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New technologies applied to surgical processes: Virtual Reality and rapid prototyping

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Abstract. AYRA is software of virtual reality for training, planning and optimizing surgical procedures. AYRA was developed under a research, development and innovation project financed by the Andalusian Ministry of Health, called VirSSPA. Nowadays AYRA has been successfully used in more than 1160 real cases and after proving its efficiency it has been introduced in the clinical practice at the Virgen del Rocío University Hospital . Furthermore, AYRA allows generating physical 3D biomodels using rapid prototyping technology. They are used for surgical planning support, intraoperative reference or defect reconstruction. In this paper, some of these tools and some real cases are presented.

Keywords. Surgical planning; training; virtual reality; surgery; rapid prototyping

Introduction

The virtual reality (VR) in surgical planning allows to study patient data before surgery and so plan the best way to carry out the process. On the other hand, rapid prototyping (RP) has been introduced in different specialties for surgical planning as maxillofacial, orthopedic and cardiology. It has been shown that significantly reduces operative times. In this paper, we present innovative tools developed and implemented by a multidisciplinary team in Virgen del Rocio University Hospital (VRUH).

1. Methods

AYRA is an application of VR which was developed in 2005 under a research, innovation and development project, funded by the Andalusian Ministry of Health, Spain. AYRA uses radiological images (CT, MRI, PET) in DICOM (Digital Imaging and Communications in Medicine) format or from surface scanning to generate of the 3D model of patients. The radiological image is composed by pixels and vowels with Hounsfield values. Each image has different ranges of Hounsfield values due to capture machine, exposition time, configuration, etc. Due to the segmentation process

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considers these values, a standardization process is need. With the standardization all images will have the same range of Hounsfield values, from 0 to 1. Also, images can have noise for elimination a Median filter is applied. Furthemore, an enhancement of contrast is made to increase the difference between tissues. This pre-process is transparent to users. After preprocessing, segmentation is applied to the image [1-2]. There are three segmentation methods. The first and second are based on thresholding and region growing by seeds. The third method is an innovative semiautomatic algorithm based on self-assessed adaptive region. In this algorithm seeds are provided manually but the typical tolerance parameter, that determines if a new pixel is included in the segmented region, is managed internally using a measure of the varying contrast of the growing region. After the tissue segmentation, the 3D model is generated using an algorithm based on Marching Cubes and graphics engine designed in OpenGL.

Biomodels in virtual reality obtained with AYRA are exported to an .stl format to generate a 3D physical biomodel. Concretely, we use Fused Deposition Modeling (FDM) technology. The piece is generated layer by layer of a thread obtained by melting and extrusion of a polymer that solidifies over the previous coat creating the 3D object. The main resin with which we are working is FDA approved food grade polylactic acid (PLA). PLA mechanical properties make it ideal for such applications because it has a physical behavior similar to the bone. For example, when clinicians perform bench surgery they use the same tools used for surgery which improves the quality of training. The polymer melting temperature, 160 ºC, makes it necessary to cut the PLA with liquid cooling as in the case of bone surgery. All process is indicated in Figure 1.

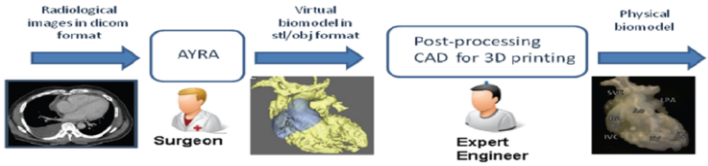

Figure 1- Process for surgical planning

2. Results

For AYRA validation, a prospective study of patients undergoing preoperative imaging with CTA and AYRA 3D virtual model for breast reconstruction was undertaken. 35 consecutive patients were included in the study. A comparative group was formulated by performing a retrospective review of 35 patients operated on by the same primary and assisting surgeons at the same institution. Specific parameters that might potentially contribute to surgical complications were examined. The use of AYRA preoperative planning correlated with operative times reduced by a mean of 2 hours 8 minutes. In addition, it also decreased above 50 percent in overall donor site morbidity [3-4]. RP and VR models are used in different kind of surgery. In Figure 2, you can see some cases. In the top on the left, a complex mandible reconstruction with fibula bone is presented. On the right, a personalized implant was designed to correct the contour defect of Poland Syndrome. Finally underneath, a 3D physical model of complex congenital heart disease (transposition of the great arteries, ventricular septal defect and pulmonary stenosis) is generated to surgical planning.

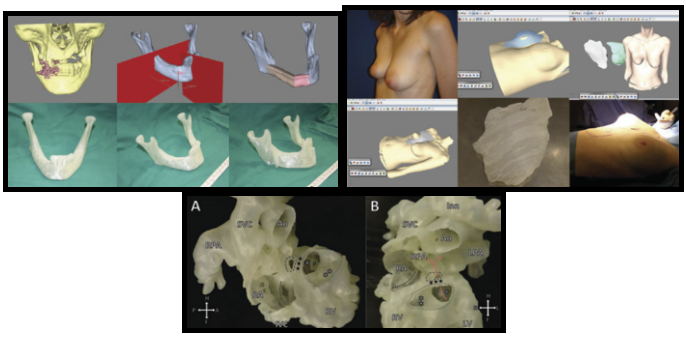

Figure 2- *In the top on the left* Mandible reconstruction using fibula bone and osteotomy guides. *In the top on the right* Poland Syndrome and *down* cardiac model

VR and RP models have been introduced in the surgical process *in* VRUH*, after its efficiency and effectiveness* were *tested in more than 1160* planned cases [5-7*]*.

3. Discussion

In this paper we present innovative tools which main aims are training surgeons and optimize the planning and surgical procedures in order to improve the quality of care in our hospital. They improve the quality of care because surgeons have a support system for decision-making in the surgical field based on real patient images that contribute to improve the clinical practice. With theses technologies, surgical planning is personalized for each patient, with the benefits: decreasing potential risks and operating time, improving the confidence of professionals and opting for less invasive and aggressive solutions in many cases. 3D physical biomodels is a very useful tool for surgeons accustomed to operate people and not to handle 3D software and could become the link between the virtual surgery and the real one.

We are actually investigating new challenges as designed of algorithm for segmentation of tumor in soft tissues with diffuse edged.

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