Augmented Reality Application for Surgery Simulation: Circumcision Augmented Reality Simulation (CARS)

Muhammad Sobri Maulana*[1], Hariyono Winarto[2], Gassani Amalia[3]
Universitas Indonesia, Indonesia

ARTICLE INFO

This Article is Available in:
https://journal.umy.ac.id/index.php/mt/article/view/9592

DOI:
https://doi.org/10.18196/mt.020111

Article History:
Received:
22 Agustus 2020
Reviewed:
31 Agustus 2020
Revised:
08 September 2020
Accepted :
11 September 2020

Correspondence:
muhammadsobrimaulana31@gmail.com

ABSTRACT

As one of the most common minor surgical procedure performed globally, male circumcision has some complications when performed by medically trained providers and non-medically trained providers. Presently, there is no standardized circumcision training approach, and there have been variable resources and materials. We constructed a low-cost, and mobile augmented reality circumcision training application called Circumcision Augmented Reality Simulation (CARS). CARS is built in a computer with minimum processor 4Ghz (RAM 4GB, VGA 2GB) and smartphone with Blender, Inkscape, Audacity and Unity3D software. Features in CARS includes 3D models, animation and sound of circumcision procedure. CARS was tested through several steps including black box technique, response time loading and layer resolution examination through various smartphones. The angles detected ranging from 20o-90o, with a maximum distance of 4 m using markers measuring 20x22 cm. Based on the percentage of the enclosed barrier, the marker can be detected between 0-90 percent. CARS as an example of augmented reality application for surgery simulation has been successfully built with features performing circumcision simulation and suitable for potential users (medical students and doctors). Implications for future research include assessing reliability and validity by growing its use to a broader population, creating another surgery procedure simulation with augmented reality technology using smartphone.

Keywords: *Augmented Reality, Simulation, Circumcision*

1. INTRODUCTION

Male circumcision, as one of the most common minor surgical procedures performed globally, has been practiced for social, religious, cultural, and medical reasons for a long time. It is predicted that one in three males are circumcised worldwide.[1] Circumcision reduces the risk of acquiring HIV infection in heterosexual males by 50-60%.[2-4] Genital ulcerative disease prevalence and incidence is higher among uncircumcised men.[5] There are some complications following circumcision performed by medically trained providers (medical doctors, nurses, paramedics, and health workers) and non-medically trained providers (civil society trainer and shaman). From ten prospective studies, the median frequency of any complications following circumcision by medically trained providers was 6% (range 2–14%), and the median frequency of any severe complications was 0% (range 0–3%). Five studies show a higher frequency of complications following circumcision by non-medically trained providers. Male circumcision is prevalent in much of Asia and African countries.

In several countries, circumcision is mainly performed by non-medically trained personnel.[1]As stated by the American Academy of Pediatrics, circumcision providers should become sufficiently skilled at technical aspects of the procedure in order to minimize the complication.[6] Primary care providers must have sufficient equipment to learn and evaluate circumcision skills as their role is merged with the specialty providers.[7] The focus of the residency circumcision training curriculum is highlighted in standards of competency during the last decade. However, residents involved in (Le et al., 2010) study have doubts in their competency to assess the appropriate contraindications of neonatal circumcision, although they are able to perform the circumcision procedures confidently.[8] Presently, there are no standardized

circumcision training tools, educational approaches, or expert standards regarding how routine circumcision skill techniques should be evaluated.[7,8] Circumcision training methods are variable among institutions. Resources that are utilized among institutions, including reusable circumcision, surgical instrument set, and disposable materials such as surgical suture and needle. Kigozi et al. described a penile model for use in circumcision training in resource-limited settings with an initial cost of $10 and a recurrent cost of $5.[9] Roca et al. built a low-cost and low-fidelity penile model connected to a high-fidelity newborn simulator that moves and cries, providing a realistic neonatal circumcision setting.[7] As information technology expands, several medical procedure training currently can be performed with a personal computer, laptop, and smartphone. Smartphone-based augmented reality technology operation may facilitate physicians in the surgical procedure.[10-12]

CARS (Circumcision Augmented Reality Simulation) is constructing a novel Augmented Reality in Medical Innovation Product, low-cost (free download and install), and mobile circumcision training application described through this paper. The application is an augmented reality that is compatible with the mobile phone and is connected to circumcision set surgical instruments while running. This application is primarily delivered to medical students, doctors, and non-medically trained providers.

2. METHODOLOGY

To be used efficiently, all computer software needs specific hardware components or other software resources to develop Augmented Reality. These prerequisites are known as system requirements. The hardware and software needed in CARS development are as follows:

2.1. Hardware

a. Computer with minimum processor 4Ghz
b. RAM 4GB
c. VGA 2GB
d. Smartphone Android and iOS

2.2. Software

a. OS Windows 10 AIO
b. Android version 4.0 or more (ICS)
c. Vuforia SDK
d. Game Engine Unity 3D with plug-in NGUI
e. Blender
f. Inkscape
g. Audacity

CARS can be launched in the smartphone with all current Android and iOS operation system. The main feature of CARS is pre-operative, intra-operative, and post-operative circumcision surgical techniques, which are displayed in 3D animation and sound.

2.3. D Model Design

The first step of CARS development was gathering circumcision simulation data. Data that is inserted into this application consisting of circumcision procedure steps as follows:

2.3.1 Pre-operative skills

a. Indications and contraindications of circumcision explanation
b. Informed consent obtained, including risks, benefits, alternatives, complications, description of the procedure
c. Patient identity form completion
d. Equipment preparation

2.3.2. Intra-operative techniques

a. Anatomy and landmarks identification (prepuce opening, corona, coronal

sulcus, frenulum, ureteral opening)
b. Aseptic and antiseptic
c. Anesthetic agent administration (dorsal block, ring block, ventral infiltration method)
d. Clamp placing and locking
e. Dorsal incision of the prepuce
f. Circumcision
g. Bleeding control
h. Remaining edges of skin suturing

2.3.3. Post-surgical skills

a. Antibiotic application and wound dressing
b. Post-surgical patient education, including penile hygiene, wound management, and consumption (nutritive food, vitamins, and analgesics).

The data were created into 3D objects. The circumcision procedures duration mentioned above will be counted with a timer. Creation of 3D objects, models staining process, and animations building were completed in Blender Software.

2.4. Making Marker and Sound Editing

Marker consists of several images which are readily detected by augmented reality technology. The next step was making markers with Inkscape software by editing the image. The image is uploaded to Vuforia website. After the image was processed, we downloaded and exported it into unity 3D with the format (.unitypackage). The selection and sound editing was launched in Audacity software.

Figure 1. Marker used in the application design

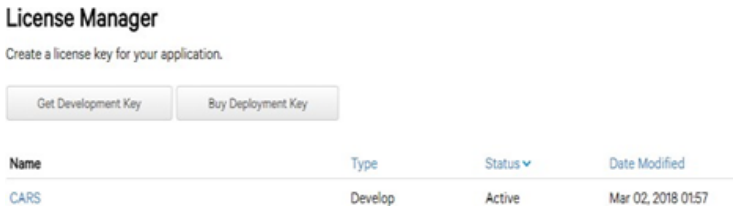

Figure 2. Uploaded marker in Vuforia Website

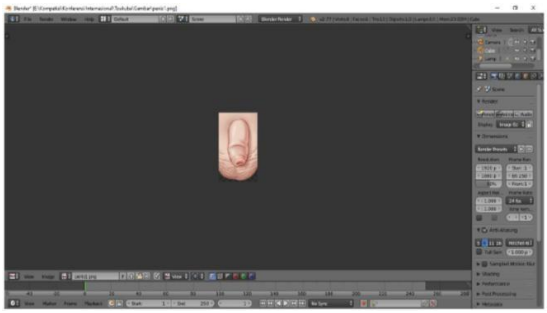

Figure 3. Screenshot of penile 3D model design in Blender

Figure 4. Screenshot of Making marker in Inkscape software

2.5. Designing Augmented Reality

Subsequently, the materials (image and sound) are processed with markerless Augmented Reality software Unity 3D. The finished Augmented Reality project can be launched in the Android and iOS operating system

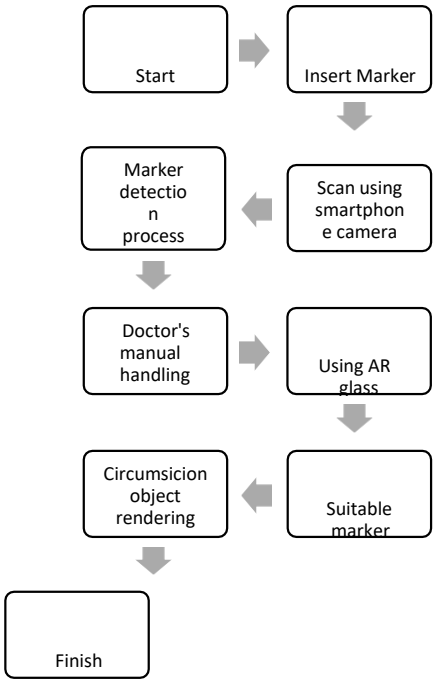

Figure 5. Flowchart showing the design process of CARS

2.6. Menu Creation

Consequently, the main menu display sign is inserted into the interface folder. The menus are created with NGUI plug-in on unity3D software. The application's main menu navigation displays circumcision and suturing mode. Other menus in the application are circumcision and basic suturing tutorial, basic knowledge such as penile anatomy, and help feature.

2.7. Database Design

Markers that have been made are incorporated into a database. The database was designed with Vuforia SDK tools as the target manager and can be accessed through Vuforia website.

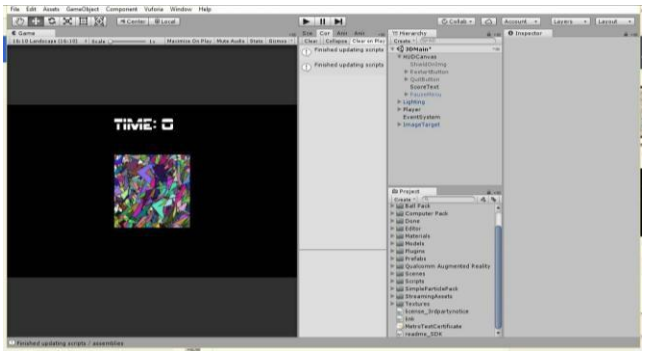

Figure 6. Screenshot of database design

2.8. Application building

The application building comprises two steps.

The first step, the build and revise step, is where the design sampling is done promptly. The application design process includes all software previously stated. The next step was application building with an export tool in the Unity3D into android and iOS. Afterward, the trial of the application was completed in hardware (mobile phone).

The last step, Medical Doctor Test -drives mock-up, is performed. This step is a method to evaluate the CARS application to enlighten the software requirements subsequently. After the application is successfully built, the following step is the Medical Doctor Test, in which the application will be tested by a medical doctor as the sample of our application's main target. From this step, we had found several technical errors in the application. Consequently, we conducted several rechecks and debugged errors.

3. RESULTS AND DISCUSSION

Figure 7. Screenshot of CARS home navigation

Figure 8. The splash screen of CARS

Figure 9. Screenshot of hand-held detection display

Figure 7 is the screenshot of the CARS home navigation. When marker or penile structure is captured by a smartphone camera, penile 3D object will be displayed in accordance with the detected image of the penis. Figure 8 shows the splash screen of the CARS application. Figure 9 is a hand-held detection display. Pressing ON and OFF keys on the smartphone serve as validation for the marker when circumcision procedure is launched by Augmented Reality. However, this property only works if the smartphone has an LED Flash.

This application has been tested through several steps. Firstly, the trial was performed using the black-box technique to examine the function of some features of the application as follows:

a. APK install
b. Connected application launching
c. Different marker detection
d. Similar and chosen marker detection
e. Pressing the “Circumcision” button
f. Pressing the “EXIT” button

The next step was CARS response time loading examination. This step is implemented because the application contains many 3D objects. Different specifications among smartphone devices used in the application while running will result in diverse response time. The next trial is CARS layer resolution examination. This trial is done because each smartphone device has a different size and layer resolution. In this step, marker detection and Augmented Reality hand constitute the influential factors. We have conducted some trials of CARS through an android device with Lenovo brand a6010 using 5MP camera, RAM 512, and 1GHz dual-core processor. When CARS is launched, the initial page shows an explanation of how to use the application, designer information, and reference appears. Augmented Reality results will be displayed in 3D format with sound and a circumcision animation. Following the whole circumcision procedure, the user will be provided an overall score of their performance through simulation. The score is based on circumcision procedure steps mentioned in the previous section. The warning label will appear

when the exit button is pressed. CARS testing is done with several test parameters. The distance parameters can be detected normally between 6 cm to 4 m. The slope can be detected between angles 20^o-90^o. Based on the percentage of the enclosed barrier, marker can be detected between 0-90%. CARS have been launched by some potential users, and CARS may provide engaging, fun, and practical circumcision steps simulation to be used for learning and demonstration.

This application provides a circumcision simulation technique with several advantages. By using augmented reality technology, disposable instruments such as needle, suture, and anesthesia-mimicking agents are unnecessary. Therefore, the cost will be cheaper when compared to other circumcision simulation methods. This application is mobile and ready to be accessed from various hardware with Android or iOS. Thus, this application will be beneficial in repetitive use. Besides, there is a timer feature in this application that can be an objective evaluation method for the user. The main disadvantage is associated with the tactile issue. There is no physical model of penile used when running the application since the users practice the circumcision steps with hands holding the instruments freely in the air. This issue also omits the user's recognition of skin injection or suturing sensation compared to conventional circumcision simulation with the penile model.

3.1. Alpha Testing

The first stage is Alpha testing performed by internal testers (supervisor). Alpha testing will be asserted if the internal tester (supervisor) states that the application is running well to be tested to the next stage. Here is table 1, alpha test table:

Table 1. Alpha Testing.

No	Scenario	Expected Results	Test Result	Conclusion
1	APK Install	Installation process properly in android smartphone	According to expectations	Valid
2	Running installed applications	App works and runs well	According to expectations	Valid
3	Marker detection	The marker object corresponds to the marker that has been provided	According to expectations	Valid

4	Detection of markers to display objects with appropriate object information	Camera smartphones can capture well on markers, and 3D objects can appear along with the information	According to expectations	Valid
5	Make sure the back button works	If pressed the back button, then the display will return to the previous menu	According to expectations	Valid
6	Make sure the profile button work	If the profile button is pressed, the display will appear about the application developer information	According to expectations	Valid
7	Make sure the help button work	If pressed the help button then the display will appear about the information on how to use the application	According to expectations	Valid
8	Ensure the buttons on the app match with listed in the guides menu	User easy to operate buttons on the application	According to expectation	Valid

9	Ensure the application display design are clear and easy to understand	User easy to know the information contained in the application in the form of 3D objects, images, and writing	According to expectation	Valid

In table 1 is the result of testing done on the application, and the final step has been revised by the developer and then tested on the internal tester so that all tests performed run as expected to enter the RCP (Release Candidate Product) stage.

3.2. Application Testing

In the testing phase, the app will be tested and compared through three smartphones with different specs and brands. Smartphones used are experia ray, asus fonepad, and Lenovo a6010. Three smartphones were chosen because they have RAM and OS Android that capability to run CARS app properly. All three smartphones will be fitted with the "Circumcision Augmented Reality Simulator" application by utilizing markers and will be recorded weaknesses and advantages of each operation processing speed per smartphone. From here, the CARS application will be compared to the operation processing of each smartphone from different specs and brands, access speed, display, resolution, and rendering of 3D objects. Before doing the testing operation processing, then we need to know the spec smartphone that will be compared first.

Table 2. The comparison spec smartphones

No	Specfication	Experia Ray	Fonepad 7	Lenovo a6010
1	Ram	512 Mb	1 Gb	1 Gb
2	Os Android	Gingerbread	Jelly Bean	Lolipop
3	CPU	1 GHz Scorpion	Dual-core 1.6 Hz	Quad-core 1.2 GHz Cortex-A53
4	Chipset	Qualcomm MSM8255 Snapdragon	Intel Atom Z2560	Qualcomm MSM8916 Snapdragon 410
5	GPU	Adreno 205	PowerVR SGX544MP2	Adreno306

6	Camera	8 MP	5 MP	8 MP
7	Layar	3.3 inches	7.0 nches	5.0 inches

After knowing the spec of each smartphone, next is to do the comparison when the application "Circumcision Augmented Reality Simulation" runs, whether the application runs smoothly when moving to the next menu or back to the previous menu.

No	Operation Processing	Experia Ray	Fonepad 7	Lenovo a6010
1	Loading application start	Slow	Smoothly	Smoothly
2	Application display resolution	Expectation	Expectation	Expectation
3	Marker	Smoothly	Smoothly	Slow
	detection process			
4	Process to the capture marker menu	Smoothly	Smoothly	Smoothly
5	3D object rendering process and information	Smoothly	Smoothly	Slow
6	Loading when the process returns to the previous menu	Smoothly	Smoothly	Smoothly

Smoothly means fast and Expectation means running well. In table 2, it is explained that the better smartphone spec used to run the application "Circumcision Augmented Reality Simulator" by utilizing the marker, then the process displayed will be better, but there are still some shortcomings.

3.2.1. AR Glasses

The proposed architecture describes a wearable system based on the use of AR and on gesture-based input devices. More specifically, we focus on AR glasses since glasses are an accepted way of altering our perception of the world.

3.2.2. Future Work

The next stage of this project is implementing an interaction technique based on the proposed architecture using some devices and testing it on surgical simulator players inside a game concept. This will include an iterative and tactile response, aiming to reveal the potential problems of the proposed architecture.

4. CONCLUSION

CARS or Circumcision Augmented Reality Simulator, as an example of an augmented reality application for surgery simulation, has been successfully built with Blender, Inkscape, Audacity, and Unity3D software. Features in CARS are 3D models, animation, and sound of circumcision procedure. CARS has been tested through various smartphones, lighting, and angle. Based on some trials, CARS is suitable for potential users (medical students and doctors). Implications for future research include assessing reliability and validity by growing its use to a broader population and creating another surgery procedure simulation with augmented reality technology using a smartphone.

REFERENCES

[1] World Health Organization. Neonatal and child male circumcision: a global review. Switzerland: UNAIDS; 2010.
[2] Gray RH, et al. Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised controlled trial. Lancet 2007;369:657-666
[3] Bailey RC, et al. Male circumcision for HIV prevention in young men in Kisumu, Kenya: a randomised controlled trial. Lancet 2007;369:645-56.
[4] Auvert B, et al. Randomized, controlled intervention trial of male circumcision for reduction of HIV infection risk: the ANRS 1265 Trial. PLoS Med 2005;2(11):e298.
[5] Howe RSV. Sexually Transmitted Infections and Male Circumcision: A Systematic Review and Meta-Analysis. ISRN Urology. 2013. 2013: 42 pages. doi:10.1155/2013/109846
[6] American Academy of Pediatrics. Circumcision policy statement. Pediatrics 1999;103:686-693.
[7] Roca P, Alvarado C, Stausmire JM, Farooq S, Hill-Engstler EA. Effectiveness of a simulated training model for procedural skill demonstration in neonatal circumcision. Simul Healthc. 2012 Dec;7(6):362-73. doi: 10.1097/SIH.0b013e3182634ace.
[8] Le B, Mickelson J, Gossett D, Kim D, Stoltz RS, York S, Sharma V, Maizels M. Residency training in neonatal circumcision: a pilot study and needs assessment. J Urol. 2010 Oct;184(4 Suppl):1754-7. doi: 10.1016/j.juro.2010.03.077.
[9] Kigozi G, Nkale J, Wawer M, Anyokorit M, Watya S, Nalugoda F, Kagaayi J, Kiwanuka N, Mwinike J, Kighoma N, Nalwoga GK, Nakigozi GF, Katwalo H, Serwadda D, Gray RH. Designing and usage of a low-cost penile model for male medical circumcision skills training in Rakai, Uganda. Urology. 2011 Jun;77(6):1495-7. doi: 10.1016/j.urology.2010.11.031.
[10] Shen Y, Norfleet J, Zhao Z, Hananel D, Burke D, Reihsen T, Sweet R. High-Fidelity Medical Training Model Augmented with Virtual reality and conformable Sensors 1. J

Med Device; 2016 10(3):030915-030915-3. DOI: 10.1115/1.4033847

[11] Jamali SS, Shiratuddin MF, Wong KW, Oskam CL. Utilising Mobile-Augmented reality for learning human anatomy. Procedia Soc and Beh Scie. 2015:5;25 Pages. 659-669 DOI: 10.1016/j.sbspro.2015.07.054

[12] Lee S, Lee J, Lee A, Park N, Lee S, Song S, Seo A, Lee H, Kim J-I, Eom K. Augmented reality intravenous injection simulator based 3D medical imaging for veterinary medicine. The Veterinary Journal; 2013 Pages.197-202