Meanwhile, the measurement uncertainty

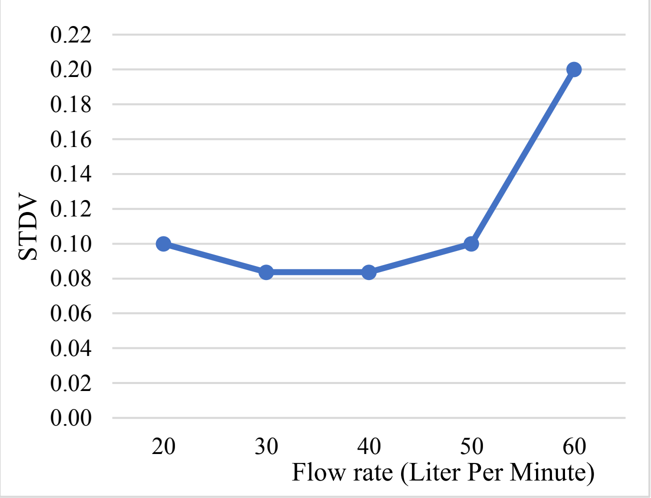

FIGURE. 4 Chart of the measurement inter-point uncertainty to determine the quality of measurements on the HFNC output

value indicates the quality of the measurement where the smaller the measurement uncertainty, the more precise the tool. In Figure 5, the highest measurement uncertainty value at the 60 LPM point was 0.09, while at the 20 LPM – 50 LPM point was 0.04. Therefore, this module was considered precise.

3) STABILITY TEST RESULTS

Table 3 shows the results of testing the stability of the HFNC tool for 30 minutes to show the performance of the tool with several flow settings from 20 - 60 LPM. When testing the stability of the HFNC output, the device was left on and for 30 minutes the output was measured in the first minute and in the 30th minute.

TABLE 3
Measurement of the stability test output of HNFC for 30 minutes

Flow Settings (HFNC) LPM	Calibrator (Gas Flow Analyzer)		Testing Time
	Initial Flow Reading (LPM)	Final Flow Reading (LPM)	
20	18.1	18.1	30 minutes
30	28	28	30 minutes
40	37.3	37.3	30 minutes
50	47	47	30 minutes
60	55.5	55.5	30 minutes

Based on the data test stability of the HFNC flowrate, the stability graph for 30 minutes on the table above the graph was obtained as below.

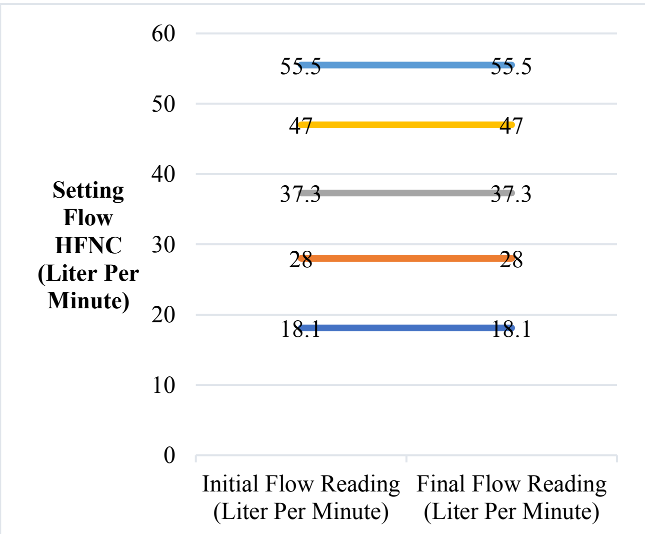

FIGURE 5. **Chart of the measurement of the output HFNC stability test for 30 minutes**

FIGURE 5 shows that the flow rate setting of 20 - 60 LPM for 30 minutes is very stable. This can be seen from the Initial Flow Reading and Final Flow Reading for 30 LPM values that did not change.

IV. DISCUSSION

Based on the measurement results using a comparison tool, namely a gas flow analyzer, the results can be seen in TABLE 1, TABLE 2 and TABLE 3. The error value between measurement points had the lowest error at the 30 LPM measurement point by 4.93%, while the highest error was at 20 LPM by 8.5%. In terms of feasibility, this module is considered feasible because overall the error results of this tool were less than 10%. The highest measurement uncertainty value was found at the 60 LPM point by 0.09 and at the 20LPM – 50LPM point was 0.04. Therefore, this module is considered precise. The stability performance test of this module is good because after a stability test has been carried out for a certain time, the displayed data results still show stability. For High Flow Nasal Canula users, this may affect the reliability of the device. This makes the feasibility of HFNC devices not as long as required by the manufacturer.

This tool can work well and is able to display graphs of discharge measurement results. However, this tool still has some drawbacks, including the GFS131 sensor reading which can be said to be not good because according to the specifications the sensor accuracy value is 4%, while the results of the readings carried out by researchers have an error of more than 4%. Therefore, the tool should use another type of sensor because the accuracy of the sensor is not good when applied even though it is precise. Using a larger TFT LCD or using 2 TFT LCDs is also recommended so that each graphic image can be seen more clearly.

V. CONCLUSION

Based on the results of planning, module creation, writing, and overall data analysis from this study, it can be concluded that the GFS131 Sensor can measure high flow rates in HFNC. The development of the equipment that the authors use is the addition of graphics to the TFT LCD to help monitor stable data in real time. This development can assist medical personnel in monitoring the flow rate and oxygen fraction in the device. Furthermore, the addition of this TFT LCD can also check the stability of the output flow and oxygen fraction of the device. This tool is expected to be more efficient, especially for developing domestic products so that the domestic products are not inferior to foreign products. In this case, the aim of this study is to ensure accurate and stable HFNC readings so that they are safe and comfortable when used in patients. Accuracy and stability really need attention because it greatly affects the reliability of HFNC so it must be monitored to ensure that patient support is working.

The error value between measurement points has the lowest error at the 30 LPM measurement point by 4.93%, while the highest error is at the 20 LPM point by 8.5%. On the reading of the GFS131 sensor, it can be said that it is not good because according to the specifications, the accuracy value of the sensor is 4%, while the results of the readings carried out by researchers have an error of more than 4%. However, in terms of feasibility of using this module, it is considered feasible because the overall error result of this tool is less than 10%. The highest measurement uncertainty value at the 60 LPM point is 0.09 and at the 20LPM – 50LPM point is 0.04. So that this module can be said to be precise.

In the future, this research can be developed using other sensors or making a better analog conditioning signal. In addition, the module can use two graphic LCDs to make it easier for users to remotely monitor stability with the IoT system as these devices are usually located in the infection room. The development of this tool can also use automatic pulse oximetry settings for oxygen flow and fraction so that users do not need to stay inside the room to change the settings.

REFERENCES

[1] K. KESEHATAN and T. L. COVID-19, “Tatalaksana Covid-19.” Jakarta, p. 93, 2021.
[2] D. B. Jernigan, “Update: Public Health Response to the Coronavirus Disease 2019 Outbreak — United States, February 24, 2020,” *MMWR. Morb. Mortal. Wkly. Rep.*, vol. 69, no. 8, pp. 216–219, 2020, doi: 10.15585/mmwr.mm6908e1.
[3] A. M. Dondorp, M. Hayat, D. Aryal, A. Beane, and M. J. Schultz, “Respiratory support in COVID-19 patients, with a focus on resource-limited settings,” *Am. J. Trop. Med. Hyg.*, vol. 102, no. 6, pp. 1191–1197, 2020, doi: 10.4269/ajtmh.20-0283.
[4] M. Nishimura, “High-flow nasal cannula oxygen therapy devices,” *Respir. Care*, vol. 64, no. 6, pp. 735–742, 2019, doi: 10.4187/respcare.06718.
[5] W.H.O., “Novel Coronavirus (2019-nCoV) Situation Report - 34 23 februar 2020,” *World Heal. Organ*, vol. 2019, no. February, p. 2633, [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019.
[6] W. Geng, W. Batu, S. You, Z. Tong, and H. He, “High-Flow Nasal Cannula: A Promising Oxygen Therapy for Patients with Severe Bronchial Asthma Complicated with Respiratory Failure,” *Can. Respir. J.*, vol. 2020, pp. 1–7, 2020, doi: 10.1155/2020/2301712.
[7] D.-L. Salvador *et al.*, “Things to Keep in Mind in High Flow Therapy: As Usual the Devil is in the Detail,” *Int. J. Crit. Care Emerg. Med.*, vol. 4, no. 2, pp. 1–8, 2018, doi: 10.23937/2474-3674/1510048.
[8] Fănel Dorel ȘCHEAUA, “Theoretical Approaches Regarding the VENTURI Effect,” *Hidraulica*, no. 3, pp. 69–72, 2016.
[9] J. Li, J. B. Fink, and S. Ehrmann, “High-flow nasal cannula for COVID-19 patients: Low risk of bio-aerosol dispersion,” *Eur. Respir. J.*, vol. 55, no. 5, 2020, doi: 10.1183/13993003.00892-2020.
[10] D. M. Devices, “Medical device guidance,” *US Patent 10,314,559*, no. October. pp. 1–15, 2008. [Online]. Available: http://www.hsa.gov.sg/content/dam/HSA/HPRG/Medical_Devices/Overview_Framework_Policies/Guidances_for_Medical_Device_Registration/GN-15-R6.1 Guidance on Medical Device Product Registration.pdf
[11] Komite Akreditasi Nasional, “Kan Guide on the Evaluation and Expression of Uncertainty in Measurement,” 4, 2016
[12] S. R, “ISO/IEC 17025:2005,” 2006
[13] International Electrotechnical Commission, “IEC 60601-1, 2005: A revolutionary standard, Part 1. Medical Device and Diagnostic Industry,” 2005
[14] A. Saguni, “Metode Kerja Pengujian Dan Atau Kalibrasi Alat Kesehatan,” *Metode Kerja Pengujian dan / atau Kalibrasi Alat Kesehatan*, vol. 70. p. 32, 2015.
[15] Departement Kesehatan Republik Indonesia, “Pedoman PENGUJIAN DAN KALIBRASI ALAT KESEHATAN,” 601.28
[16] A. Agarwal *et al.*, “High-flow nasal cannula for acute hypoxemic respiratory failure in patients with COVID-19: systematic reviews of effectiveness and its risks of aerosolization, dispersion, and infection transmission,” *Can. J. Anesth.*, vol. 67, no. 9, pp. 1217–1248, 2020, doi: 10.1007/s12630-020-01740-2.
[17] E. S. Muhammad Khosyi’in , Agus Suprajitno, “Alat Penghitung Volume dan Timer Penggunaan Oksigen,” *Alat Penghitung Volume dan Timer Penggunaan Oksigen*, vol. d. Sekolah Tinggi Teknologi Nasional Yogyakarta, Yogyakarta, pp. 1–8, 2017.
[18] J. A. Prakosa and L. P. Kozlova, “Design and simulation of automatic control valve for gas flow meter calibrator of bell prover,” in *Proceedings of the 2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2018*, 2018, vol. 2018-Janua, pp. 966–969. doi: 10.1109/EIConRus.2018.8317250.
[19] Y. N. Firdaus, S. Syaifudin, and M. P. A. Tetra Putra, “Alat Ukur Konsentrasi Dan Flow Oksigen Pada Ventilator,” *J. Teknokes*, vol. 12, no. 1, pp. 27–32, 2019, doi: 10.35882/teknokes.v12i1.5.
[20] D. L. Grieco *et al.*, “Effect of Helmet Noninvasive Ventilation vs High-Flow Nasal Oxygen on Days Free of Respiratory Support in Patients with COVID-19 and Moderate to Severe Hypoxemic Respiratory Failure: The HENIVOT Randomized Clinical Trial,” *JAMA - J. Am. Med. Assoc.*, vol. 325, no. 17, pp. 1731–1743, 2021, doi: 10.1001/jama.2021.4682.
[21] A. Medical, *AirBlend*, Manual Boo. 1984.
[22] D. A. Suffredini and M. G. Allison, “A Rationale for Use of High Flow Nasal Cannula for Select Patients With Suspected or Confirmed Severe Acute Respiratory Syndrome Coronavirus-2 Infection,” vol. 36, no. 1, pp. 9–17, 2021, doi: 10.1177/0885066620956630.
[23] D. Yildizdas, A. Yontem, G. Iplik, O. O. Horoz, and F. Ekinci, “Predicting nasal high-flow therapy failure by pediatric respiratory rate-oxygenation index and pediatric respiratory rate-oxygenation index variation in children,” *Eur. J. Pediatr.*, vol. 180, no. 4, pp. 1099–1106, 2021, doi: 10.1007/s00431-020-03847-6.
[24] M. O. Yolanda, T. Rahmawati, and Moch. Prastawa, “Analisis Keakuratan Hasil Kalibrasi Pada Rancang Bangun Alat Kalibrator Gas Flowmeter Menggunakan TFT LCD,” in *Prosiding Seminar Nasional Kesehatan Politeknik Kesehatan Kementerian Kesehatan Surabaya*, 2020, pp. 1–6.
[25] M. F. Radzi, H. M. Saputra, C. H. A. H. B. Baskoro, M. Mirdanies, R. I. A. Aziz, and N. Ismail, “PID-Based Fraction of Inspired Oxygen (FiO2) Control System in ICU Ventilator,” *2021 IEEE 7th Int. Conf. Smart Instrumentation, Meas. Appl. ICSIMA 2021*, pp. 185–189, 2021, doi: 10.1109/ICSIMA50015.2021.9525942.