

Development of an Anaglyph Anatomical Atlas of Rabbit as a New Generation of Printable 3D Anatomical Atlases

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Article info:

Received: 21 Apr 2013

Accepted: 10 Aug 2013

Key Words:

Anatomy,
Rabbit,
Education,
Anaglyph,
Three- dimensional Image.

ABSTRACT

Introduction: To improve anatomical atlases, we tried to create a printable 3D atlas of rabbit's anatomy based on the Anaglyph.

Methods: In this study, twenty white rabbits euthanized and dissected. All 3D images were reconstructed by means of "stereo photo maker (SPM®)" software.

Results: By this atlas, users can easily understand nomenclature, the topography and, certainly, the transposition of the anatomical structures in each image even if they are not at the dissecting room.

Conclusion: The novelty of this atlas may encourage students to spend more time and concentrate on the material more as opposed to the classical atlases, thereby, leading to better understanding of anatomy. It is worth mentioning that this atlas has been prepared as an example for other works.

1. Introduction

In the last few years, dramatic technology-driven advances in biochemistry, genetics, and molecular biology have led to reduction in the time devoted to teaching basic disciplines such as anatomy [1].

Unfortunately, this fact has led to the transfer of a large amount of knowledge to students in a very short time. Due to reduction in laboratory time and lecture content in anatomical education, curriculum has been over-

crowded and student emphasized on excessive memorization, often clinically irrelevant facts during learning with no sufficient exercise in critical analysis and synthesis into concepts, and inadequate training in the application of theoretical knowledge [2-3], thus, traditional teaching of anatomy through tutorials, textbooks and atlases and performing prosection/ dissection, may seem pedagogically outdated, boring and unnecessary, since it requires too many names and too much factual detail to be learned [1, 4]. Particularly, descriptive anatomy is more traditional and static than the other anatomic sub-disciplines. Also, since its methodology is based on dis-

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section, it is morally unacceptable and disgusting. And, if the other accusations are accepted even in part, dissection is very expensive [1].

It is worth mentioning that anatomy is the principle of science and art of medicine and the most important part for understanding organs' function, therefore, anatomy is at the threshold of undergraduate education and training [5-6].

As a result, contemporary teaching of anatomy, as an academic discipline, needs to reconsider how it can best teach students to serve their needs in training. There is no doubt that teaching of anatomy like other disciplines, at any level, is inevitable of adapting with significant modern technological and social changes that affecting all aspects of our lives.

Due to focusing of veterinary and medicine on patient as a three-dimensional (3D) object, anatomical education involves learning and applying 3D information which is the first time that most students encounter courses so dependent on 3D information, thus, so difficulties might arise in both vocabulary and concepts [7].

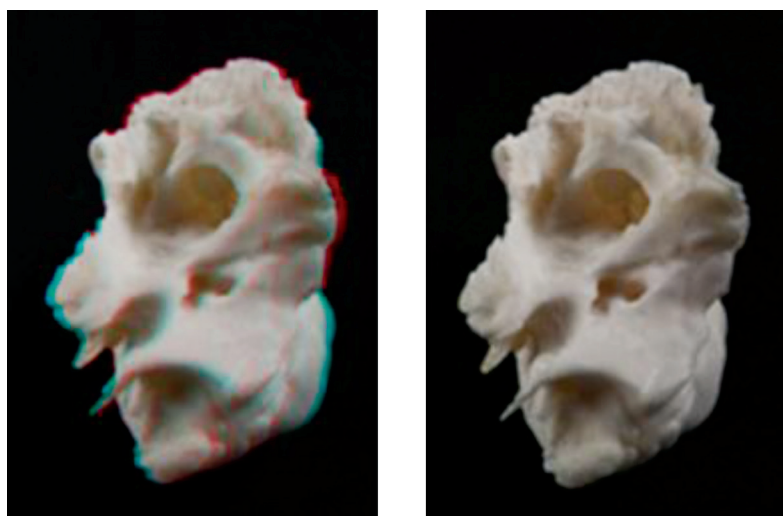
To find ways for making anatomy as attractive as its importance, due to critical advantages that 3D anatomical images are provided not only for anatomy learning but also for simulation of surgical approaches and procedures, veterinary and medical anatomy education tend to employ 3D visualization to provide definitive and in-depth training [8].

In this way, many researchers have considered the enormous potential of computer-assisted learning and virtual reality systems (CAL and VR) as a potent adjunct modality to anatomical education. Recently, the decline in the cost and availability of computer technology have facilitated the implementation of digital images databases of dissection [9-10], web-based anatomy atlases [11], and other computer aided learning modalities [12-13] with the detail required in modern diagnostic and surgical techniques [14]. Unlike the classical 2D atlases, these digital 3D images enable the students to perceive the subtle structures of any organ from any desired angle [2, 15-16].

Although the gross anatomical details of these 3D computer-based atlases are certainly sufficient, in the cases with fine details, computer models do not yet have the realism comparable to drawings in a classical atlas. Furthermore, there are some matters, i.e. the improvements in detail and spatial resolution of the described organ and the answer to this question "how can we create realistic images?".

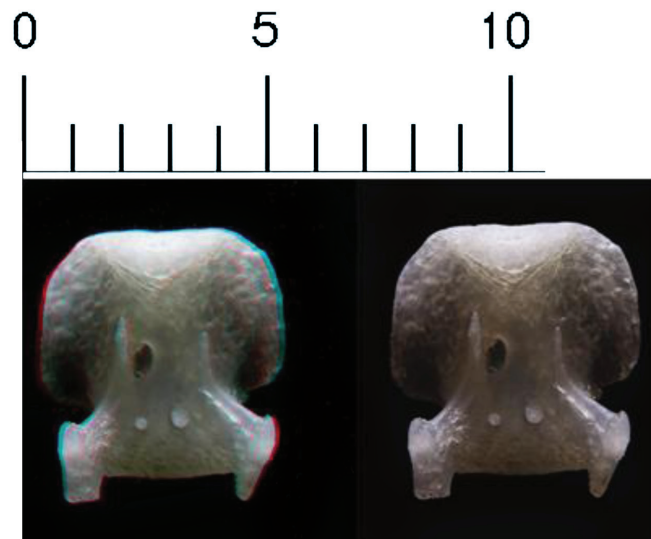
Computer-based 3D atlases have a major limitation that are still too time consuming with their many possibilities and options that make them too complicated [14]. Two other important limitations for these atlases are also worth-mentioning, i.e. insufficient functional information and their need to use sophisticated equipment [17].

Consequently, to make teaching of anatomy more attractive without those limitations that mentioned previously, other three-dimensional representing methods should be considered which create realistic images with



ANATOMICAL SCIENCES

Figure 1. Right medial view of rabbit's temporal bone; the right image is 2D unilateral lighting and the left image is an anaglyph (the stereoscopic effect will be visible with red/cyan glasses only).



ANATOMICAL SCIENCES

Figure 2. Dorsal surface of seventh caudal vertebrae of rabbit; the right 2D image doesn't show actual morphometric details because this image conveys only one aspect of the data (the stereoscopic effect will be visible with red/cyan glasses only).

no need to spend more money and time. The simplest and most economical method of them is Anaglyph.

Anaglyph is a scale-independent method of presentation that can be printed and projected at any size [8, 18]. Furthermore, it is very inexpensive and people with normal vision can easily see anaglyphs in three-dimension [18].

In this study, we tried to create a 3D anaglyph atlas of rabbit anatomy due to the increase in rabbit-pet population and the widely use of this species both in husbandry and laboratory practice [19-20]. This atlas consists of a large variety of full-color illustrations that show appropriate details of configuration, adjacencies, transposition, boundaries, and nomenclature of organs.

2. Materials and Methods

This study has been approved by the Ethics Committee of the Research Council of Bu-Ali Sina University, Hamedan (license number 88/10/28-490).

2.1. Preparation of Carcass and Anatomical Dissection

Twenty white rabbits (*Oryctolagus cuniculus*) were anesthetized by the injection of sodium thiopental (Nesdonal) 2.5% which was followed by Heparin, 3000 IU through marginal vein. Then, common carotid artery and jugular vein were cannulated. An equal volume of warm

Ringer lactate was infused through the jugular vein to facilitate the washout of blood from the vessels. Ringer was infused until the animal's spontaneous breathing ceased [21]. For representing the vessels, after completion of bleeding out from carotid artery, the injection of 50 ml red and blue latex into carotid artery and jugular vein carried out, respectively.

Anatomical dissection as the systematic manner was performed on preserved rabbit carcass by the sequential division of tissue layers and the liberation of certain structures through removing the regional fat and connective tissue to provide anatomical views.

To obtain normal color presentation of organs and the best contrast in the photography, the anatomical dissection and photography procedure were performed by the fresh specimens.

2.2. Application of Anaglyph Method

All parts of the rabbit's body were photographed by using a Canon G10 digital camera (14.0 megapixels with macro lens) and reconstructed to make 3D images.

For reconstructing of anaglyphs, there are several softwares, the simplest of which is the Stereo Photo Maker (SPM®¹).

1. <http://stereo.jpn.org/eng/stphmkr>

Our algorithm for generating an anaglyph with SPM can be summarized as the following:

1. Make the image stereo pair.
2. Open the right and left images.
3. Activate the "Easy Adjust" to merge two images.
4. Find a number of corresponding points across the image pairs manually in order to image alignment.
5. Activate the "Half Color" to create a red/cyan anaglyph. There are various anaglyph combinations such as red/cyan (blue + green = cyan), yellow/blue, and green/magenta, but red/cyan is the most general combination that was used in this work.
6. Then, manually adjust the color components used for the left and right components of the anaglyph to suit the filter in the glasses used.
7. Review each image on the computer monitor at a distance of 30-50 cm and if it was found proper, it would be selected and saved as TIF format.

However, some limitations such as ghosting artifact that occurs due to misalignment of the color components which form the anaglyph, decrease the image's quality; there are several studies that propose methods to produce anaglyphs with high quality and the reduction of undesired ghosting artifacts [22]. To achieve this goal as far as possible, the saturation of the original color

images was modified. It was observed that color saturation should be altered carefully because reducing the saturation would give good 3D visualization with grey appearance; nevertheless, unaltered saturation would result in poor 3D visualization [18].

Marginal parts of anaglyphs may be disappeared due to light background, then, dark background should be used, and the margins of each stereo pair should carefully be cut.

2.3. Layout

"A colour Atlas of Anatomy of Small Laboratory Animals" [23] was the framework on the basis of which the general structure and arrangement of the atlas were designed.

To find out the names of structures and to use 3D images easily, each 3D image was adjusted the next page of an annotated 2D image.

3. Results

To improve the resources available in the education of rabbit anatomy, we have generated a 3D printable atlas of muscles, tendons, skeletal structure, nerves, and blood vessels. Pictures of all parts of rabbit's body were digitally taken and reconstructed to make 3D images.



Figure 3. Unilateral lighting was used which makes deep shadow to show the depth and dimensions of small and flat objects (this is the figure 51 of atlas).

This atlas includes 136 images (sixty eight 2D and sixty eight 3D) with annotated 2D image for each, which has been adjusted before the same 3D image. This layout might enable users to find out the topography of each structure. Forty four pictures were allocated to skeletal structure, and 92 pictures to muscles, nerves, tendons, blood vessels, and lymphatic system.

Also, shadow and lighting has been used in order to show the depth and dimensions of objects (Figs. 1- 3).

The atlas was split into seven chapters with an introductory chapter including:

Chapter 1, Head and Neck; Chapter 2, Trunk; Chapter 3, Thoracic Organs; Chapter 4, Abdominal Organs; Chapter 5, Pelvic Organs; Chapter 6, Fore Limb; and Chapter 7, Hind Limb.

In all of the chapters, photographs were taken from newly dissected specimens. The pictures are visualized in the organs' natural colors, giving them a more realistic look (Fig. 4).

The chapters of regional anatomy are consequently placed behind the systematic illustrations of the anatomical structures so that students can study the systematic anatomy of bones, joints, muscles, nerves, and vessels e.g. before dissecting an extremity. By using high quality pictures, there is no need to magnify in order to study the photographs.

Despite numerous photos, the size of the volume did not increase so that an atlas was offered for the students, which was easy to handle and cope with.

4. Discussion

To determine how anatomy should be taught, currently, that make it as attractive as its importance, we developed a 3D anatomical atlas of rabbit.

In comparison with digital atlases, the main advantage of our atlas is that anaglyph method is used for construction of 3D images and it is available as a printed book. Anaglyphs have the capacity for quick representation of very complicated morphology, and enable a researcher to spatially investigate the specimens' morphology without any sophisticated equipment (Fig.1). Moreover, it can illustrate some morphometric measurements (Fig. 2). Also, it can be readily available whenever or wherever, for example, this is very easy to do in bed if you choose to use the book as a late-night read.

Furthermore, by adjusting the annotated 2D image before each 3D image, users can easily understand nomenclature, the topography, and certainly, the transposition of the anatomical structures in each image without being at dissecting room (Figs. 3, 4). The readers will have verification of facts from their primary knowledge and they will gain a real three-dimensional understanding of

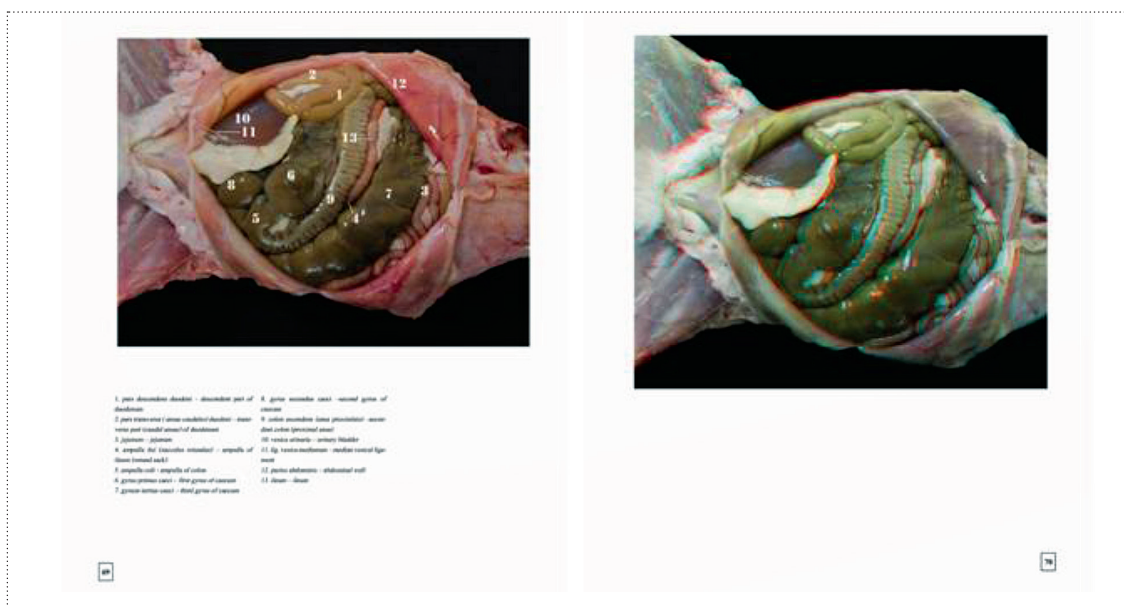


Figure 4. The pictures are visualized in the organs' natural colors, giving them a more realistic look (this is the figure 35 of atlas).

anatomical details. Also, it will give readers more confidence and improves their competence.

The use of shadow and lighting is one way to show depth and dimensions of objects. Since it is shown in Figure 1 on the right, you can observe the rabbit's temporal bone with unilateral lighting which makes deep shadow and with the same anaglyph next to it. In spite of the fact that all efforts were made to show depth, dimensions and structural complexity of the bone, it is, nevertheless, not comparable to the left anaglyph.

Its capacity is clear when the image has a small and flat object without any bumps and dents. This ability of anaglyph in 3D viewing a delicate object (seventh caudal vertebra of a rabbit) is observed in Figures 2 and 3.

Another important feature of this atlas is the realism of images. Because in hand drawn classical atlases, there are many parts in each painting that possibly have been missed at real dissection. Although some structures are not found in the pictures of our atlas, they are as real as those that can be seen in an actual dissection. Moreover, this atlas is a practical way to create realistic images that computer-based anatomical atlases cannot [14].

The novelty of this 3D anatomical atlas may encourage students to spend more time and concentrate on the material more as opposed to the classical atlases, thereby, leading to better understanding.

However, the dissecting room is an extremely expensive item in any department of anatomy and the ever-growing financial burden affects the budget of medical and veterinary medical schools, we can claim that our 3D atlas with the ability to render three-dimensional real views of any structure might play like an actual cadaver by which a trainee develops a clinically-oriented map of deep-seated anatomy.

In general, regarding the convenience, low cost and other advantages that mentioned about this atlas in the teaching of descriptive and applied anatomy, we can suggest similar works to develop other medical and veterinary anatomical atlases.

Acknowledgment

The authors wish to thank all coworkers specially Dr. Mahdi Rouhi and Mr. Jafar Zeinalian for their helps in the development of the 3D Atlas of Rabbit Anatomy. We would like to express our great gratitude to authors of "A

Colour Atlas of Anatomy of Small Laboratory Animals", a great anatomical atlas with admirable beauty.

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