# Virtual Reality Simulator for Cardiopulmonary Resuscitation (CPR) as Lifesaving Method in Many Emergencies Patients

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Abstract: This Cardiopulmonary Resuscitation (CPR) simulator media is synchronized with Virtual Reality (VR) as practicum media of medical student. Student or user of this simulator will act as a medical worker or volunteer who helps patient with respiratory arrest or cardiac arrest by restoring his breathing and circulation functions. This skill and competency are the basic need or the basic SOP procedure in the medical handling especially in emergency room. However, this skill actually should be mastered by everyone if someday we meet a victim person who needs the CPR handling. Several CPR procedures such as airway handling, compression, and ambubag installation will be immersively simulated with the complete guidance, healthcare equipment, and actual medical laboratory surrounding. Furthermore, this CPR virtual laboratory is expecting in guiding its user to be more active, especially in his motor-sensor skill. At least, this approach hopefully could be like the real condition how to handle with the right rules and understand the medical CPR procedures in the health-laboratory. So, this VR is developed using Blender 3D modeler and programmed in Unity engine which integrated to the SDK or plugin of Oculus Quest framework. The Oculus Quest device is used as the main media of its VR simulator which is included head mounted display as the eyesight headset and two hand controllers that allowed user to interact with virtual assets inside the immersively.



## 1 INTRODUCTION

Augmented Reality (AR) and Virtual Reality (VR) technologies have been transformed to become the most popular technology areas of the decade, especially in simulation technology and game development. Many technology companies change the focus and support the devices-development of both area, either the largest companies like Oculus, Microsoft, Samsung, etc., or several startup companies in this world with their unique products.

Thus, the Fourth Industrial Revolution (or Industry 4.0) and the response of the current covid 19 pandemic made the impact of distance learning and virtual simulations seem absolutely necessary. Some laboratories in schools, or even physical devices in various institutions and companies in the past year are very difficult to access directly because of the WFH (Work from Home) requirement and contact with strict health protocols. Therefore, the challenge is how to convert these laboratories into a virtual simulator with immersive interaction like the real physical device (or at least close to it).

Several VR simulators for internal campus laboratories have been successfully converted into virtual laboratories in previous studies, such as VR for multimedia broadcasting laboratories, Oscilloscope VR simulators, and several other devices. Then, since the beginning of the pandemic, the main challenge has been focused how to empower medical institution that have become the frontline to save humanity health today. Healthcare workers or prospective healthcare (medical students) should still be able to access their practicum in various ways as they usually do in hospitals or health campus laboratories.

Therefore, in this study, the Cardiopulmonary Resuscitation (CPR) simulator was chosen as the main virtual laboratory tool that developed in this research and tried to implement the result on Semarang Health Polytechnic Indonesia which has become a partner of this research. Apart from its urgency, skill in CPR is the main activity for healthcare workers in dealing



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with patients. Then, we choose Oculus Quest as the VR device which is relatively very cheap and capable enough to build this VR CPR Laboratory. Its controller can direct the eye and imitating hand movements into a virtual form both in position and orientation, thus the buttons on the device act as interactions in the hand, such as finger movements, grasping, pointing, and so on.

# 2 LITERATURE REVIEW

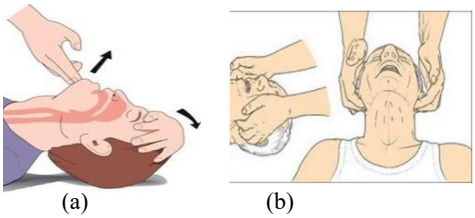
## 2.1 Cardiopulmonary Resusitasi (CPR) Procedure

Cardiopulmonary resuscitation (CPR) is a method to restore respiratory and circulatory function in patients experiencing respiratory and cardiac arrest (Ganthikumar, 2016). CPR is an effort created by healthcare worker for patients who are in emergencies or critical condition to prevent a death. This condition is usually happened in patients, either in condition related to certain diseases such as heart attacks, being exposed to viruses such as covid 19 virus, in accident such as drowning in water, choking on the respiratory tract, drug or alcohol poisoning, inhaling a lot of smoke to shortness of breath, or the other life-threatening conditions. For handling those patients, healthcare person or maybe all of people if they face this situation should be familiar with the basic techniques of CPR, therefore, CPR practicum is basically required to be mastered in all medical fields

There are many stages of CPR in patient treatments, starting from basic medical checkup until the specific advance handling likes respiratory tubes/ ventilators installation or direct handling with healthcare's hands (when the accident suddenly happened far from the hospital). This action in medical handling is formulated with three parts, it used to call ABC: (a) A for airway, (b) B for breathing, and (c) C for circulation. Before performing these three actions, healthcare personnels are advised to make an approach likes touch and talk, both methods can be simulated like waking up a sleeping person or stimulating the victim to react, while talking to him or calling him in a loud voice (American Heart Association Guideline Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) of Pediatric and Neonatal Patients, 2006), if there is no reaction then check his pulse, and the last if still no reaction and that patient is in cardiac arrest, now the CPR procedure can be carried out as soon as possible as these procedural steps:

*a) Airway*

This process is handled by opening the airway using the *Head Tilt–Chin Lift Maneuver* method, this method is processed by placing one hand on the patient forehead and push it down, and another hand just placing its fingers on the bone under the chin then open the patient's airway, thus the next method can be performed by maneuvering his jaw thrust, it is called by the mandibular thrust maneuver. This method is performed by holding both sides of the jaw while slowly moving it to the front position and keeping the patient's mouth open. This process is simply as illustrated in Figure 1

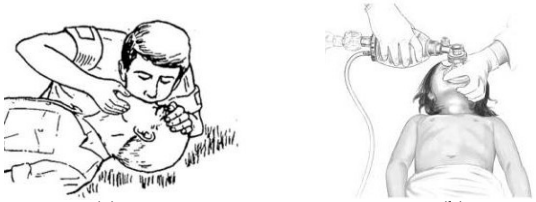


(a) (b)

Figure 1: Airway Process: (a) *head tilt chin lift* method and (b) *jaw thrust maneuver* procedure (SA, 2010).

*b) Breathing*

This method can be performed after ensuring that the patient is not breathing or breathing problems occur, this situation can be analyzed by seeing the movement of the chest, hearing the presence or absence of breath sounds, and feeling his breath by bringing the healthcare's ear closer to the patient's mouth and nose, while keeping the airway open. If the respiratory have not been shown, then the patient can be given respiratory support. Perform 5 rescue breaths if its patient is not breathing until he can breathe effectively by expanding the chest wall, if the chest does not expand, reposition the victim's head in order that the airway is open. This breathing assistance can be installed by ambubag pump or directly (mouth to mouth and mouth to nose) of its patient. Figure 2 is an example of a direct breathing method and using an ambubag installation



(a) (b)

Figure 2: Breathing Assistance; (a) direct breathing assistance and (b) breathing assistance using an ambubag

*c) Circulation*

The next help if there is no re action after performing artificial respiration, it can be continued by giving a chest compressions 30 times. The position of chest compressions starts from locating pressure on the *processus xyphoideus* and take a path of line to the cranial 2 fingers above it and just do it in that place. Then, the patient should be given breathing assistance twice anymore. If the pulse still has no reaction, then that process can be repeated until 5 times looped with a compression speed of 100 times per minute. Figure 2.3 is an example of healthcare's giving compression to improve blood circulation with reference to the large arteries (carotid artery and femoral artery).


Figure 3: The process of chest compressions for patient's rescue in CPR method.

## 2.2 Several CPR Simulators

C.-H. Yang et al. (Cheng-Hong Yang, 2020) made interactive VR-CPRs for health education using Arduino and VR headset or usually called Head Mounted Display (HMD). Both devices are paired using Bluetooth module. In this research, they blended physical mannequin (real mannequin) with virtual reality and guidance. Also, they add force-sensor to measure the pressure of user's hand. So, with this simulator, Cardiopulmonary Resuscitation (CPR) process is felt like a real sensing. User simulates a rescue to the patient (which substituted by mannequin) looks like doing to the real person, as he touches the patient's body and sees a 3D patient's life-character on his HMD display. Their equipment totally spent about $200 for one simulator cost; includes Arduino, Bluetooth module, force-sensitive resistors, and VR headset. It was relatively cheap and affordable to duplicate in several laboratory classes of medical school or the other medical institutions.

On another research, Greis F. M. et al made a CPR mannequin training use 3D-printable equipment with monitor head up display to measure the success performance of healthcare user (Greis F. M. Silva-Calpa, 2018). They use Nintendo Wii Balance Board for measuring CPR compression and weight. Thus, these data are sent to the device, either computer or android using a Bluetooth connection. So, as mentioned before, this device shows the graphs of user performance with a real-time. Including force, frequency, and the angle of mannequin posture when compression is applied. 3D-printable with Wii devices are chosen because a low-cost reason and the efficiency of its device. As we know, Nintendo Wii Balance Board can be used for several measurement purposes.

Thus, the simple CPR simulator also performed by Neil Vaughan et all (Neil Vaughan, 2019). They made a simple VR simulator for CPR training. They built this VR simulator for training school children uses. They use Oculus Rift as head mounted display (HMD) which attached by Leap Motion controller to detect the user's hand movement and orientation. They use a simple 3D object which scanned from Torso mannequin. Although it can't be effective procedure of CPR, at least children understand the procedure sequence in CPR performance as the general perspective of CPR competencies.

# 3 METHODOLOGY

Based on several previous research, we want to build the low-cost CPR simulator with immersive interaction and lively surroundings environment, either in human mannequin, ambubag, detail procedures, counter display (when compression implemented), and the other instructions need.

Technically, this simulator designed with the concept of interactive animation based on Virtual Reality (VR). VR simulation is currently still considered as the low-cost simulator, both in terms of equipment and development costs. This simulator device will be developed using the Oculus Quest SDK and Steam VR Plugin which is available on their official website. As we know that Oculus Quest is one of the low-cost HMD devices, but it covered complete interaction, either in displaying picture on its HMD with IMU sensor, speakers, and detecting the hand orientation. Furthermore, software and programming will be carried out in the Unity game engine, while modeling assets, mannequins, and all the needs of 3D objects environments built using Blender 3D. These stages can be illustrated in Figure 4.

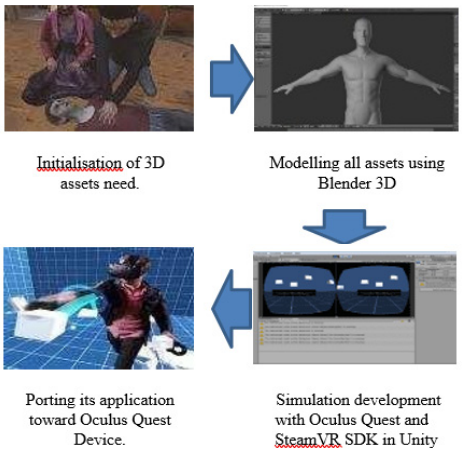



Figure 4: Several milestones in CPR simulator development.

## 3.1 Simulator Equipment

Head Mounted Display used on this VR simulator is the Oculus Quest. Oculus Quest runs under an Android OS. It is different with the older one; either Oculus Rift (Oculus Quest is totally wireless), and Oculus Touch which is still needs a computer as the main server for installing the application. In Oculus Quest, we can play with it just after porting VR application to this device, because it can run with stand-alone device. The most important thing that Oculus Quest is simpler and cheaper than both previous devices, so it is very affordable to duplicate for several classes or multiplayer users. As shown in Figure 5, the sensors used on the Oculus Quest as usual sensors on HMD, there are IMU sensor and motion tracking where tool will detect x, y and z axis, provides a room-scale tracking, accommodates until 64 GB internal storage, and capable in transferring user's hands into the HMD while their hand's gestures appear with realistic precision (Facebook Technologies, n.d.). So, this device is the main equipment in this CPR simulator. The VR application is ported into it, so that a user will see VR perspective on its display, then he will perform several CPR procedures using those two stick handlers.


Figure 5: Oculus Quest Display CITATION Fac21 \L 1033 (Facebook Technologies, N.D.).

Figure 6: Head Mounted Display of Oculus Quest and its features.

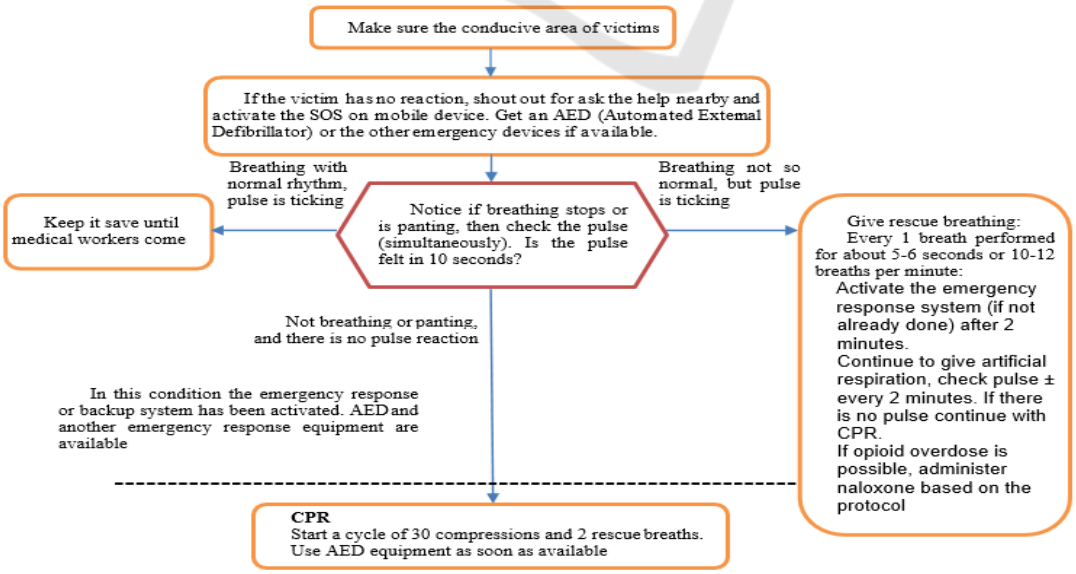



Figure 7: Flowchart of procedure in performing CPR based on Basic Life Support Health Service according to AHA 2015 (Robert W Neumar, 2015).

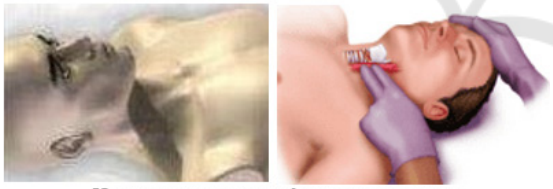
One of the features that really very useful to support immersive environment is attached speakers. As displayed on Figure 6, Oculus Quest has embedded two active speakers on the left and right side, even it can be paired to the external headphone or bigger active speaker with 3.5 mm audio jacks. For the further interaction, it also has an integrated Microphone, compression, and so on. So, the summary of the cardiopulmonary resuscitation (CPR) procedure as shown at the flowchart on Figure 7.

## 3.2 Scenario Simulation

In this section, the VR simulator will be designed so that the user can perform the procedures as described before, starting from preparing the equipment, checking the pulse in the carotid artery, until performing several actions .

Thus, based on this CPR procedure, in this development simulator, the main assets needed in performing pulse and breath checkup are 3D visuals of the hands as the virtual user/ healthcare interaction and human mannequin as the virtual victim or patient Some examples of CPR assets are shown in Figure 8.

*3D objects of Hand's User*



*Human mannequin as the victim or patient*

Figure 8: Assets for the early process in checking pulse and breathing of CPR procedure.

After checking the pulse and found to be abnormal, the next scenario is compression rescue as described before in the discussion and flowchart of CPR procedure. At this stage, the position of healthcare's two-hands positioned together in the middle of the sternum and push the chest with a compression depth for about 5-6 cm and 100-120 times/minute of speeds. Furthermore, if there is no reaction, continued the compression process 30 times (see the patient's complete recoil or the return of the chest wall). After these 30 times of compressions, this healthcare or user must give twice rescue breaths (ventilations) using an ambubag. After performing 1 cycle of CPR (30 compressions and 2 ventilations), user should recheck the carotid pulse. If still there is no reaction on carotid pulse, repeat the CPR process for another 1 cycle. Perform this CPR until finding carotid pulses and breathing returns. So, to perform this process, at this stage we need an additional asset of the ambubag to be attached to the patient, the ambubag and its installation as shown in Figure 9.

Figure 9: Ambubag and its installation to the virtual mannequin after compression process.

As the last step, after the CPR process is finished and the last evaluation results that the pulse has been run and breathing is back, the VR user should position the patient in the recovery position, which is tilted his body to relieve its airway, as shown in Figure 10.

Figure 10: The patient's recovery position after giving the CPR.

## 3.3 SDK and Plugin Programming on Unity Engine

After building all assets in 3D models and establish the scenario procedures, the Unity programming can be developed. This development process can be integrated to the VR SDK or Plugin for Unity Engine in order the result can be displayed and integrated to the proposed VR-headset device.

On this development, we used the Steam VR SDK, SteamVR works as an SDK for Virtual Reality in universal devices which can be downloaded freely in Unity Asset Store (Unity, n.d.). With this SDK, the application output of Virtual Reality can be installed in several VR devices such as Oculus, HTC Vive, or the other various HMD devices that compatible with SteamVR. So with this SDK package, we can install for several devices without configurating the specific device anymore. Figure 11 is the thumbnail picture of Steam VR which is displayed on Unity Asset Store.

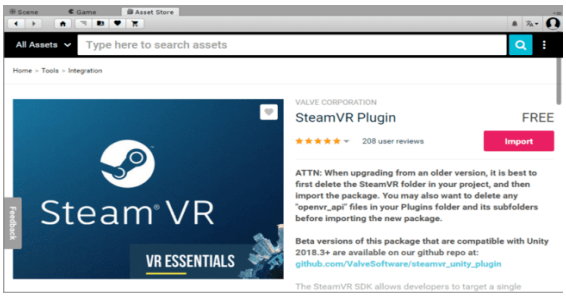



Figure 11: Downloadable SteamVR Plugin on Unity Asset Store (Unity, n.d.).

# 4 RESULT

A. Checking a Patient's Pulse on his Neck

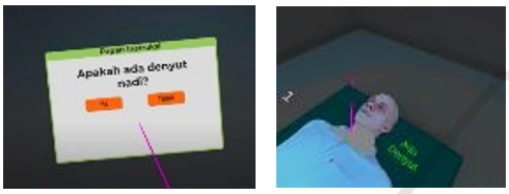



Figure 12: Left side showed the process of pulse checking and right side is user's question board displayed about patient situation.

In this scene, as shown in Figure 12, user is provided the patient in lying position. User as the healthcare person, firstly must check him up the pulse with touching patient's neck. Note will appear beside it and its result must be synchronized to the question board. User must choose "yes" answer if the result showed the pulse, and vice versa. Which means pulse tick in the neck indicates the patient is still alive. Purple line appears in front of user virtual hands to pointing and answering multiple choice button in the board question.

A system will random this condition, if user didn't get a neck pulse, then he must repeat until he get it, otherwise the next procedure can't be processed, which means the patient can't be helped anymore.

B. CPR Compression Action

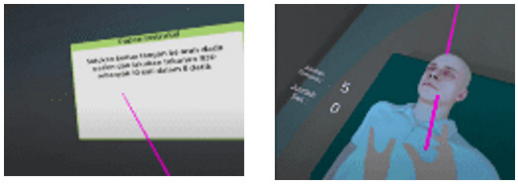


Figure 13: Compression Procedure which is showed by instruction board on the left side and process snapshot on the right side.

After user got the patient's pulse, system will continue to the main procedure of CPR, namely compression. As the instruction showed in Figure 13 on the left-side, user should stack his hands (both of hands) on patient's chest to apply the pressure-procedure 10 times in 5 minutes, then it must be repeated until 3 set (three times). In this case, actually on every set, user should check a patient's breathing. If the patient has been breathed just with one set or twice, compression can be sufficient, and the procedure can be continued directly to the ambubag installation.

C. Ambubag Installation


Figure 14: Ambubag installation steps and instruction.

Ambubag installation can be performed after compression process. In this scene, user should take the ambubag which is placed on the table beside the patient. Thus, he must pump it twice as the instruction showed on virtual board-instruction as Figure 14.

D. Recheck Patient's Pulse


Figure 15: Ensuring process of patient breaths after compression and ambubag installation.

For ensuring the patient has been breathed and his pulse are running normally, user should check his carotid artery on the neck one more time as the procedure shown in Figure 15. Then, if its pulse is running well, everything has been done. User just need to reposition his resting position in recovery position as the last procedure.

E. Rescue the Patient in Recovery Position

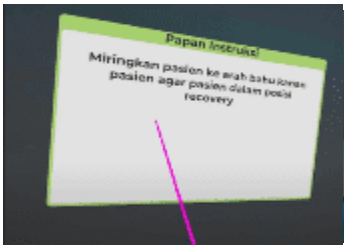


Figure 16: Recovery position.

As the last procedure, the patient should be left with the right resting and recovery position. Recovery position means a user should push the patient body until tilted to relieve the airway as shown in Figure 16.

F. Experiments and Testing

In several events and exhibitions, it has been performed to the public and related institutions. We interviewed them the experiences when performing this CPR VR simulator. Most of them are feeling with immersive interaction and follow the instruction and procedure properly. Figure 17 showed several documentations of this simulator exhibition and coverage on the JawaPos newspaper (Indonesian popular newspaper), when simulated by General Director of Vocational Education of Education and Culture Ministry of Indonesia.


Figure 17: Experiment on the exhibition and newspaper coverage.

# 5 CONCLUSION

Based on the result of this VR simulator prototype, we can conclude the following points:

1. This simulator was built to convert a physical laboratory into a virtual laboratory with the aim of minimizing risk, reducing the cost, easing in media duplication for student practicums, but still feeling with immersive interaction approaching a real physical-simulator.
2. Virtual laboratory or virtual simulator have many opportunities to be developed, especially during today's pandemic and industrial revolution 4.0 challenges. So that, distance learning or practicum will be very easy to be implemented with virtual laboratory idea.
3. Based on these experiments, user just feel pure virtual experience and doesn't interact wiyh collision immersivity. So, for the next development, it will be better if this simulator is mixed with the real mannequin.

# ACKNOWLEDGEMENTS

This work was supported by Postgraduate Program of Semarang Polytechnic of Health as the partner and resources supporter in developing this virtual laboratory. Hopefully, with this memorandum of understanding, we can support each other and develop the other several health-laboratory devices for supporting the adaptable recent education media.

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