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Analysis of Changes in Flow Setting Against Rise Time Using Gas Board 7500E Sensor on Bubble CPAP

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ABSTRACT Respiratory distress syndrome (RDS) is a breathing disorder that occurs in newborns, often in premature babies born before 28 weeks of gestation. The bubble CPAP (Continuous Positive Airways Pressure) is a device used to provide positive pressure to newborns who can breathe spontaneously but are still prone to apnoea. The rise time is the time it takes for the airway pressure to reach the maximum standard value. The aim of this study is to analyze the changes in flow regulation during the rise time using a 7500E gas sensor card on a bubble CPAP probe. The method used in this study is to use the mean hijacking of the sensor to reduce the noise generated by the sensor. When analyzing the data, the researcher recorded data up to five times and calculated the mean measurement error. The research design is calibrated to confirm the correctness of the displayed values. The results of the data analysis are a mean error value of 0.88% at a setting of 30% oxygen content, 0.78% at a setting of 50%, and 0.95% at a setting of 90%. For liters per minute (LPM) at the 1 LPM and 5 LPM settings, the mean error values are 0.18 % and 0.03 % for the 10 LPM setting. From the test results with 3 bubble CPAP devices, it appears that when a high LPM setting is used, the oxygen concentration is reached faster with a mean value of ±10 seconds. The conclusion from this study shows that increasing the oxygen flow rate affects the duration of the rise in bubble CPAP oxygen concentration. The implication of this study is that this data will help add artificial intelligence to bubble CPAP to automatically determine settings by combining breathing data from patients.

INDEX TERMS Bubble CPAP, Gas Board 7500E Sensor, Rise Time, SD Card, Graphics.

I. INTRODUCTION

Respiratory distress in newborns is one of the biggest problems we face on a daily basis. Breathing difficulties often show up in newborns as tachypnoea or breathing that is above the normal rate. These symptoms can appear from a few hours to a few days after birth. Proper diagnosis and treatment are very important in determining the use of a bubble CPAP device. Bubble CPAP is a method [1] or procedure of administering CPAP [2] that creates positive pressure by inserting an exhalation tube into water to a certain depth to provide positive air pressure to the patient through the proper nasal passages [3]. The use of bubble CPAP has been shown to reduce respiratory distress, reduce oxygen dependence [4], help increase and maintain residual lung capacity, prevent upper airway obstruction and lung collapse, reduce apnea, bradycardia, and cyanotic episodes, and shorten ICU length of stay. In the bubble CPAP device, the given oxygen concentration in the mixture with free air can be adjusted from 21% to 98%, and the flow can be adjusted from 0 to 7 LPM at the flowmeter output mixture, and by adding moisture to the circuit, the oxygen concentration can be reduced from 1% to 5% [3][5][6] [7]. Oxygen and free air are fed into the bubble CPAP system via the compressor pressure. If there is a drop in pressure of any of the input gases, an alarm will sound indicating that the device is not working [8]. It is very dangerous to give oxygen therapy [9] to newborns without first measuring arterial oxygen pressure and oxygen saturation [10][11]. to achieve an oxygen tension (PO2) of 40-80 mmHg and/or oxygen saturation (SpO2) of 88-92% [12]. Nasal continuous positive airway pressure (CPAP) is a common form of non-invasive respiratory support for the treatment of preterm infants with respiratory distress [13]. The main mechanism of action of CPAP is to increase airway pressure to ventilate the lungs, maintain functional residual capacity, improve oxygenation and reduce the work of breathing [14]. This pressure is partially transmitted to the infant's airway via a short, close-fitting binasal joint or nasal mask [15]. When using the bubble CPAP, the resulting resistance is a certain depth of the "expiratory tube" underwater [16]. One of the troubleshooting for the use of CPAP in infants is to ensure that the blander is set according to the correct oxygen percentage [17], ensuring that it is able to regulate changes in the fluctuating administered oxygen concentration [18] and ensuring that the bubble CPAP is the right device for the newborn. Breathing stops [19] with the NPM (Neonatal Volume Monitor) can accurately detect tidal volume flow [20] with a frequency of 0-150 breaths/min and a minimum of 1.0 ml tidal volume, but cannot be measured accurately. The bubble CPAP system also does not measure the concentration of oxygen produced at the outlet. The rise time has been defined as the time it takes for the airway pressure [21] to rise to a given maximum value. The fast rise time value allows immediate flow delivery at the start of the breath, resulting in an immediate pressure rise to a predetermined value. The slow rise time, on the other hand, prevents flow delivery at the beginning of the application [22], delaying the pressure rise to a predetermined level. The setting of the rise time can, directly and indirectly, affect other parameters of mechanical ventilation [23]. Controlling the circulatory criteria allows the clinician to adjust the supportive ventilatory pressure based on peak inspiratory flow [24]. Simply stated, the circulation criteria define the terminal portion of the inspiratory flow at which the ventilator will cycle the pressure supporting [25] the breath into the expiration phase. Circulation criteria only work as long as the breath supports pressure [26].

Oxygen concentration on the bubble CPAP device states that bubble CPAP works by using oxygen supply and compressed air from a compressor mixed with free air with a mixing machine to produce the desired oxygen concentration. PEEP depth is the pressure at the end of exhalation. In this study, it is not displayed digitally, cannot measure flow, and cannot analyze the effect of pressure drop on a gas supply on the concentration of oxygen produced. The measurement of oxygen concentration on the bubble CPAP device using an oxygen sensor of the 7500E ultrasonic gas panel as an oxygen concentrator gives quite good results after comparing with the results of LPFK calibration with an oxygen concentration limit of ±3%, but in this study, the measurement of oxygen flow rate is not performed.

Based on the research literature, discussions about bubble CPAP are more often about oxygen input pressure and oxygen output concentration, but analysis of rise time is still rarely studied. In this study, the researcher use the 7500E gas sensor board to measure and analyze changes in flow settings in relation to rise time and their effect on the output oxygen concentration on the Bubble CPAP device by displaying a graph of rise time and storing the data on an SD card so that it can be displayed on a PC. The aim of this study is to determine the time it takes for the patient to receive oxygen delivery according to the patient's needs.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

In this study, the researchers used 3 (three) bubble CPAP machines and took 5 (five) measurements. Measurements were taken for each setting with oxygen concentrations of 21%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. The results of the measurement of oxygen concentration and rise time on the CPAP are compared with a calibrated oxygen analyzer.

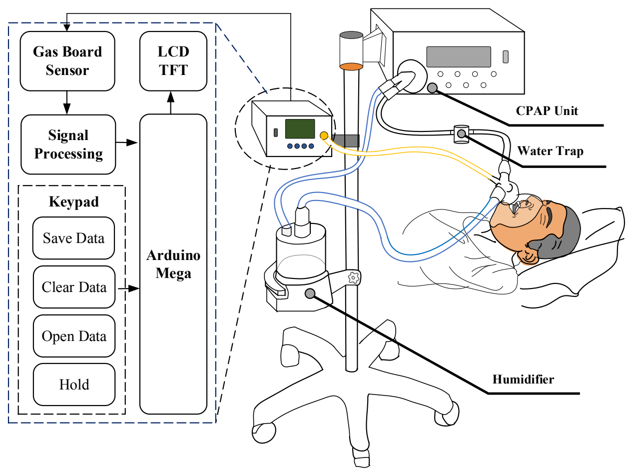

FIGURE 1. The Diagram Block Of Module Bubble CPAP Unit using Arduino Nano, Gas Board 7500E oxygen sensor and displayed with LCD TFT.

1) MATERIALS AND TOOL

This study uses a calibrated CPAP calibrator as a comparison of the data obtained during the experiment. The sensor used is the Gas board 7500E oxygen sensor which has the ability to measure oxygen concentration. Furthermore, the use of a microcontroller in the form of Arduino nano is used in the data processing. The display of the results of this module uses a TFT LCD with an SD Card as a place to store measurement data that has been carried out. Lithium battery in this study is used as a voltage source.

2) EXPERIMENT

After the design is completed, the module is tested by Ventest 800 Series RIGEL Medical made in the UK with a standard model for universal application appearance [27] [28]. At the beginning of the experiment, it must be ensured in advance that the value of the oxygen concentration and oxygen flow rate is in accordance with the standard. Then, the mean rise time is measured by assessing the increase in oxygen flow rate at each concentration stage for five repetitions on three CPAP bubble devices.

B. THE DIAGRAM BLOCK

In FIGURE 1 shows when the system starts to work when the appliance is on.
The Mega Arduino as an Arduino board using the ATmega microcontroller ic initializes the connected hardware including the TFT-LCD, the SD card, and the oxygen sensor Gasboard 7500E. The oxygen sensor of the Gas-Board 7500E is used to measure the oxygen concentration. The Arduino Nano microcontroller IC then processes the sensor readings and displays them on the TFT-LCD. The measurement results of the proximity sensor and the light sensor are stored on the SD card so that the measurements taken can be retrieved one day using a PC.

C. THE FLOWCHART

FIGURE 2 shows the flowchart when the unit is switched on and initialization of the LCD, the 7500E gas sensor board and the SD card begins. Then the sensor starts measuring the oxygen concentration and proceeds to convert the data into the ADC. If the previous reading is not recognized, the sensor returns to measuring the oxygen concentration. However, if the reading is recognized, the data is saved directly to the SD card. The results of the rise time and oxygen concentration measurement on the TFT LCD are also saved on the SD card. And the process has been completed.

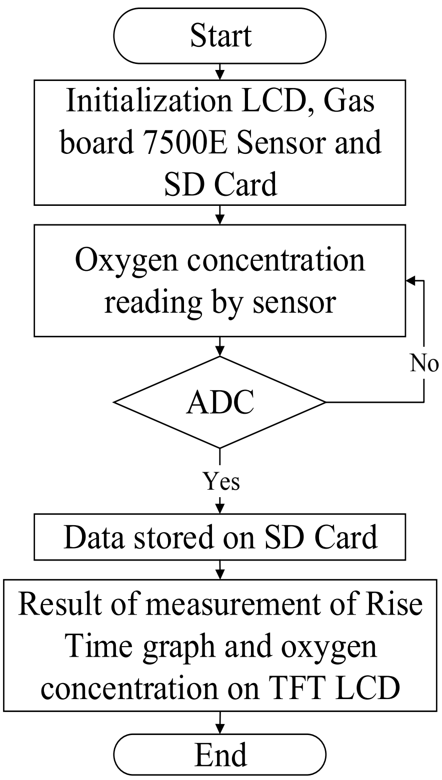

FIGURE 2. **The Flowchart Of Module Bubble CPAP Unit**

III. RESULTS

FIGURE 3 shows the results of the design, which consists of a 7500E gas sensor board, a 12 V amplifier module, a TFT LCD display, and a protection device.

The photograph of the design is shown in FIGURE 3, respectively. In FIGURE 3, the design consists of a Gas board 7500E Sensor, step-up module 12 V, LCD TFT as its display and shield.

III. RESULTS

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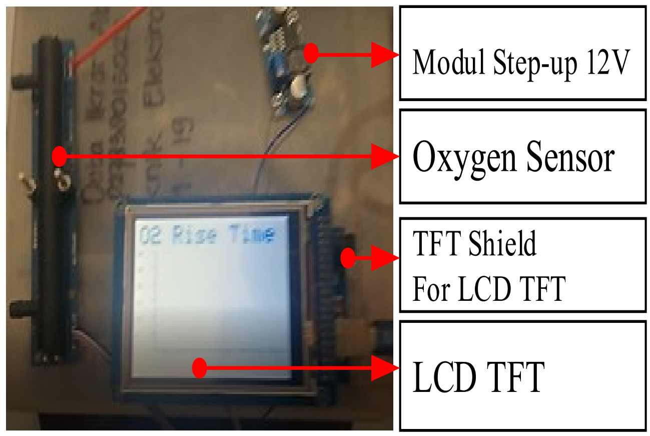

FIGURE 3. **Design of oxygen sensor using gas board 7500E sensor, step up module 12 V and LCD TFT displayed**

3) MEASUREMENT RESULT

This device is tested with the Ven Test 800 calibrator. TABLE 1 shows the mean and STD values of the oxygen concentration. This value is obtained by repeating the data collection 10 times.

TABLE 1
The Measurement of oxygen concentration with 30%, 50% and 90% setting with Mean, STD Value and Mean Error

Setting (%)	Mean (%)	STD	Mean Error %
30%	30,88	0,04	0.88%
50%	50,78	0,04	0.78%
90%	89,05	0,08	0.95%

In TABLE 1, the mean error at the 30% oxygen setting is 0.88%, at the 50% oxygen setting is 0.78% and at the 90%, oxygen setting is 0.95%. TABLE 2 shows the mean value and

STD of the oxygen flow modules. This value is determined with 10 repetitions.

TABLE 2
The measurement of oxygen flowrate for 1, 5, and 10 LPM setting with Mean, standard deviation (SD) value and mean error. The mean values were obtain from ten repeat measurement.

Setting	Mean (^{0})	SD	Mean Error %
1 LPM	1,18	0,03	0.18%
5 LPM	5,17	0,01	0.17%
10 LPM	10,03	0,00	0.03%

TABLE 2 shows the mean error value in liters per minute (LPM) at a setting of 1 LPM and 5 LPM, the mean error value is 0.18% and 0.03% at a setting of 10 LPM. This measurement is done with 5 repetitions and the mean rise time is measured when the oxygen flow rate is increased. They are then compared with the three CPAP bubbles. TABLE 3 shows the mean value of rise time for the first CPAP bubble.

TABLE 3
The mean rise time value in seconds on bubble CPAP 1 for different flow setting LPM with concentration setting from 21 to 100 %.

Setting (%)	Mean of rise time (s)		
	1 LPM	5 LPM	10 LPM
21	24.28	16.25	14.10
30	23.22	15.18	11.38
40	23.22	15.24	10.45
50	23.81	16.41	12.94
60	23.44	16.38	12.80
70	24.53	14.31	12.38
80	25.18	13.48	11.47
90	24.55	12.53	10.37
100	24.09	10.39	10.15
Mean	24.03556	14.46333	11.78222

FIGURE 4 shows the rise time graphic on the first bubble CPAP when the oxygen flow rate is increased. In FIGURE 4, the oxygen flow setting of 1 LPM has a mean rise time of 24,036 seconds, the oxygen flow setting of 5 LPM has a mean rise time of 14,463 seconds, the oxygen flow setting of 10 LPM has a mean rise time of 11,782 seconds. In TABLE 4 shows the mean rise time value on the second bubble CPAP.

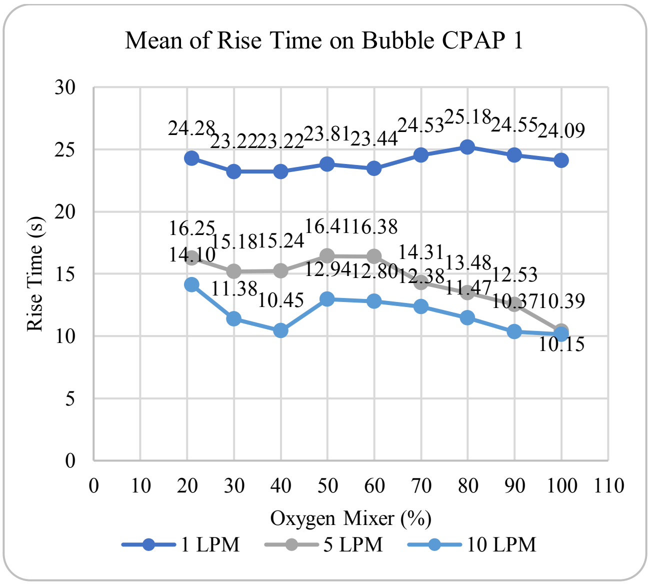

FIGURE 4. Graphic of Mean Rise Time on First Bubble CPAP I in 0-110% of oxygen mixer with 1, 5 and 10 LPM setting and

TABLE 4
The mean rise time value in seconds on bubble CPAP 2 for different flow setting LPM with concentration setting from 21 to 100 %.

Setting (%)	Mean of rise time (s)		
	1 LPM	5 LPM	10 LPM
21	24.34	16.40	14.16
30	23.35	15.23	13.39
40	23.40	15.25	12.47
50	23.84	16.36	13.11
60	23.26	16.47	12.80
70	24.82	14.17	12.51
80	25.17	13.63	11.59
90	24.65	12.71	10.30
100	24.12	10.43	10.11
Mean	24.10556	14.51667	12.27111

FIGURE 5 shows a graph of the second bubble CPAP rise time when the oxygen flow rate is increased. The LPM settings are 1, 5 and 10. The highest value for the oxygen mixer rise time is at the 1 LPM setting. The lowest value for the oxygen mixer rise time is at the 10 LPM setting. The highest bubble CPAP 2 rise time value is 25.17 s at 80% oxygen mix. In FIGURE 5, the 1 LPM oxygen flow setting has an mean rise time of 24.106 seconds, the 5 LPM oxygen flow setting has an mean rise time of 14.517 seconds, and the 10 LPM oxygen flow setting has an mean rise time of 12.271 seconds.

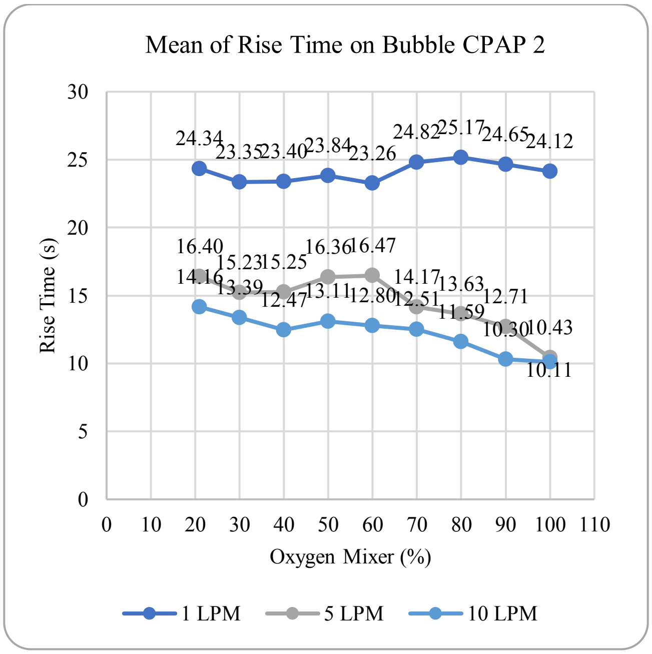

FIGURE 5. Graphic of mean rise time in 0-110% oxygen mixer with 1, 5 and 10 LPM setting on first bubble CPAP II

In TABLE 5 shows the mean rise time value on third bubble CPAP.

TABLE 5

The mean rise time value in seconds on bubble CPAP 3 for different flow setting LPM with concentration setting from 21 to 100 %.

Setting (%)	Mean of Rise Time (s)		
	1 LPM	5 LPM	10 LPM
21	24.28	16.25	14.09
30	23.30	15.30	13.33
40	23.40	15.50	12.41
50	23.84	16.28	12.84
60	23.28	16.49	12.89
70	24.80	14.60	12.39
80	25.16	13.82	11.45
90	24.72	12.57	10.31
100	24.14	10.36	10.12
Mean	24.10222	14.57444	12.20333

FIGURE 6 shows the rise time graphic on the third bubble CPAP when the oxygen flow rate is increased. In FIGURE 6, the oxygen flow setting of 1 LPM has a mean rise time of 24,102 seconds, and the oxygen flow setting of 5 LPM has a mean rise time of 14,574 seconds, the oxygen flow setting of 10 LPM has a mean rise time of 12,203 seconds.

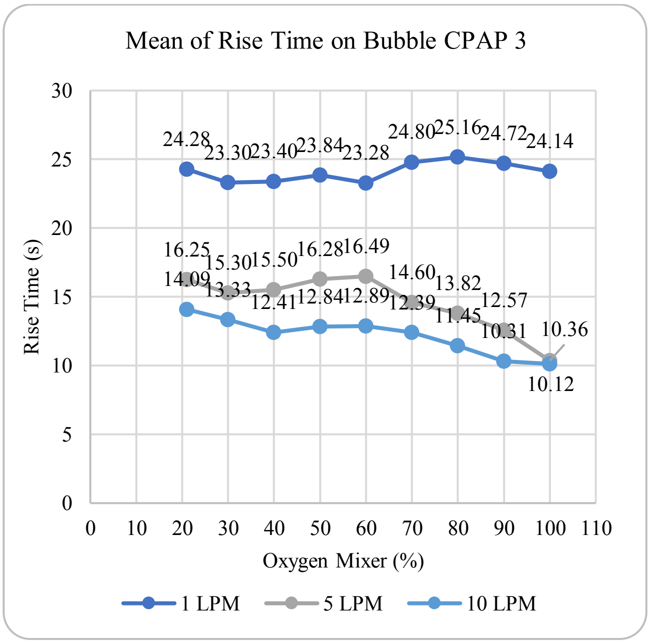

FIGURE 6. Graphic of mean rise time in 0-110% oxygen mixer with 1, 5 and 10 LPM setting on first bubble CPAP III

IV. DISCUSSION

In this study, a module is created with the title analysis of flow rate changes to rise time settings using the 7500E gas sensor board on the CPAP blower. The 7500E sensor selected in this study has the advantage of being able to detect oxygen concentrations. The microcontroller in the form of an Arduino nano acts as a data processor and displays the output in the form of graphs on the TFT LCD. There is a memory in the module in the form of an SD card where the data of the measurement results can be stored.

The tests of this module were compared with a built-in calibrator. The best results were obtained for measurements with oxygen concentrations at setting points of 30%, 50%, and 90%. Similarly, the value of the tariff module is checked on the calibrator. In both tests, the value of the standard deviation is less than 1, which means that the mean value obtained for the calibrator is close or has been measured with this module and is considered good and can be used as a reference in further data collection. Then the relationship between the rate of rise and the time of rise of oxygen is determined using data collected with three different CPAP spheres. The average data is obtained by 5 iterations for each setting. Looking at the graphs of CPAP I to III (FIGURE 4-6), it is found that there is an effect between the rate of rise of oxygen and the time of rise of oxygen concentration of CPAP. Whereas the measurement results with 3 different CPAP devices obtained with a high LPM setting reach the desired oxygen concentration faster.

Comparison the appearance of this module is also compared with the work of previous researchers. In the study conducted by Won [13], he monitored the oxygen concentration in the CPAP machine, but this study did not display the data digitally, could not measure the rate, and had not previously analyzed the effect of the pressure drop during gas delivery on the concentration. Andjar Pudji's study developed a measurement of oxygen concentration in CPAP bubbles using a 7500E ultrasonic gas sensor card, but this study did not measure the oxygen flow rate [29]. Triwiyanto et al. studied analyzing the difference in input pressure on the output concentration of CPAP bubbles appears TFT display [30]. This study has measured the input pressure on CPAP and from the results of the research oxygen concentrations of 30%, 50%, and 90% explain the effect of pressure on CPAP output, but in this study, we have not analyzed the results of CPAP output when changing the settings. This is the limitation of this module because repeated data collection requires a lot of energy, so the battery runs out quickly. The graph displayed on the TFT LCD then does not cover all measurements.

V. CONCLUSION

The purpose of this study is to test the use of the 7500E gas sensor card in measuring and analyzing changes in flow regulation as a function of rise time, and also to determine its effect on the output of oxygen concentration in the bubble CPAP machine by displaying a graph of rise time, the data for which is stored on the SD card so that it can be viewed on the PC. The other purpose of this study is to determine the time it takes for the patient to receive an on-demand oxygen supply. The research design is calibrated to confirm the correctness of the displayed values. The results obtained are the average error value of 30% oxygen level of 0.88%, 0.78% for the 50% setting, and 0.95% for the 90% setting. for liters per minute (LPM) with 1 LPM and 5 LPM settings, the average error value is 0.18%, and 0.03% for 10 LPM settings. From the results of the graph, it can be concluded that the higher the oxygen supply, the faster the time to reach the maximum oxygen concentration increases. From the test results with 3 CPAP devices, it can be seen that when a high LPM setting is used, the oxygen concentration is reached faster with a mean value of ±10 seconds. For the next researcher, the results of this study can be used for research related to the use of bubble CPAP in adding artificial intelligence to CPAP for automatic settings by combining respiratory data from patients.

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