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SALINE FLUID FLOW SUPERVISION IN INTENSIVE CARE UNIT USING PRECISION ALGORITHM

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ABSTRACT

Saline fluid infusion in intra vein supervision is imperative to correct significant abnormalities. The fluid infusion rate influence on the physiological parameters like systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), pulse rate (PR) and respiration rate (RR). The temperature (T) will change with rapid infusion of saline fluid. Saline fluid level monitoring is also significant. Monitoring these parameters continuously using Atmega 328 controller and energizing the alarm system and sending alert signals to the registers persons to curtail further disorders. With preset volumetric flow rate of the fluid patient is observed for 30 minutes with dextrose solution. Heart rate and cardiac stroke volume (CSV) and cardiac stroke volume index (CSVI) values change with increasing fluid infusion rate. Ther saline fluid infusion rate is controlled based on the changes of HR level, CSV, CSVI, SBP, and DBP variations, body temperature and RR values. The experimental finding shows blood pressure variation (BPV) change of 11.56%. systolic blood pressure (SBP) is increased 8% and diastolic blood pressure is decreased 3.25%. The heart rate change is 1.25 BPM. After 30 minutes of observation the heart rate change is 12%. This is significant.

Keywords: *Saline Fluid Monitoring, Systolic Blood Pressure, Diastolic Blood Pressure, Heart Rate, Pulse Rate, Cardiac Output, Cardiac Stroke Volume.*

1. INTRODUCTION

Infusing fluid into intracellular vessels is imperative to balance the electrolytes, to correct acid-based abnormalities and some specific disorders. The inadequate infusion of saline fluid and rapid infusion leads to disorders in human body. Infusion of saline is influencing on HR and of the atrial valve pressures. The CSV and CSVI is considered. Infusion of saline increases the CSVI value. Diastolic pressure levels are increased, and systolic pressure levels decreased significantly. The heart rate is continuously monitored during infusion of saline. Significant changes of diastolic and systolic pressure volume levels influencing on the heart rate.

Most of the relevant papers focused on mechanical system development and its kinematics. Some research papers considered heart rate and blud pressure parameters impact with saline fluid infusion.

But the proposed article/ paper meticulously regulating the fluid flowrate and addressing insight analysis of the physiology. The clinical investigations or findings are corelated with the physician recommendations.

The difference of diastolic and systolic volume levels represents the stroke volume. The heart rate is much influenced with stroke volume. With increase in stroke volume, the heart rate is significantly increased. The cardiac output is estimated with the multiplication of stroke volume and heart rate. Changes in heart rate is influencing on the changes of cardiac output.

Literature review screening is done to develop a reliable model. Relevant work discussion is not included in the paper owing to more results and discussion. Research work is presented to impart good significant study.

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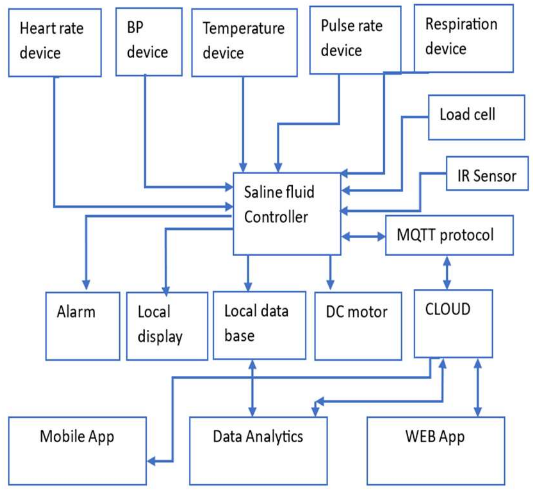

Fig.1.1. Block Diagram Of Saline Fluid Infusion Control With Varying Parameters

The heart rate is continuously measured during infusion of saline. Cardiac output increases with increasing heart rate value [1][3]. The cardiac stroke volume represents the volume of blood intake and pushing out for every heartbeat. During the resting position the normal cardiac output is 5-6 l/m.[4][14]

The HR, RR, Blood pressure (BP), body temperature and PR are continuously measured and supervised by the saline fluid controller. Fig.1.shows Atmega 328 Micro controller is used to acquire the above physiological parameters while infusing the saline fluid [2][8]. The fluid level of the saline bottle is measured using loadcell device and IR sensing device. The data acquired from these devices processed using Atmega 328 micro controller. Rapid infusion of saline will change the physiological parameters results adverse effects on the patient [9]. If any parameter value is exceeding the threshold value, the local alarm is energized. The processed information is stored in the local data base and upload to the cloud. Mobile app or web app is used to receive the alert messages dynamically. 100 RPM DC motor is used to regulate the fluid flow to keep the BP, RR, body temperature, and PR within the threshold values. Geared assembly is attached to the shaft of the DC Motor. This gear is directly connected to the mechanical saline flow control wheel. The position of the wheel determines the amount of fluid is infusing into the human body [10][11]. The positional adjustment supervised and controlled by the saline fluid controller with the variation of the physiological parameters. Message queuing and telemetry transport protocol is used to publish the information in cloud. This is publish and subscribe type of protocol. The body surface area is considered during infusion of saline. Body surface area is the surface area of human body. This is estimated using the eq.1

Body surface area= 0.007184X(height of the human body)0.007184 X (Weight (kg.)0.425 … Eq1

The breathing rate is estimated with number of breaths per second multiplied with the multiplication factor 4. [5]The breath rate is estimated as 112. This breath rate increases with rapid infusion of the saline infusion. The saline infusion is influence on body temperature. The heat dissipation is increased which results core temperature of the body is decreased. The change of body temperature is considered during saline infusion. The rapid saline infusion is impacted on the blood pressure levels. The size of the catheter is considered to regulate the flow speed of the saline fluid [14]. The flow of saline fluid depends on the bore size. With increasing bore size, the flow rate is increased. The position of the fluid bottle also influenced on the flow of fluid. The flow rate of the fluid increased with the height of the intra vein fluid bottle. This parameter is also considered to regulate the fluid flow stability.

The objective of this study to regulate the fluid flow without elevating the physiological parmeters. Specifically, SBP,DBP, CSV,and HR. An abrupt pumping of fluid flow results adverse effects especially on the lung and cardia functions. So autonomous fluid flow system design by safeguarding the physiological parametyers is addressed.

2. METHODOLOGY

Volumetric flow rate (Q) and mass flow rate (m) of the fluid flow is considered.

Volumetric flow rate (Q) m3/sec = Velocity of the fluid flow (V) X Cross-sectional area of the tube (A) ….. Eq.2

The velocity of fluid flow is determined based on the number of drops of saline infusing per second. The velocity of the fluid flow is depending on the body weight of the human body and the physiological temperature and respiration rate. The body weight is estimated using eq.1. i.e., 3.225×10^{-5}. Increasing fluid flow impacted on the RR value and lowering the body temperature. So, Infusion of the fluid flow regulation is imperative to curtail further abnormalities. HR

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and CSV and CSVI values changed with increasing fluid infusion rate.

The fluid ejection fraction is estimated using the formula $\frac{[EDV-ESV]}{EDV}$ … Eq.3

Mass flow rate of the fluid flow (m) = Velocity of the saline fluid flow (V)×Area of the Tube (A) × density of the fluid flow (ρ) … Eq.4

Per every 1000ml of saline contains 0.90 grams of sodium chloride. Its density is 1.0046 g/cm3 at 22 degrees centigrade.

The cross-sectional are of the saline pipe:

$A = \pi \left(\frac{d}{2}\right)^2$ --- Eq.5

The inner diameter of the pipe (d) is estimated to 1mm.

The cross-sectional are of the saline pipe (A) = 3.14 × (1/2)2 = 0.785 …Eq.6

The saline fluid bottle volume = 1000ml

Infusion duration is 2 hours.

Total infusion interval = weight of the saline fluid/ drip rate … Eq.7

=1000/2=500ml/h

=1.38ml/min

one 'ml' of the saline fluid is deliberated with 20 saline drops. 1.38 ml/min of saline fluid is estimated as 27.6 drops / min this determines the saline fluid flow rate.

2.1. Algorithm

Step1: Initialize the threshold value of heart rate.

Initialize the threshold value of Pulse rate.

Initialize the threshold value of SBP.

Initialize the threshold value of DBP. Initialize the threshold value of Respiration rate. Initialize the threshold value of temperature.

Set the initial Volumetric saline fluid rate.

Set the initial fluid level to 1000 ml.

Set the Sample time is 5sec.

Step2: Read the data from the Load cell.
Read the data from IR sensor.
Estimate the mean value of the load cell and IR sensor data.
Normalize the output value to fluid level.

If the fluid level is ≤ 50ml

Enable the alarm system.

Send the message to registered mobile devices.
Estimate the volumetric and mass flow rate values.
Else store the fluid level change in data base. Upload to cloud.

Step3: Read the SBP and DBP values.

Table 3.1. Case Study

Name	Age	Abnormality	Fluid	Body weight (Kg)	BP		HR	RR	T	V m/sec	A M^2
					SBP	DBP					
Patient 1	45	Hypertension and pneumonia	Dextrose	74.6	148	91.3	99.4	21	37.48C	0.18	0.785

Table 3.2. Variation Of Physiological Parameters With Fluid Infusion

TI min	Fluid level		SBP mmHg	DBP mmHg	PP mmHg	HR (BPM)	CSV (ml/m)	CO l/m	CSVI ml/m2	RR	T ºC	Q mm^3/s	M mg/s
	LC	IR											
-	1000	1000	138	89	49	99.4	60.4	5.4	43.0	26	37.4	1.08	1.08
5	993.1	992.9	140.7	87.7	59.3	98.8	60.4	5.5	46.1	26	37.4	1.08	1.08
10	986.2	987.0	140.7	87.3	59.9	92.6	60.4	5.2	41.2	27	37.3	1.08	1.08
15	979.3	979.2	143.5	86.7	56.8	86.3	60.4	4.95	41.0	27	37.2	1.08	1.08
20	972.4	972.1	144.9	86.4	58.5	81.5	60.4	4.72	39.8	28	37.2	1.08	1.08
25	965.5	964.9	148.6	86.3	62.3	75.25	60.3	4.47	38.9	28	36.8	1.08	1.08
30	958.6	958.7	149.0	86.1	62.9	73.25	60.4	4.36	38.6	28	36.7	1.08	1.08

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Estimate the mean values of SBP and DBP

If the SBP ≥ threshold value

Enable the motor assembly and decrease the volumetric flow rate to 50 % of the initial flow rate.

Else if

DBP ≤ threshold value

Enable the motor assembly and increase the volumetric flow rate to 15 % of the initial flow rate. Store the rate change in data base

Step4: Read the respiration rate.

Step5: Read the heart rate.

Estimate the mean value of it.

If the heart rate ≤ the threshold value

Then

Enable the motor assembly and increase the volumetric flow rate to 15 % of the initial flow rate and store the rate change in data base.

If the respiration rate is ≥ the threshold value

Then

Enable the motor assembly and increase the volumetric flow rate to 15 % of the initial

Flow rate and store the rate change in data base.

Step6: Read the pulse rate.

If the pulse rate is ≥ the threshold value

Then

Enable the motor assembly and decrease the volumetric flow rate to 25 % of the initial

Flow rate and store the rate change in data base.

Repeat step2.

3. RESULTS AND DISCUSSION

The level of the saline fluid bottle is estimated using load cell and Infrared radiation (IR) sensing devices. Two different sensing devices considered to achieve redundancy.

This paper is considered 1o2 (one out of two) phenomena. And the mean of the two sensor outputs is considered to determine the level of the saline bottle fluid. Load cell is used as deflection flow meter to estimate the fluid level. The HR, SBP, DBP, CSV and CSVI value, RR, temperature of the human body, is deliberated with respect to the change of the fluid level and the fluid flow rate of the fluid. The blood pressure variance (BPV) is much significant for hypertension patients and cardiovascular abnormal patients [6][7]. Based on the study, the BPV value is varying with 11.58 % with two bottles of 500 ml of the fluid is infusing into the intra vein vessel.

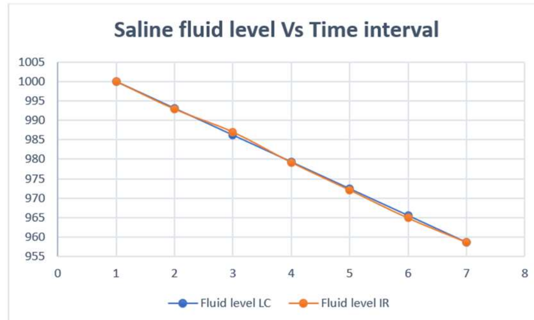

Fig.3.1. Saline Fluid Level Vs Time

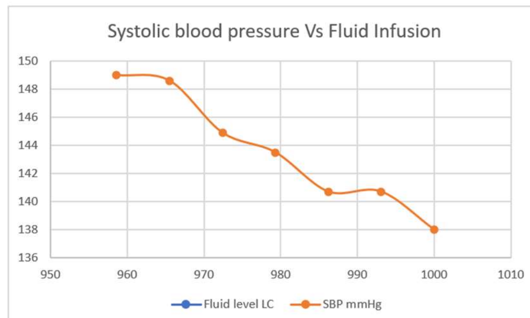

Fig.3.2. SBP Vs Fluid Infusion

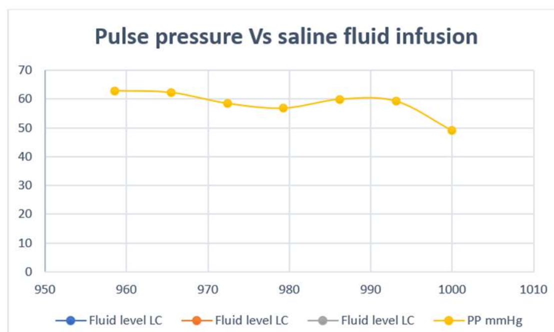

Fig.3.3.Pulse Pressure Vs Saline Fluid Infusion

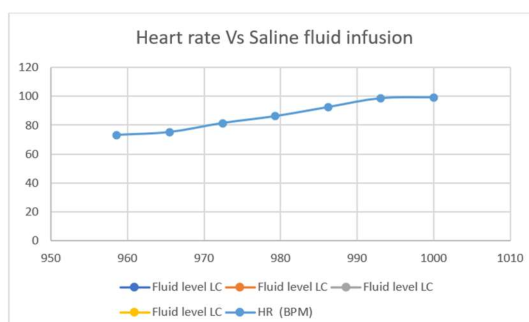

Fig.3.4. Heart Rate Vs Saline Fluid Infusion

A patient case1 study age of 45 years with pneumonia abnormal. The patient is with arterial hypertension. Before the infusion of the saline the patient blood pressure variations are 145/89, 149/93, and 150/92 mmHg. The heart rate 99.4 bpm (beats per minute) and temperature are 37.48C. with infusion of the saline the blood pressure levels are stable at 110-136/72-83 mmHg. The intravenous saline infusion results adverse effects on physiological parameters of patient. Infusion of saline over 30 minutes increased the blood capillary volume level by 10 percent. Subsequently the cardiac output is decreased. The percent of increase of capillary volume level is depending on the volume of the fluid infusion within 30 minutes.

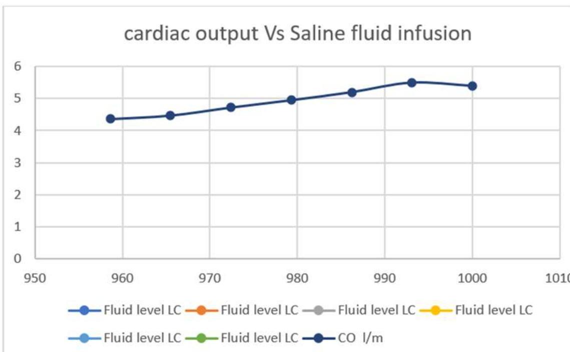

Fig.3.5. CO Vs Saline Fluid Infusion

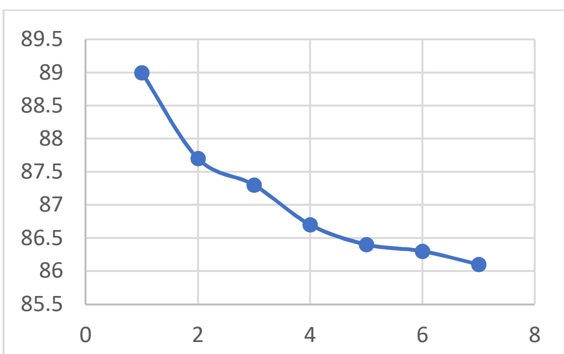

Fig.3.6. DBP Vs Saline Fluid Infusion

the volume of the fluid infusion is depending on the velocity of the fluid and the volumetric saline fluid flow rate. From Fig.3.2. the findings for 30 minutes show systolic blood pressure is increased ‘8’ percent and diastolic blood pressure decreases 3.25 % shown in Fig.3.6 Significant change in the heart rate is observed. The variation of diastolic blood pressure is nominal but is decreased minimally shown in fig.3.6. The heart rate is decreased at the rate of 1.25 beats per minute shown in fig.3.4.

The percentage of heart rate decreasing is influenced by the saline fluid infusion rate.

It varied between 7-15 percent with hypertension patients. Normal heart rate is 60-100 beats per minute. Lower heart rate is deliberated as good health condition. The fluid infusion over 30 minutes results 12% lowering the heart rate. Case1 patient before infusion the heart rate is recorded as 90 beats per minute. After 30 minutes infusion of the fluid at constant volumetric fluid flow rate, the heart rate is significantly dropped to 81 BPM. After one hour, the heart rate is significantly lowered to 78 beats per minute. With increasing the infusion of saline fluid will lower the heart rate further shown in fig.3.4., results severe adverse effects. Owing to this reason monitoring the heart rate, pulse pressure and blood pressure is significant. The arteries are stretchy and flexible. The atrial compliance determines the amount of blood is holding at a time. The arteries start impending its stretchy and flexibility with chronic deceases and aging. So, pulse pressure measurement is considered. These values are much influenced by the volumetric flow rate of the fluid.

The fluid responsiveness of a patient is determined by pulse pressure variation (PPV) parameter. The stroke volume alters the pulse pressure. With increase in stroke volume and cardiac preload increased the pulse pressure.This is significant for patient’s responses to fluid infusion. The threshold value of pulse pressure variation Δpp is 13% to discriminate the fluid responsiveness of the patient. If Δpp is ≤ 13% is the indication of fluid infusion is to be ceased. After 30 minutes of fluid infusion, the patient Δpp is ≥ 13 %. The patient is responsive to saline fluid infusion. So continued the saline infusion.

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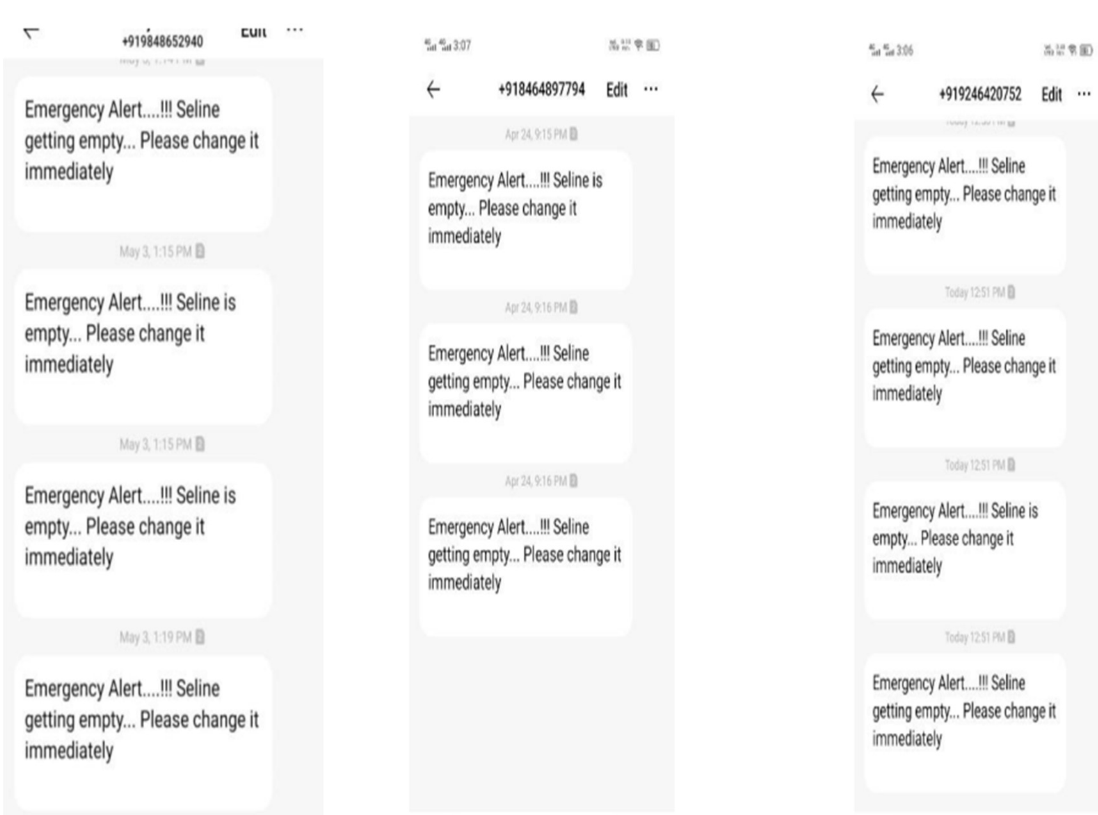

Fig. 3.7. Alert Messages To The Supervising Persons.

The blood pressure (BP) levels are recorded with an interval of 2 minutes. The average of the readings is deliberated before infusion of the saline fluid. If the deviation of the two readings is greater than 5mmHg then the third reading is taken after five minutes. Then the mean is considered to estimate the precise blood pressure values. The sample time for continuous measurement is deliberated as 5 minutes. The difference of final systolic blood pressure and final diastolic blood pressure value is deliberated as pulse pressure of the patient.

The patient final blood pressure values are greater than 140 owing to hypertension. And diastolic value is greater than 90 is observed. With 30 minutes study of saline fluid infusion results the cardiac stroke volume level is lowered to 10 %. this value is raised to 22% after an hour infusion of the fluid. The volumetric flow rate of the fluid is considered 50ml/ minute increases the cardiac output value. Subsequently the atrial pressure value is increased.

The developed model is continuously supervising the state of the saline bottle and send alert messages periodically. Fig.3.7. represents the alert messages as saline fluid is getting empty and empty status. Lower 20% of the saline bottle is considered as saline fluid empty.

4. CONCLUSIONS

Fluid infusion is a essential to correct medical abnormalities. Rate of saline fluid increase impact on physiological parameters. Especially, the systolic and diastolic blood pressure, heart rate, respeiration rate and cardiac stroke volume. Each physiological parameter is analyzed with varying fluid infusion rate. A reliable model is developed to cater the medical assistance to rural people. Remote monitoring of the fluid infusioin rate is porposed by uploading the data dynamically to the cloud. Using a web app or mobile app the fluid infusion rate can be supervised. This unique feature will strengthen the attention of the mediacl supervisor. The intravenous saline infusion results adverse effects on physiological parameters of patient. Infusion of saline over 30 minutes increased the blood capillary volume level by 10 percent. Subsequently the cardiac output is

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decreased. The percentage of heart rate decreasing is influenced by the saline fluid infusion rate. It varied between 7-15 percent with hypertension patients. After 30 minutes infusion of the fluid at constant volumetric fluid flow rate, the heart rate is significantly dropped to 10% BPM. Further decrease in heart rate introduce adverce effects on the cardiac beat. Insufficient blood pumping due to poor heart rate leads to short of breath. It is observed that cardiac stroke value=me influence of the pulse pressure. The pulse pressure variation Δpp is $\leq 13\%$ is the indication of fluid infusion is to be ceased. This study strengthen the automous design of the system for meticulous fluid infusion without altering the normal phisological parameters.The experimental finding shows blood pressure variation (BPV) change of 11.56%. SBP is increased 8% and DBP is decreased 3.25%. The HR change is 1.25 BPM. After 30 minutes of observation the HR change is 12%. This is significant. The variation of the physiological parameters is deliberated to regulate the fluid infusion without human intervention. This work will become a full function device for intensive care units and bed side saline infusing mechanism. The work is considered for 30 minutes of observation and continued for one hour. In future this work is extended with data analytics using machine learning algorithms.

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