Rapid Resuscitation Machine

[1]Adnan Habib, [2]Dr. Prashant Chaturvedi
[1]Research Scholar, [2]Professor
[1&2] Department of Electronics and Communication Engineering,
[1&2] Lakshmi Narain College of Technology, Bhopal, India

***Abstract*— Cardiac arrest is a catastrophic event in which the heart stops beating. This means the body is deprived of the oxygen it needs to survive. Beyond the high risk of death, one major concern is the impact of prolonged oxygen deprivation on the brain and the damage that can occur within three minutes of the heart stopping. When cardiac arrest occurs, cardiopulmonary resuscitation (CPR) must be started within two minutes. After three minutes, global cerebral ischemia—the lack of blood flow to the entire brain—can lead to brain injury that gets progressively worse, by nine minutes, severe and permanent brain damage is likely. After 10 minutes, the chances of survival are low. Even if a person is resuscitated, eight out of every 10 will be in a coma and sustain some level of brain damage. Simply put, the longer the brain is deprived of oxygen, the worse the damage will be. The aim of this paper is to introduce a machine that reads the patient heart rhythm, oxygen levels and acts immediately to save the patient's life and decides on its own that a person needs more C.P.R or A.E.D shocks or not.

INTRODUCTION

Imagine a moment when someone's heart suddenly stops beating - that's a cardiac arrest, a life-threatening situation where the body loses its oxygen supply. Shockingly, more than 356,000 out-of-hospital cardiac arrests occur annually in the United States, with a devastating 90% resulting in fatalities. Even more alarming is the potential brain damage that can set in just three minutes after the heart stops.

Time is everything during cardiac arrest. Starting cardiopulmonary resuscitation (CPR) within two minutes is crucial. Beyond this point, the brain faces global cerebral ischemia, meaning it's not getting the blood it needs, and brain injury becomes a real risk. At nine minutes, severe and lasting brain damage is likely, after ten minutes, chances of survival are slim.

Our project, the "Rapid Resuscitation Machine," arises from thorough exploration and a drive to make a difference, crafted a device that's compact, user-friendly, and brilliantly automatic, harnessing the power of advanced intelligence.

Imagine this: a portable machine that can revive someone experiencing cardiac arrest or clinical death. It doesn't waste a second - it immediately reads the person's heart rhythm and oxygen levels, then takes action to save their life. It decides whether more CPR or electric shocks are needed, all on its own.

Traditional CPR and Automated External Defibrillators (AEDs) take around 9 to 10 seconds to set up, and fully automatic AEDs are big and not easily portable. But our system changes the game. It's like a superhero for your heart. You place it on the person's chest, and it springs into action, monitoring vital signs, delivering shocks, and performing chest compressions with unmatched accuracy.

Speaking of shocks, traditional AEDs use capacitors that take time to charge up. We took a smarter approach by using step-up transformers. These devices can convert a low voltage to a higher one - from 12 volts to up to 1000 volts and below by applying concepts of physics for transformers - making sure the energy is used wisely.

Our CPR machine is equally ingenious. Inspired by the design of a 2-stroke engine, we've created a machine that can do chest compressions just like a human hand. It's tireless, ensuring the perfect 100 to 120 compressions per minute without tiring out. A Machine that ingeniously mimics the motion of human hands during chest compressions. With a powerful motor intricately connected to a crankshaft, a connecting rod, and a piston featuring a spherical silicon attachment, our CPR machine achieves unparalleled compression efficiency.

And here's a wake-up call: In India, around 12 lakh young people die due to cardiac arrest. In the US, more than 4,75,000 lives are lost every year. The " Rapid Resuscitation Machine " addresses this crisis head-on. It's our way of fighting against these grim statistics. By putting our minds to work, we've developed a system that's easy to use, super smart and saves lives.

Our mission is unequivocal: to mitigate the harrowing toll of cardiac arrests on lives. The " Rapid Resuscitation Machine" encapsulates our dedication to sculpting a future where each passing second holds the potential to rescue, to heal, and to rejuvenate. It embodies the harmonious union of advanced technology, boundless compassion, and unwavering progress. By channeling the full potential of science and intelligence, we endeavor to rewrite the narrative of cardiac emergencies – a narrative that emphasizes timely intervention, celebrates triumphant recoveries, and ultimately redefines what's possible in the realm of medical innovation.

AUTOMATED EXTERNAL DEFIBRILLATOR

The Automated External Defibrillator (AED) stands as a hallmark advancement in defibrillator technology, representing a pivotal stride in recent medical innovation.

Its genesis stemmed from a profound understanding of the prevalent cardiac arrhythmias afflicting adults during cardiac arrest, notably ventricular fibrillation or pulseless ventricular tachycardia. Recognizing the criticality of swift intervention, the imperative to minimize the delay preceding defibrillation emerged as paramount in ensuring survival.

The Automated External Defibrillator (AED) automates key stages of defibrillation, simplifying the operator's role. Upon recognizing a potential cardiac arrest, the operator attaches two adhesive electrodes to the patient's chest, which both record the electrocardiogram and deliver a shock if necessary.

The device's algorithm interprets the electrocardiogram automatically, detecting ventricular fibrillation or certain ventricular tachycardias, prompting the machine to self-charge to a preset level.

Once fully charged, the AED signals the operator to administer the shock, providing clear instructions through voice prompts and on-screen guidance. Some models offer intuitive numerical schemes for procedural guidance, with illuminated controls for shock administration. After delivering the shock, the AED reanalyzes the electrocardiogram. If ventricular fibrillation persists, the process repeats, with a maximum of three attempts per cycle.

AEDs are programmed to deliver shocks in sets of three, aligning with current guidelines. If the third shock proves ineffective, the device prompts the initiation of cardiopulmonary resuscitation (CPR) for a designated period, typically one minute. Subsequently, the AED instructs rescuers to stand clear as it reanalyzes the rhythm. Should the arrhythmia persist, the machine automatically charges itself and signals the need for an additional shock.

Traditional AEDs encounter challenges related to setup time, portability, and reliance on human intervention. Their setup process can be time-consuming, potentially impeding swift treatment during cardiac arrest. Moreover, their bulkiness and weight restrict their portability, limiting accessibility in various settings. Additionally, effective operation often necessitates trained personnel, which may not be readily available in emergencies. These limitations highlight the urgency for advancements in AED technology to enhance response times and outcomes for cardiac arrest patients. [1,7,8]

AUTOMATED MECHANICAL CPR

Cardiac arrest remains a leading cause of death in developed nations, with CPR guidelines rooted in closed chest compression principles since 1960. However, manual CPR, while crucial for successful resuscitation, can lead to rescuer fatigue and interruptions, potentially affecting outcomes. To address these challenges, mechanical CPR devices have been developed, aiming to enhance chest compression quality and potentially improve resuscitation outcomes. This protocol outlines a systematic review and meta-analysis approach to evaluate trials investigating automated mechanical CPR devices' therapeutic impact on return of spontaneous circulation rate, neurological status, and secondary endpoints, such as short- and long-term survival, injuries, and surrogate CPR quality parameters, compared to manual chest compressions in adults experiencing cardiac arrest.

Existing literature includes heterogeneous studies, with inconsistent results regarding the efficacy of manual versus mechanical CPR. High-quality randomized controlled trials (RCTs) such as Circulation Improving Resuscitation Care (CIRC), LUCAS in Cardiac Arrest (LINC), and Pre-Hospital Randomized Assessment of a Mechanical Compression Device in Cardiac Arrest (PARAMEDIC) have produced conflicting findings. Subgroup analyses to determine optimal timing for mechanical CPR installation or identify patient subgroups benefiting most from mechanical chest compressions are lacking.

Despite numerous trials comparing manual and mechanical CPR, subgroup analyses to identify specific patient populations or circumstances where mechanical CPR may offer advantages are notably lacking. Understanding optimal timing for mechanical CPR installation and which patient subgroups benefit most from mechanical chest compressions requires further investigation. In summary, while rigorous studies have been conducted, the results remain inconclusive, highlighting the need for focused research to elucidate the circumstances under which mechanical CPR may be most beneficial. [2,3,4,5,6]

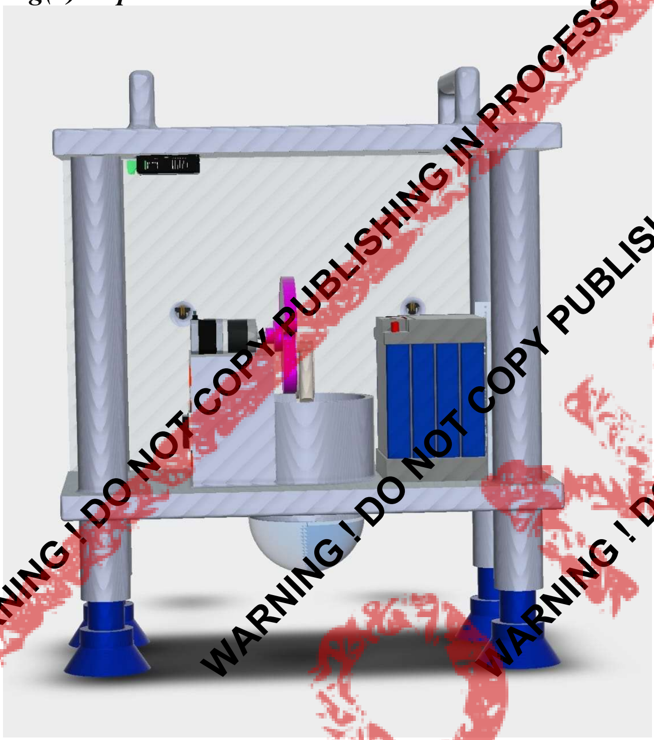
PROPOSED METHDOLOGY

The proposed technology aims to revolutionize the management of cardiac arrest by combining the capabilities of Automated External Defibrillators (AEDs) and mechanical CPR into a single, compact device. Inspired by the need for rapid and effective intervention during cardiac emergencies, this innovative system integrates advanced engineering principles with cutting-edge medical technology to deliver timely and targeted care to patients in critical need.

The system is housed within a meticulously crafted unit, designed to be compact yet robust, ensuring portability and adaptability across various environments, including homes, hospitals, clinics, and public spaces. This purposeful design facilitates seamless integration into existing infrastructures, allowing for swift and efficient deployment during critical situations. Within this unit, a sophisticated array of engineering components operates in synergy, meticulously engineered to deliver precise and effective care to patients experiencing cardiac emergencies.

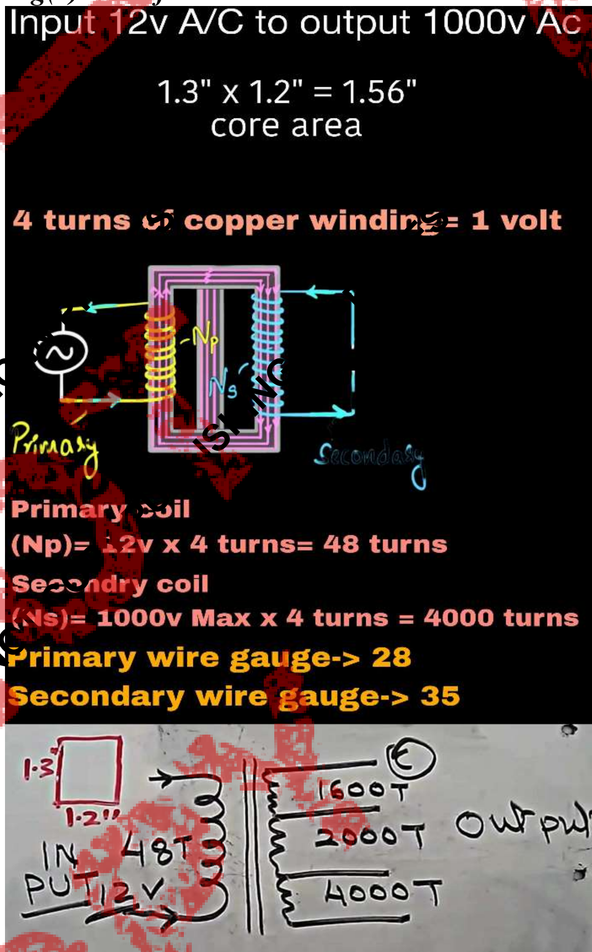
Drawing inspiration from the piston of a 2-stroke engine, the mechanical CPR mechanism features hydraulic legs that are positioned across the patient's chest with precision, while the device is situated on the floor or bed. Powered by a robust motor, crankshaft, connecting rod, and piston with a spherical silicon attachment, the mechanism simulates the rhythmic chest compressions performed by human hands, ensuring consistent and effective circulation. The positioning of the hydraulic legs across the patient's chest facilitates optimal contact and alignment, allowing for precise and controlled chest compressions without directly imposing pressure on the patient's body.

Fig(1).Rapid Resuscitation Machine



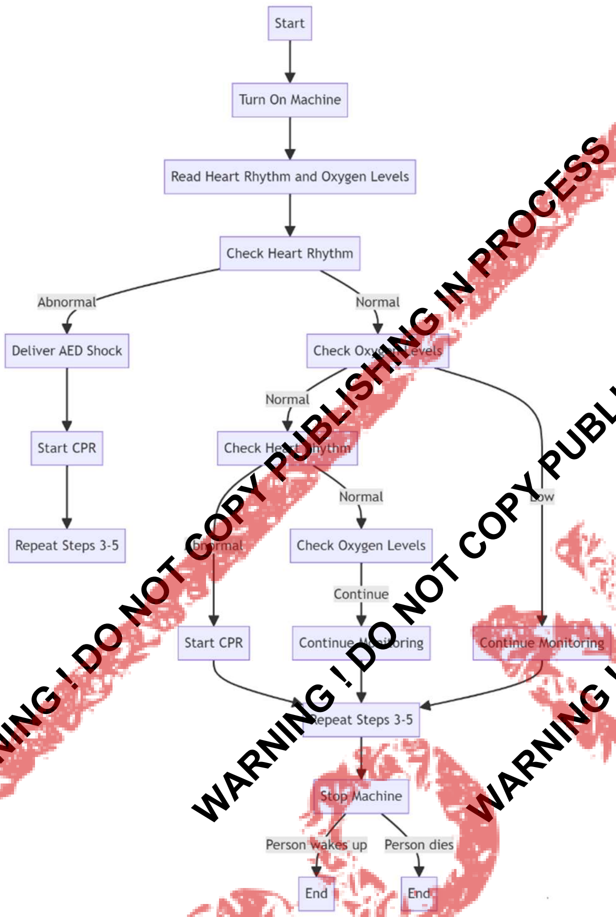
Complementing the mechanical CPR functionality, the system incorporates an integrated AED component equipped with electrode pads for delivering precise electrical shocks to restore normal heart rhythm when necessary. This seamless integration of AED technology enhances the system's ability to address a broader range of cardiac emergencies, further optimizing patient outcomes. By integrating the AED functionality with the Raspberry Pi, the system ensures swift and accurate delivery of electrical shocks tailored to each patient's condition, maximizing the effectiveness of the resuscitation process. Additionally, instead of capacitors, the system utilizes a step-up transformer, which swiftly converts the available 12 volts to various voltages up to 1000 volts. This innovation eliminates the time required for capacitors to charge, thus significantly reducing the time needed to administer life-saving treatment to the patient.

Fig(2) Transformer in AED



Central to the operation of the system is an advanced decision-making algorithm, informed by machine learning or deep learning models trained using data from hospitals and real-time feedback. This algorithm meticulously analyses sensor data collected from integrated sensors, including oxygen levels and heart rate, to dynamically guide the operation of the mechanical CPR and AED functionalities. Utilizing the computational power and flexibility of a Raspberry Pi, with GPIO (General Purpose Input/Output) pins interfacing with sensors and controlling actuators, the algorithm autonomously directs the system to initiate mechanical CPR and deliver AED shocks when deemed necessary. This comprehensive approach ensures timely and targeted intervention tailored to each patient's unique condition, effectively bringing the project to life and maximizing its potential for saving lives in emergency situations.

Fig(3) Algorithm flowchart



Upon activation, the system is initiated by the user placing it across the patient's chest. The user then applies pressure on the top of the device, causing the hydraulic legs to collapse fully, deploying the device into close proximity with the patient's chest. Once in position, electrode pads are applied to the patient's chest following established guidelines for optimal placement. With the pads in place, the user turns on the machine, initiating the system's operation. As the algorithm analyzes real-time physiological data, the system autonomously delivers AED shocks as needed to restore normal heart rhythm, while simultaneously initiating mechanical CPR with precision and efficiency.

Our Rapid Resuscitation Machine offers several distinct advantages, including reduced response times, improved patient outcomes, and enhanced accessibility. By streamlining the resuscitation process and automating key interventions, the proposed system has the potential to significantly impact the treatment of cardiac arrest, saving lives and improving survival rates in emergency situations. Moreover, the integration of our designed CPR and AED functionalities enhances the accessibility of life-saving interventions, as the machine can be operated by any individual, even those without formal medical training. This user-friendly design empowers bystanders and first responders to provide immediate assistance to cardiac arrest victims, potentially increasing the likelihood of survival. In essence, the proposed Rapid Resuscitation Machine represents a significant leap forward in emergency medical technology, offering a comprehensive and effective solution for addressing cardiac emergencies. Through its innovative design, advanced functionality, and potential for widespread deployment, this system can revolutionize the way cardiac arrest is managed, ultimately saving lives and improving patient outcomes on a global scale.

OPERATION RESULT

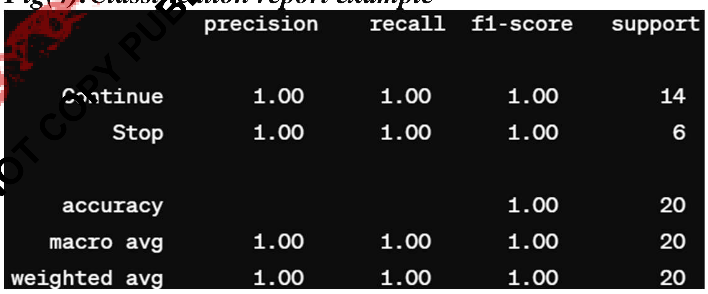
Machine Learning Model Performance:

The machine learning model was trained using a sample dataset containing simulated patient data, including heart rate, oxygen level, CPR status, AED shock intensity, and process status. The model's performance was evaluated using standard classification metrics, including precision, recall, and F1-score.

Table(1):Sample dataset

Heart Rate	Oxygen Level	CPR (on/off)	AED Shock_ Intensity	Process
80	98	1	0	Start
82	97	1	0	Continue
84	96	1	0	Continue
85	95	1	0	Continue
0	90	1	150	Continue
0	88	1	200	Continue
0	85	1	250	Continue
0	82	1	300	Stop
78	97	0	0	Start
81	95	0	0	Continue
83	93	0	0	Continue
86	92	0	0	Continue
0	89	1	150	Continue
0	87	1	200	Continue
0	84	1	250	Continue

Fig(4):Classification report example



	precision	recall	f1-score	support
Continue	1.00	1.00	1.00	14
Stop	1.00	1.00	1.00	6
accuracy			1.00	20
macro avg	1.00	1.00	1.00	20
weighted avg	1.00	1.00	1.00	20

The classification report indicates that the model achieved perfect precision, recall, and F1-score for both classes ("Continue" and "Stop") on the test dataset, suggesting excellent performance in predicting the need for continuing or stopping CPR and AED shock intensity.

To demonstrate the real-time operation of the proposed Rapid Resuscitation System, we implemented a simplified version of the algorithm.

Fig(5):Output

```
Classification Report after Feedback:
              precision    recall  f1-score   support

    Continue       1.00      1.00      1.00        15
       Start       1.00      1.00      1.00         3
        Stop       1.00      1.00      1.00         2

    accuracy                           1.00        20
   macro avg       1.00      1.00      1.00        20
weighted avg       1.00      1.00      1.00        20
```

Precision, recall, and F1-score are common metrics used to evaluate the performance of a classification model. Precision measures the accuracy of positive predictions made by the model. Recall, also known as sensitivity or true positive rate, measures the ability of the model to identify all relevant instances. The F1-score is the harmonic mean of precision and recall. Support refers to the number of actual occurrences of each class in the dataset.

Fig(5.1) Output

```
Sample Output after Feedback:
Patient : Predicted Process - Start
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Stop
Patient : Predicted Process - Start
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
Patient : Predicted Process - Continue
```

The code successfully simulates the operation of the machine, collecting patient data, executing actions based on the machine learning model's predictions, and providing sample output indicative of the system's decision-making process.

The section outlines the performance of the machine learning model and demonstrates the real-time operation of the proposed system through code implementation and sample output. Further experimentation and validation will be conducted to assess the system's efficacy in real-world scenarios.

CONCLUSION

We envision several key enhancements to further optimize its effectiveness and versatility in responding to cardiac emergencies:

Adaptive Shock Energy: Our system will incorporate adaptive shock energy delivery, allowing for the adjustment of shock intensity based on patient-specific factors such as age, weight, and medical history. This personalized approach ensures that the energy delivered is precisely tailored to the individual's needs, enhancing effectiveness while minimizing the risk of adverse effects.

Secondary Assessment: To augment the capabilities of our algorithm, we plan to integrate a secondary assessment module that evaluates additional vital signs and cardiac health indicators, including blood pressure and ECG waveform analysis. By conducting a more comprehensive evaluation, our system will provide healthcare professionals with a more nuanced understanding of the patient's condition, enabling more informed and targeted treatment decisions.

Emergency Communication Integration: System will integrate advanced communication capabilities to facilitate seamless coordination with emergency medical services. Upon successful resuscitation or in the event of patient demise, the system will automatically trigger a call to the nearest ambulance service using advanced SIM adapter technology. Additionally, it will transmit real-time patient data to the designated hospital for immediate treatment, ensuring that healthcare providers receive vital information promptly and enabling timely intervention. This integration enhances the system's ability to provide comprehensive care and support beyond the initial resuscitation, potentially improving patient outcomes and reducing response times in critical situations.

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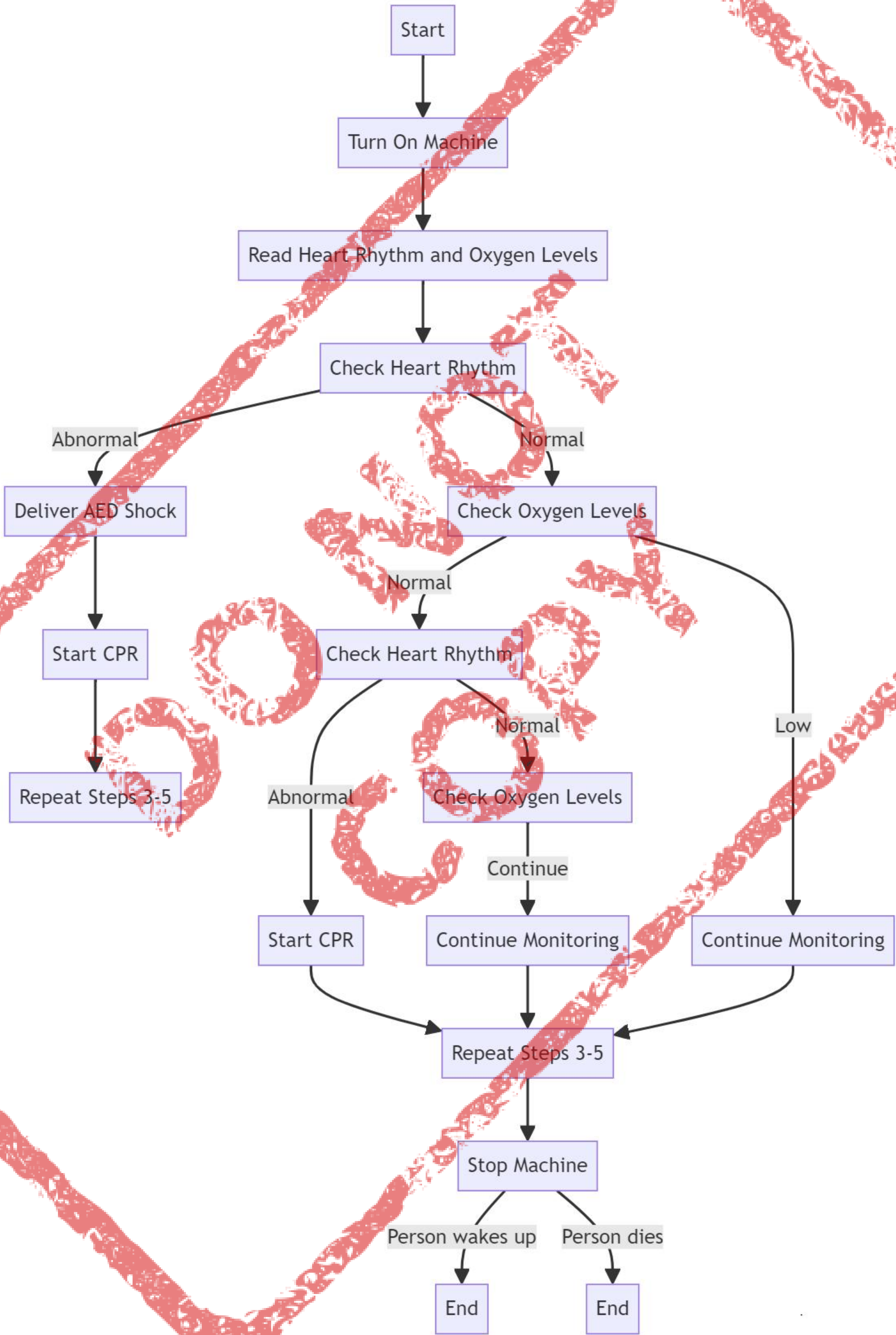
Start
Turn On Machine
Read Heart Rhythm and Oxygen Levels
Check Heart Rhythm
Abnormal
Normal
Deliver AED Shock
Check Oxygen Levels
Normal
Start CPR
Check Heart Rhythm
Normal
Low
Repeat Steps 3-5
Abnormal
Check Oxygen Levels
Continue
Start CPR
Continue Monitoring
Continue Monitoring
Repeat Steps 3-5
Stop Machine
Person wakes up
Person dies
End
End