Building a Web-Augmented Reality application for demonstration of kidney pathology for veterinary education

H.T. Atmaca[1], O.S. Terzi[2]

[1] Department of Pathology, Faculty of Veterinary Medicine,
Balikesir University, Cagis Yerleskesi, 10145, Balikesir, Turkey
[2] Department of Internal Medicine, Faculty of Veterinary Medicine,
Ankara University, Ziraat Mahallesi Sehit Omer Halisdemir Bulvari, 06110, Altindag, Ankara, Turkey

Abstract

Three-dimensional (3D) models created with computers and educational applications designed using such models are used in the medical field every day. However, there is a lack of macroscopic demonstration applications built with digital 3D models in the field of veterinary pathology. The aim is to build a fully interactive 3D educational web-based augmented reality application, to demonstrate macroscopic lesions in kidneys for educational purposes. We used open source and free software for all 3D modelling, Augmented Reality and website building. Sixteen 3D kidney pathology models were created. Kidney models modelled in 3D and published as WebAR are as follows: normal kidney, unilateral neurogenic shutdown with atrophy, hydronephrosis, hypercalcemia of malignancy tubular nephrosis, interstitial corticomedullary nephritis, renal infarct, multifocal petechial hemorrhages, polycystic kidneys, renal masses, multifocal nephritis, pigmentary nephrosis, papillary necrosis, glucose-related rapid autolysis (pulpy kidney), pyelonephritis, renomegaly and kidney stones. With the workflow shown here, it has been presented as a feasible model application for human pathology and presented to educators, researchers and developers who have 3D models and AR in their field of interest. To the best of the authors' knowledge, this is the first study on Web-Augmented Reality application for veterinary pathology education.

Key words: veterinary pathology, education, three dimensional, augmented reality, kidney

Introduction

Three-dimensional (3D) models created with computers and educational applications designed based on them are used in the medical field every day. These applications, with their wide utility range, take place online and are also accessible in university libraries (PLC Informa 2020). Although these applications are mostly in the field of human anatomy, some researchers and companies have also developed similar applications for veterinary anatomy. Although each application has a different interface and interactive software engine, a wide variety of demonstration methods and interactive material presentation have been developed,

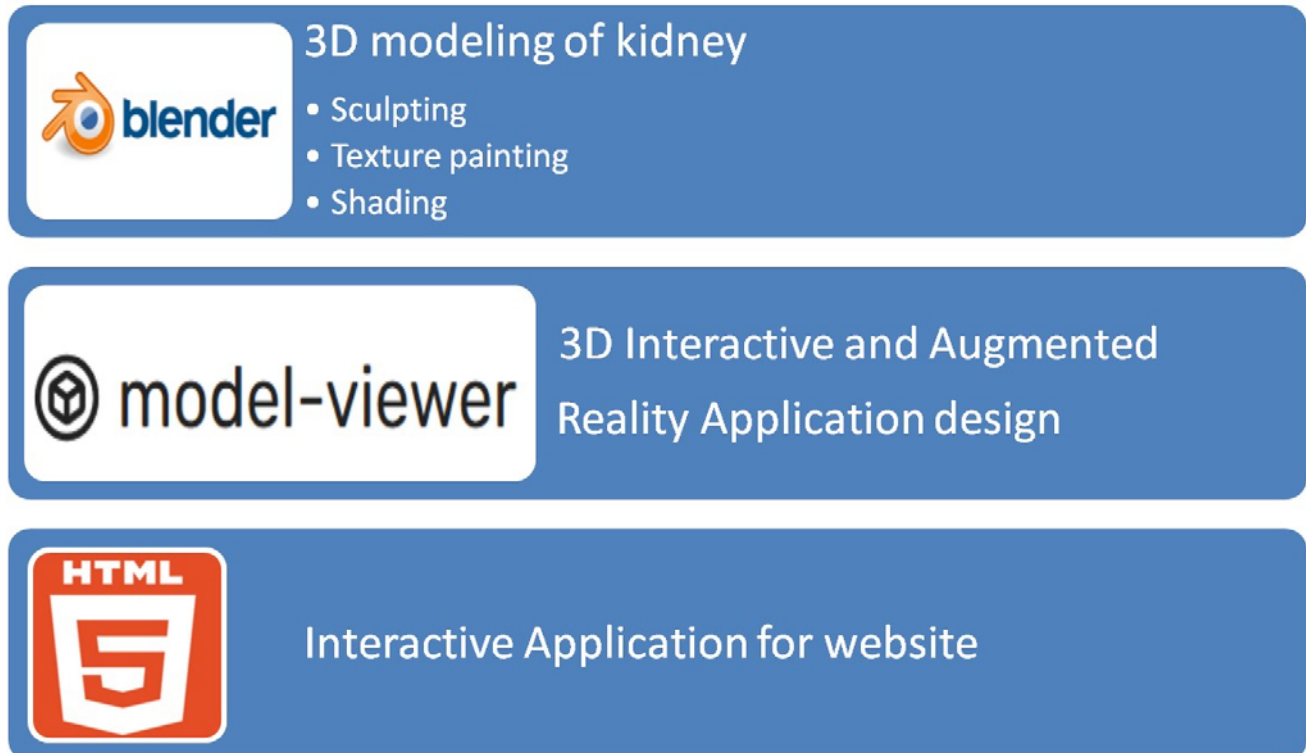Correspondence to: H.T. Atmaca, e-mail: ht_atmaca@yahoo.com

Fig. 1. Demonstration of workflow for 3D modeling and interactive application.

mainly to assist the teachers and students. Digital microscopic and macroscopic image archives and applications are the principal educational materials used in pathology education. Virtual microscopy applications (European College of Veterinary Pathologists – Histology Slide Database 2020, The Joint Pathology Center 2020) and static gross pathology photos (Necropsy Show and Tell 2021, Orvalho and Peleteiro 2021) on different websites are very important in pathology education. These digital microscopy databases play an important role in the educational process of veterinary medicine worldwide. It is indeed a fact that macroscopy for morphological diagnosis is one of the first and important stages in pathology.

Although there are 3D applications developed for veterinary anatomy education, there is a lack of macroscopic demonstration applications built with digital 3D models in the field of veterinary pathology. This makes imperative the need for such 3D applications in the veterinary curriculum for education and training. The application described in this paper will undoubtedly be a valuable tool in veterinary pathology education. Mobile augmented reality (mAR) technology, which has become widespread in recent years, permits students to enjoy flexible learning wherever and whenever they want (Bujak et al. 2013). Therefore, we designed this application for use on both the web and mAR, and named it a WebAR application. As is known, in AR technology, the real environment is used as a back-ground and a sense of reality is created by adding texts, pictures, sounds, animations or 3D objects to the video image of the real world (Billinghurst et al. 2001).

In this study, we built a fully interactive 3D educational WebAR application demonstrating macroscopic lesions in kidneys. This application was built using open source software that anyone can use. It is hoped that this will aid the understanding of gross kidney pathology by veterinary students. The workflow methodology created here could inspire further research in this field, to help educators develop certified digital educational materials for their students.

Materials and Methods

Modelling

A single basic demonstrative 3D kidney anatomy was modelled for the application. The workflow for this application is shown in Fig. 1. Modelling was done in open source and free Blender 2.82 software. First, the Blender software was run and a 3d UV sphere was added to the scene (Fig. 2). We then started to outline the kidney model in which we would show the lesions. We used a cross section kidney structure in the kidney model (Fig. 3). Thus, we showed the cortex, medulla, renal pelvis, and the capsule.
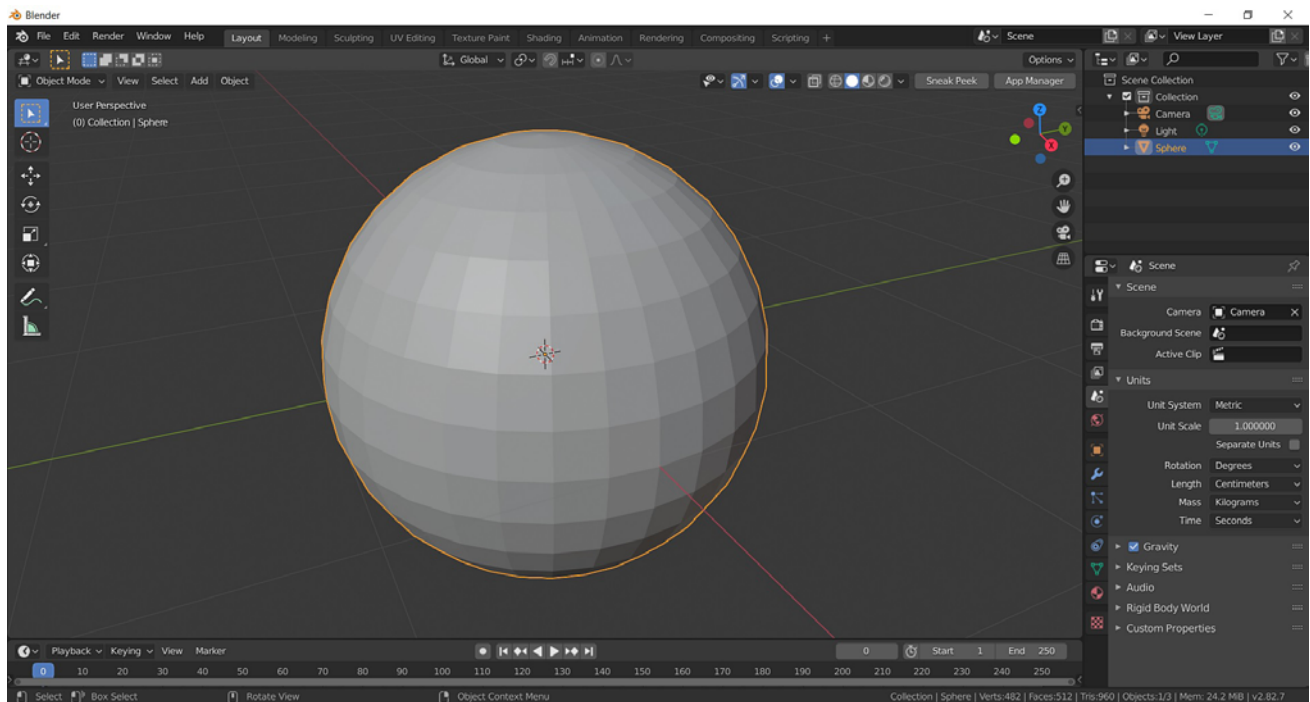
Fig. 2. Modelling interface in Blender. A UV mesh sphere was used to create a kidney model using sculpting mode.
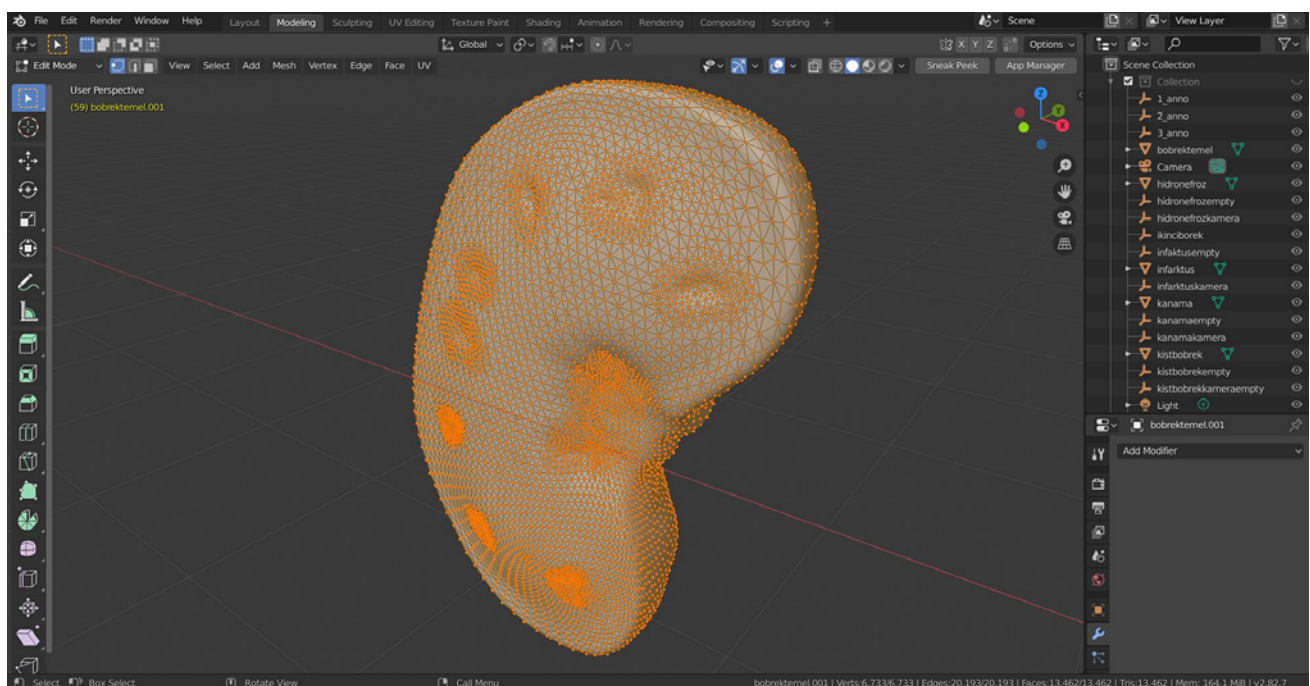

Fig. 3. Cross section kidney structure created using sculpting mode in Blender from a UV mesh sphere.

Sculpting, texture painting and shading

After the modelling process, sculpting was performed on the 3D kidney model in order to understand the different macroscopic findings (Fig. 4). Following the literature, photorealism was applied with texture painting and shading onto the 3D kidney model (Fig. 5). Lesion description and demonstration of the models were made as indicated in the literature (King et al. 2014, Cianciolo and Mohr 2015).

Augmented Reality (AR)

The 3D kidney models were saved as a single file in the GLB format, including the texture images. GLB is the binary file format representation of 3D models saved in the GL Transmission Format (glTF). GLB files were used for AR applications on both web and android applications. GLB files for AR on IOS devices were converted to USDZ format in the Reality composer program on the MacOS device and saved. Whichever
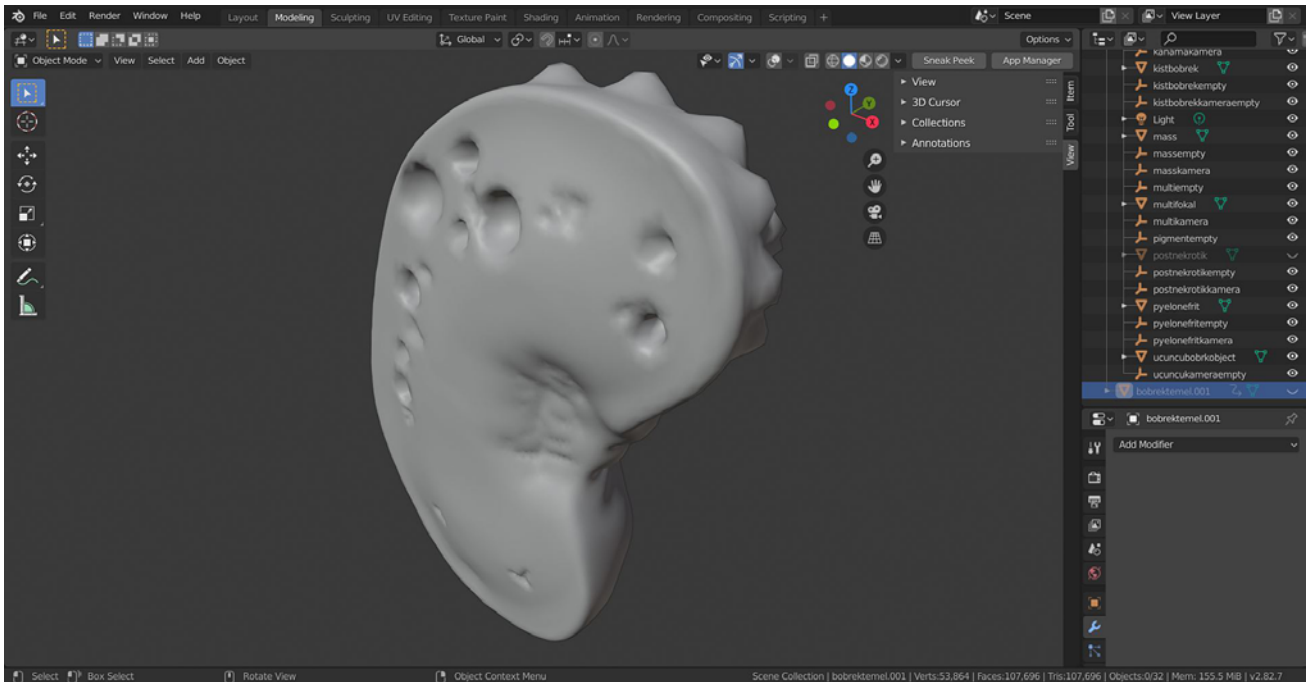
Fig. 4. Sculpting interface in Blender. Working on cystic kidney. With sculpting mode, adding cysts with blob and inflate tools in Blender.
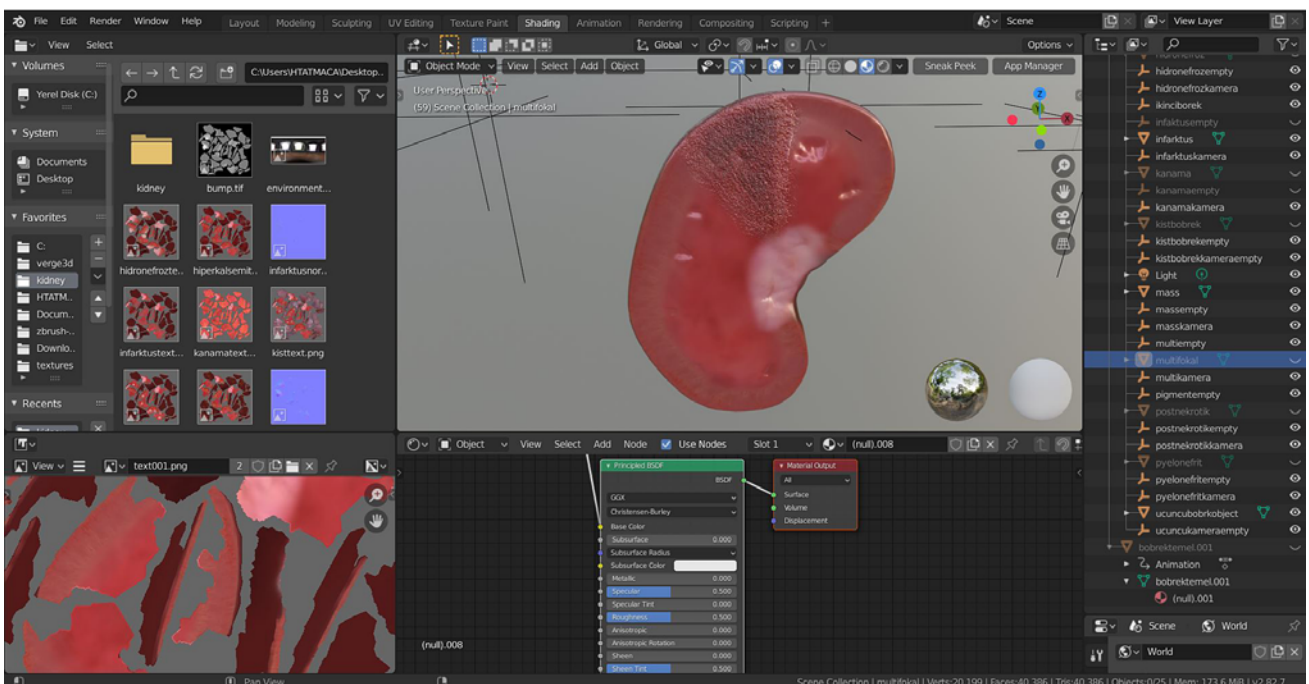

Fig. 5. Texture painting and shading interface in Blender.
Working on infarct. With referring some macroscopic image databases for veterinary pathology, lesions illustrated with painting and texturing. We do not use original macroscopic images for texturing, we use painting and shading to simulate the natural appearance of the lesions and as described in textbooks for student.

device is used for AR view, the appropriate file format for that device is automatically displayed. If you run the application with an Android mobile device, you will view the file in GLB format, if you run it with an IOS device, you will view the USDZ format file with the same 3D kidney models.

Creating interactivity

The 3D kidney models were then converted into a web-based application using HTML codes. The codes that are required for the WebAR application are open source codes and were obtained from github (GitHub - google/model-viewer 2020). The <model-viewer> web

component can be used to view and act together with 3D models on the web, and it smoothly transitions to placing, and acting together with, such 3D models in Augmented Reality on the web (Developer/Arcore, Google 2021). Annotations that make it easier for students to understand were added. These annotations were added on each web page in the application and on the 3D models. These annotations were made using the GLB editor. We also made the basic webpage contents, such as listing the 3D kidney models, providing information about the application and the contact page, with free HTML website builder softwares.

Results

Sixteen 3D kidney pathology models, with a total file size of 19.9MB, were created in the software and saved, according to the lesions. The following 3D models were created: normal kidney, unilateral neurogenic shutdown with atrophy, hydronephrosis, hypercalcemia of malignancy tubular nephrosis, interstitial corticomedullary nephritis, renal infarcts, multifocal petechial haemorrhages, polycystic kidneys, renal masses, multifocal nephritis, pigmentary nephrosis, papillary necrosis, glucose-related rapid autolysis (pulpy kidney), pyelonephritis, renomegaly and kidney stones.

These models were uploaded to the internet server. Thereafter, the website was activated immediately. It is available at https://www.veterinarypathology3d.com. All models, including annotation and information, can be viewed on the desktop from any computer through any browser. When accessing our website from any mobile device, models can be viewed exactly as from desktop browsers. Optionally, the AR feature can be activated and the model displayed on a surface with a real world background.

Discussion

In our study, macroscopic lesions in the kidneys were designed as an interactive 3D application for education and training. We have presented the workflow methodology with the application created as both a web-based and AR application. This application is built with widely used open source software and public WebGL codes and is launched for problem-free use.

The purpose of this 3D interactive application is to create an additional resource for veterinary pathology education. The next step will be user verification of this resource. Moreover, a study on the impact of this practice on students will have particular value in proving its place in the veterinary medicine curriculum. The methodology used in this study can be considered successful since the main macroscopic lesions shown. Further development of the current work by including other organ pathologies or histopathology could be the basis for future research. 3D and AR applications showing macroscopic lesions of all organs and tissues were envisaged, but due to the lack of appropriate staff and the shortage of time we could allocate for this research, we decided to confine ourselves to kidney pathology. We hope other researchers may be motivated by our effort to create similar 3D pathology applications of other organs and tissues. The anatomy of kidneys in domestic animals in veterinary medicine education is variable. Therefore, the lesions were shown on a common illustrated model.

AR technology, which has gained popularity in many areas, has been used frequently in education in recent years. AR applications are reportedly quite effective in facilitating meaningful learning, as they contribute to the understanding of the content by visualising virtual 3D structures and clarifying complex issues (Wu et al. 2013). Interacting with the 3D view of objects from different perspectives improves students' spatial and practical skills (Kerawalla et al. 2006, Cheng and Tsai 2013). Additionally, AR technology provides instant feedback through real-time interactions that enable students to control their own learning processes (Bujak et al. 2013).

Our application aims at imparting learning by demonstrating basic macroscopic lesions with the logic of illustration, based on 3D models prepared on the computer. Of course, this educational workflow could be done with other 3D techniques too. Digital 3D models (Photometry) obtained by photogrammetry, digital 3D models obtained with a 3D scanner, or 3D printed tissues and organs obtained from these 3D models, can be cited as examples of 3D techniques. There are numerous advantages to using digital 3D models in pathology, some of which can also be obtained in 3D printing (McMenamin et al. 2014, Mahmoud and Bennett 2015, Lim et al. 2016, Salazar-Gamarra et al. 2016). Each of these has an advantage over the other. There are disadvantages to 3D printing too, such as a lack of personnel and expensiveness of the devices. Providing annotations on the digital 3D models will support the students working alone, by adding notes they should pay attention to, and by indicating the way the lesions are seen. It is of course true that the lesions are exhibited in real organs in the pathology museum, and that the students obtain sufficient macroscopic morphological information from them. However, unfortunately, not every faculty of institutes offering veterinary pathology education supports these museums. To establish a pathology museum, it is necessary to carry out numer-

ous necropsies, collect, fix and store tissues with lesions. This process requires many years for newly established institutions that do not handle a wide range of cases. It is therefore an important development for students to be able to see the macroscopic lesions in 3D and obtain additional information with this application, as if they were physically in the pathology museum at a time and location of their convenience.

In addition, it has been observed that the information displayed on 3D models is always more permanent than that on two-dimensional (2D) images. This situation has paved the way for the development of education for students. The interaction arising from these 3D models provides better clinico-pathological correlation for the physician than a 2D image and a better learning environment for the student (McMenamin et al. 2014, Hua-quan et al. 2014, Allen et al. 2016, Peterson and Mlynarczyk 2016).

The aim of this study was to clearly demonstrate how widely available software can be used to build a fully interactive 3D package to increase the understanding of macroscopic lesions in the kidney, thus creating a utilitarian application for education and training.

Of course, further validation and participation by the end users – students and veterinary clinicians – will be required to fully assess the impact of this educational application. Through this process, we have created a foundation on which future veterinary educators and students can build tailor-made packages for use in veterinary pathology education. Actually, this is not limited to veterinarians and veterinary students. With the workflow shown here, it has been developed as a universally feasible model application for human pathology and is presented to educators, researchers and developers who have 3D models and AR as their fields of interest.

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