Methodology

Basic Anatomy

OA Anatomy
Open Access

Practical guide to learn human heart anatomy on animal model

FM Trovato[1], G Musumeci[2*]

Abstract

Introduction

Traditional anatomy teaching consists of textbook and cadaver use. A textbook can be easily used for private study independently of the cadaver dissection; however, it can only display visual information on an anatomical structure through diagrams or photographs which are presented in two dimensions. To appreciate the tridimensional shape of organs, the study on anatomic plastic models or animal models has overcome the limitations of cadavers use.

Method

After a brief introduction on mediastinum and thoracic cage, the practical lesson on pig heart starts with the examination of the surface and the correct orientation of the organ. Then the structures of the main vessel are evaluated, and consecutively the morphology of atria, ventricles and valves are analised.

Conclusion

In this methodological study we report the current and ultimate techniques to teach anatomy and explain in details our method on pig model to learn human heart anatomy.

Introduction

Traditional anatomy teaching consists of cadaver and textbook use[1]. Currently, anatomical study for medicine and surgery students is carried out through a combination of didactic lectures, self-directed study with textbooks and atlas, practical laboratory sessions of dissection and observation of cadaveric material. The well-known limitations (the use of formalin) with this approach have led to the introduction of alternative teaching methods[2]. The resources available for anatomy education are being expanded, through greater use of living anatomy and medical imaging, and in some cases led to the exclusion of cadaveric anatomy[3]; however, "traditional" methods of anatomy teaching are still the central teaching method in many institutions[4,5]. Dissection of the human body is considered essential in the unique ethical and technical formation of future physicians and surgeons, both in undergraduate and postgraduate medical education[6,7,8]. The cadaver gives the student an opportunity to observe the structures of the body in situ, studying them in three-dimensional space and allowing the student to gain familiarity with the textures, strength, and other physical characteristics of the bodies' different tissues and anatomical variations[9]. Textbooks support the study with cadaveric materials and aid the student to identify the 3D structures and make links between form (anatomy) and function (physiology). A textbook can be easily used for private study independently of the cadaver dissection; however, it can only display visual information on an anatomical structure through diagrams or photographs which are presented in a two-dimensional plane on the textbook's pages[9]. One compromise between dissection and textbook would be the use of both traditional (dissection, lectures, textbooks and atlas), technological (interactive three-dimensional computer model of human) resources, which are also integrated with practical laboratory exercises (on plastic models and animal organs)[10,11,12].

The aim of this methodological study is to confirm the useful of practical activity on animal organs, in this case the heart of the pig, compared with traditional anatomy teaching methods as a supplement to didactic lectures. In this issue we focused the attention in the practical activity on the pig heart, already shown to be effective in our recent study[12]. Here we explain in details our methodology adding more information and iconographic materials for better readers/students understanding.

Materials and Methods

Deepening on the practical activity on the pig heart as previously described by Musumeci and coauthors12.

Before the practical activity (total duration: 3 hours) a brief introduction on the pulmonary and systemic circulation, the thoracic cage and mediastinum was made. We specify that there are some differences between the human heart and pig heart, such as Valentine heart shape and numbers of pulmonary veins. The students were equipped with the necessary equipment to operate, listed as follows:

- Dissecting equipment (Figure. 1):
- Surgery forceps (20cm metal surgery)
- Anatomical thumb forceps (20 cm metal surgery)
- Scalpel
- Scissors
- Coat
- Latex gloves
- Pig heart

*Corresponding author
Email: g.musumeci@unict.it

[1] Department of Medical and Pediatric Sciences, Internal Medicine Division, School of Medicine, University of Catania, Catania, Italy.
[2] Department of Biomedical and Biotechnological Sciences, Human Anatomy and Histology Section, School of Medicine, University of Catania, Catania, Italy.

Competing interests: None declared. Conflict of interests: None declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

For citation purposes: *Trovato FM, Musumeci G. Practical guide to learn human heart anatomy on animal model. OA Anatomy 2014 Nov 01;2(3):30.*

Pig hearts were ordered from a biological supply company or obtained easily from a local butcher. In this case we asked the butcher to remove the organ with as many of the blood vessels as possible and not to damage the heart because in some instances there may be damage caused by the meat veterinary inspection process. Students were invited to use constantly the forceps to explore the anatomical elements, their hands to test the structural consistency and to be careful in using scissors and scalpel to avoid cutting themselves.
The standard execution was composed of several steps:

1- Remove the pericardium and observe the morphology of the intact heart (Figure 2a).
2- Place the heart with the sternocostal surface towards the observer (Figure 2b).

Remind students that the heart is directed forward, upward, and to the left. Its lower part is convex, formed chiefly by the right ventricle, and traversed, near its left margin, by the anterior longitudinal sulcus. Its upper part is separated from the lower by the coronary sulcus, and is formed by the atria; it presents a deep concavity, occupied by the ascending aorta and the pulmonary artery.

3- Explore the elements that characterize the sternocostal surface:

Remind students that the sternocostal surface is deficient in front, where it is crossed by the root of the pulmonary artery.

- The anterior atrioventricular groove;
- The anterior longitudinal sulcus;

Remind students that the anterior atrioventricular groove and the anterior longitudinal sulcus contain the coronary arteries respectively right and left.

- Ascending aorta and the pulmonary artery (Figure 2c).

4- Locate the ductus arterious Botalli, between the aorta and pulmonary trunk.
5- Find the right margin (acute) and left one (obtuse) of the heart (Figure 3b).

Remind students that the right margin of the heart is long, and is formed by the right atrium above and the right ventricle below. The atrial portion is rounded and almost vertical; it is situated behind the third, fourth, and fifth right costal cartilages about 1.25 cm from the margin of the sternum. The ventricular portion, thin and sharp, is named the acute margin; it is nearly horizontal, and extends from the sternal end of the sixth right costal cartilage to the apex of the heart.
Remind students that the left or obtuse margin is shorter, full, and rounded: it is formed mainly by the left ventricle, but to a slight extent, above, by the left atrium. It extends from a point in the second left intercostal space, about 2.5 mm from the sternal margin, obliquely downward, with a convexity to the left, to the apex of the heart.

6- Locate the diaphragmatic surface of the heart (Figure 2d).

Remind students that the diaphragmatic surface, directed downward and slightly backward, is formed by the

Figure 1: Instruction of dissection. a. Dissecting equipment. b. The pig heart within its pericardium.

ventricles, and rests upon the central tendon and a small part of the left muscular portion of the diaphragm. It is separated from the base by the posterior part of the coronary sulcus, and is traversed obliquely by the posterior longitudinal sulcus.

7- Research the elements that characterize the diaphragmatic surface:

- The coronary sulcus, also known as the posterior autrioventricular groove;

Remind students that the coronary sulcus contains the nutrient vessels of the heart, such as right coronary artery and the coronary sinus.

- The interatrial groove;
- The sulcus terminalis;
- The posterior longitudinal sulcus;

Remind students that the posterior longitudinal sulcus is on the diaphragmatic surface near the right margin; these grooves extend from the base of the ventricular portion to a notch, the incisura apicis cordis, on the acute margin of the heart just to the right of the apex.

- The incisura apicis cordis.

8- Outline the elements that characterize the base of the heart (Figure 2d).

Remind students that the base directed upward, backward, and to the right, is separated from the fifth, sixth, seventh, and eighth thoracic vertebrae by the esophagus, aorta, and thoracic duct. It is formed mainly by the left atrium, and, to a small extent, by the back part of the right atrium. Somewhat quadrilateral in form, it is in relation above with the bifurcation of the pulmonary artery, and is bounded below by the posterior part of the coronary sulcus, containing the coronary sinus. On the right it is limited by

Competing interests: None declared. Conflict of interests: None declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

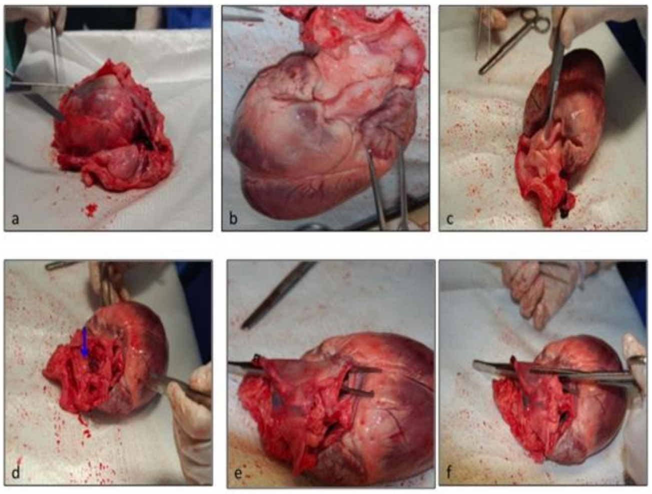

Figure 2: Instruction of dissection. a. Removing the pericardium. b. Sternocostal surface; right margin or acute, left margin or obtuse and apex. c. Ascending aorta and the pulmonary artery. d. Diaphragmatic surface; base of the heart (blue arrow). e. Lumen of the superior vena cava and inferior vena cava. f. Incision of the sinus of vena cava.

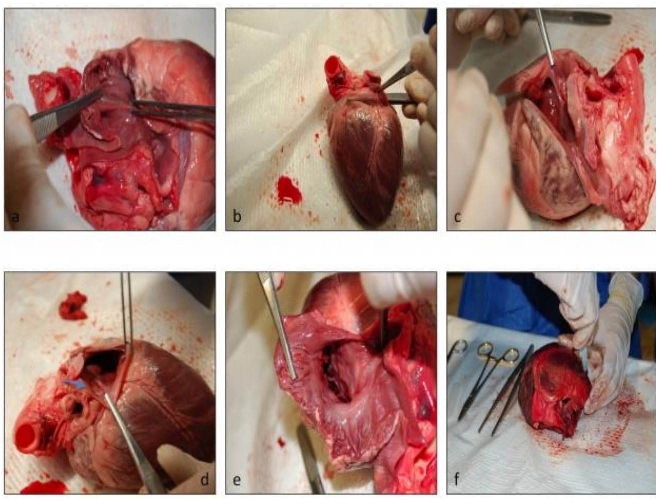

Figure 3: Instruction of dissection. a. Pectinate muscles within the right auricle and the crista terminalis. b. The coronary sinus. c. The Thebesian valve. d. The fossa ovalis (blue arrow). e. The right atrioventricular orifice. f. Start of the incision of the acute margin of the right ventricle to the pulmonary trunk.

the sulcus terminalis of the right atrium, and on the left by the ligament of the left vena cava and the oblique vein of the left atrium. The four pulmonary veins, two on either side, open into the left atrium, while the superior vena cava opens into the upper, and the inferior vena cava into the lower part of the right atrium.

9- Locate the apex of the heart (Figure 2b).

Remind students that the apex is directed downward, forward, and to the left, and is overlapped by the left lung and pleura: it lies behind the fifth left intercostal space, 8 to 9 cm from the mid-sternal line, or about 4 cm below and 2 mm to the medial side of the left mammary papilla.

10- Using forceps, highlight the superior vena cava and the inferior one.

11- Introduce the forceps above the lumen of the superior vena cava, it pops out from the inferior vena cava (Figure 2e).

Remind students that the superior vena cava returns the blood from the upper half of the body, and opens into the upper and back part of the atrium, the direction of its orifice being downward and forward. Its opening has no valve.

Remind students that the inferior vena cava, larger than the superior, returns the blood from the lower half of the body, and opens into the lowest part of the atrium, near the atrial septum, its orifice is directed upward and backward, and guarded by a rudimentary valve, the valve of the inferior vena cava (Eustachian valve).

12- Dilating the forceps highlights the sinus of vena cava or sinus venarum. Note the characteristics of the vein wall subsequently compared to the arterial.

13- From this position, use scissors to cut the sinus of vena cava (Figure 2f).

14- Move the flaps to observe the right atrial cavity.

Remind students that the right atrium is larger than the left, but its walls are somewhat thinner, measuring about 2 mm; its cavity is capable of containing about 57 c.c. It consists of two parts: a principal cavity, or sinus venarum, situated posteriorly, and an anterior, smaller portion, the auricle.

15- Identify the following structures:

- Pectinate muscles within the right auricle and the crista terminalis (Figure 3a);

Remind students that the crista terminalis is an important landmark of the sinoatrial node (not visible), a small mass of specialized cardiac muscle fibers located in the posterior wall of the right atrium of the heart that acts as a pacemaker by generating at regular intervals the electric impulses of the heartbeat. The node is located high (superiorly) in the right atrium at the junction of the crista terminalis, a thick band of atrial muscle at the border of the atrial appendage, and the superior vena cava.

- The Eustachian valve, present in the inferior vena cava, is not visible because it has been damaged by cutting the sinus venarum;

Remind students that the Eustachian valve is an embryologic remnant of the valve of the inferior vena cava. During fetal life, the Eustachian valve directs oxygen-rich blood from the inferior vena cava (IVC) toward the foramen ovale and away from the tricuspid valve. After the closure of the foramen ovale, it does not have a specific function.

- The coronary sinus (Figure.3b);
- The Thebesian valve (Figure 3c);

Remind students that the coronary sinus opens into the atrium, between the orifice of the inferior vena cava and the atrioventricular opening (tricuspid valve on the inferior aspect of the interatrial septum). It returns blood from the substance of the heart and is protected by a

FOR CITATION PURPOSES: *Trovato FM, Musumeci G. Practical guide to learn human heart anatomy on animal model. OA Anatomy 2014 Nov 01;2(3):30.*

semicircular valve, the valve of the coronary sinus (Thebesian valve).

- The fossa ovalis (Figure 3d);

Remind students that the fossa ovalis is an oval depression on the septal wall of the atrium, and corresponds to the location of the foramen ovale of Botallo in the fetus. It is situated at the lower part of the septum, above and to the left of the orifice of the inferior vena cava.

- Koch's triangle is defined by the following structures within the right atrium: (1) the ostium of the coronary sinus, posteriorly; (2) the anterior portion of the tricuspid valve annulus; and (3) the tendon of Todaro (a tendinous structure connecting the valve of the inferior vena cava ostium to the central fibrous body), posteriorly.

Remind students that Koch's triangle is used as an anatomical landmark for location of the atrioventricular node during electrophysiology procedures such as pacing or ablation.

- The right atrioventricular orifice (Figure 3e).

Remind students that the right atrioventricular orifice is the large oval aperture of communication between the right atrium and ventricle. Situated at the base of the ventricle, it measures about 4 cm in diameter and is surrounded by a fibrous ring, covered by the lining membrane of the heart; it is considerably larger than the corresponding aperture on the left side, being sufficient to admit the ends of four fingers. It is guarded by the tricuspid valve.

16- Reposition the sternocostal surface of the heart toward the viewer; suggesting to the students to grab with their hands the two surfaces of the heart with the tip towards the palm of the hand and the sharp edge towards the observer.

17- Make an incision with a scalpel, the full thickness of the sharp edge along the ventricular wall of the heart to the pulmonary trunk; thus highlighting the right ventricular cavity (Figures. 3f, 4a).

18- Identify the following structures:

The ventricular side of the tricuspid valve (Figure 4b);

Remind students that the tricuspid valve consists of three somewhat triangular cusps or segments. The largest cusp is interposed between the atrioventricular orifice and the conus arteriosus (termed the anterior cusp); a second, the posterior or marginal cusp, is in relation to the right margin of the ventricle, and a third, the medial or septal cusp, to the ventricular septum. Their atrial surfaces, directed toward the blood flow from the atrium, are smooth; their ventricular surfaces, directed toward the wall of the ventricle, are rough and irregular, and, together with the apices and margins of the cusps, give attachment to a number of tendinous cords, the chordae tendineae.

- The chordae tendineae and relative papillary muscles (Figure 4c);
- The supraventricular crest, a ridge on the inner wall of the right ventricle, marks off the conus arteriosus.
- The trabeculae carneae and related types;

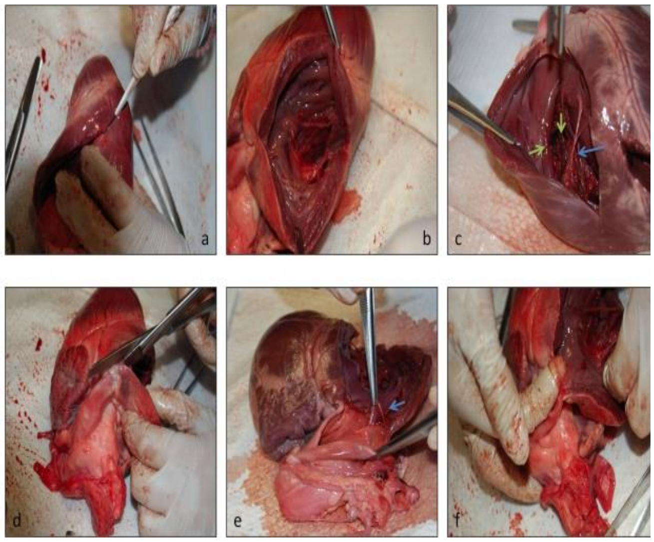

Figure 4: Instruction of dissection. a. Incision of the right ventricle to the pulmonary trunk, and right ventricular cavity. b. The ventricular side of the tricuspid valve. c. The chordae tendineae and relative papillary muscles (green arrows) and the septomarginal trabecular (blue arrow). d. The opening of the pulmonary artery. e. The pulmonary semilunar valves (blue arrow). The pulmonary semilunar valves, touching the Morgagni nodules.

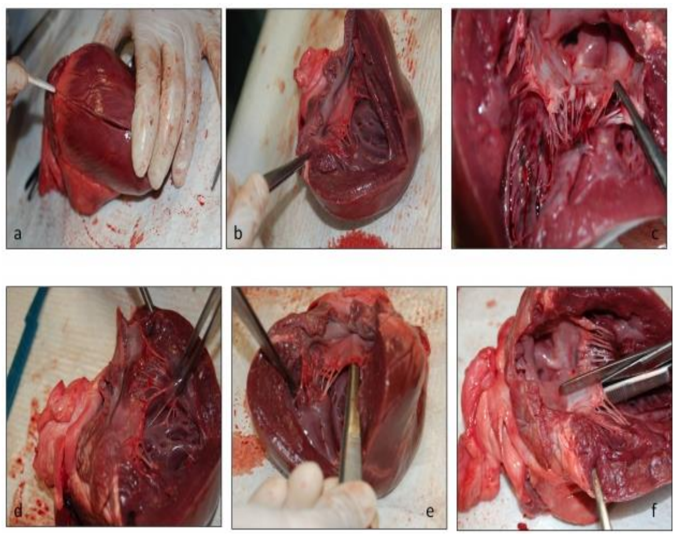

Figure 5: Instruction of dissection. a. The obtuse margin of the heart. b. The obtuse margin of the heart after the incision and the atrioventricular opening. c. The bicuspid or mitral valve. d. The trabeculae carneae and relative musculi papillares. e. Forceps below the bicuspid or mitral valve. f. Incision of the structures above the forceps.

Remind students that there are three kinds of trabeculae carneae: some are attached along their entire length on one side and merely form prominent ridges, others are fixed at their extremities but free in the middle (septomarginal trabecular), while a third set (musculi papillares) are continuous by their bases with the wall of the ventricle, while their apices give origin to the chordae tendineae which are attached to the segments of the tricuspid valve.

- The septomarginal trabecular (Figure 4c);

Competing interests: None declared. Conflict of interests: None declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

OA Anatomy
Open Access

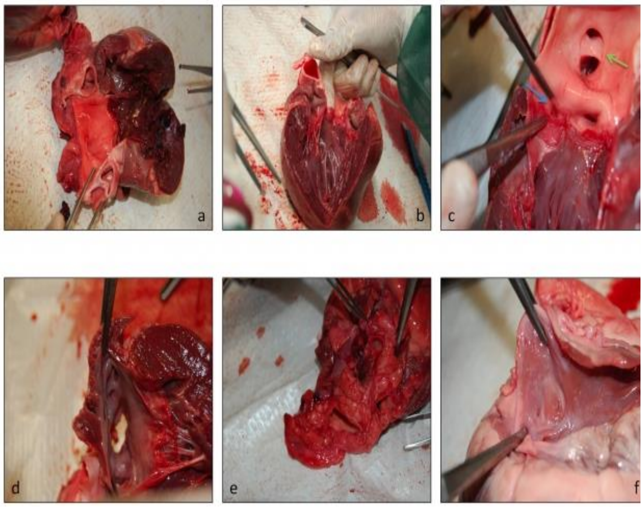

Figure 6: Instruction of dissection. a. The aortic semilunar valves. b. The aortic semilunar valves, touching the Aranzio nodules. c. The orifices of the right and left coronary arteries (blue arrow) and above the bifurcation of the aorta (green arrow). d. The appearance of the inner left atrial surface. e. The outlet orifices of the 2 pulmonary veins, not very evident. f. The area corresponding to the oval fossa.

Remind students that the septomarginal trabecula (also known as moderator band) is a muscular band of heart tissue found in the right ventricle originally described by Leonardo Da Vinci. It frequently extends from the ventricular septum to the base of the anterior papillary muscle. Through its attachments it may assist in preventing overdistension of the ventricle, and so has been named the moderator band because it is crossed by one branch of the right bundle of His.

19- Compare the anatomical variant of the septomarginal trabecular with hearts dissected by other students;
20- Identify the opening of the pulmonary artery and cut it with the scissors (Figure 4d).
21- Identify the pulmonary semilunar valves (Figure 4e), the sinuses of Valsalva and Morgagni nodules (detectable to the touch as a grain of sand; Figure 4f).
22- Show the right ventricular wall (about 3 mm thick) and then compare it with that of the left one (about 9 mm).
23- Reposition the heart with the sternocostal surface toward the observer.
24- Identify the left ventricle.

Remind students that the left ventricular wall thickness is about three times as thick as that of the right ventricle. The left ventricle is longer and more conical in shape than the right, and on transverse section its concavity presents an oval or nearly circular outline. It forms a small part of the sternocostal surface and a considerable part of the diaphragmatic surface of the heart; it also forms the apex of the heart.

25- Identify the obtuse margin.
26- Make an incision, with a scalpel, through the full-thickness of the obtuse margin of the heart (Figure 5a).
27- Separate the ventricular walls incised and identify the left atrioventricular opening (Figure 5b).

Remind students that the left atrioventricular opening (mitral orifice) is placed below and to the left of the aortic orifice. It is a little smaller than the corresponding aperture of the opposite side, admitting only two fingers. It is surrounded by a dense fibrous ring, covered by the lining membrane of the heart, and is guarded by the bicuspid or mitral valve.

28- Identify the bicuspid or mitral valve (Figure 5c).

Remind students that the bicuspid or mitral valve is attached to the circumference of the left atrioventricular orifice in the same way that the tricuspid valve is on the opposite side. It consists of two triangular cusps, formed by duplicatures of the lining membrane, strengthened by fibrous tissue, and containing a few muscular fibers. The cusps are of unequal size, and are larger, thicker, and stronger than those of the tricuspid valve. The larger cusp is placed in front and to the right between the atrioventricular and aortic orifices, and is known as the anterior or aortic cusp; the smaller or posterior cusp is placed behind and to the left of the opening. The cusps of the bicuspid valve are furnished with chordae tendineae, which are attached in a manner similar to those on the right side; they are, however, thicker, stronger, and less numerous.

29- Identify the trabeculae carneae and relative musculi papillares (Figure 5d).

Remind students that the trabeculae carneae are of three kinds, like those upon the right side, but they are more numerous, and present a dense interlacement, especially at the apex, and upon the posterior wall of the ventricle. The musculi papillares are two in number, one being connected to the anterior, the other to the posterior wall; they are of large size, and end in rounded extremities from which the chordae tendineae arise. The chordae tendineae from each papillary muscle are connected to both cusps of the bicuspid valve.

30- Insert a forceps below the bicuspid or mitral valve and reach the aortic orifice. Cut full-thickness the structures above the forceps and use the instruments as a guide. When the operation is completed you will highlight the aortic opening (Figures 5e, f).

Remind students that the aortic opening is a circular aperture, in front and to the right of the atrioventricular opening, from which it is separated by the anterior cusp of the bicuspid valve. Its orifice is guarded by the aortic semilunar valves.

31- Identify the aortic semilunar valves (Figures 6a, b), the relative Aranzio nodules, the sinuses of Valsalva and the orifices of the right and left coronary arteries and above the bifurcation of the aorta (Figure 6c).

OA Anatomy
Open Access

Remind students that the aortic semilunar valves are three in number, and surround the orifice of the aorta; two are anterior (right and left) and one posterior. They are similar in structure, and in their mode of attachment, to the pulmonary semilunar valves, but are larger, thicker, and stronger. Opposite the valves the aorta presents slight dilatations, the aortic sinuses (sinuses of Valsalva), which are larger than those at the origin of the pulmonary artery.

32- Reach, through the mitral orifice, the left atrium and highlight:

- The appearance of the inner left atrial surface (Figure 6d);

Remind students that the left atrium is slightly smaller than the right, but its walls are thicker, measuring about 3 mm; it consists, like the right atrium, of two parts, a principal cavity and an auricula. The principal cavity is cuboidal in form, and concealed, in front, by the pulmonary artery and aorta; in front and to the right it is separated from the right atrium by the atrial septum; opening into it on either side are the two pulmonary veins. The auricula is somewhat constricted at its junction with the principal cavity; it is longer, narrower, and more curved than that of the right side, and its margins are more deeply indented. It is directed forward and toward the right and overlaps the root of the pulmonary artery.

- The outlet orifices of the 2 pulmonary veins (in the pig heart there are only two veins, instead of the human heart there are four) are not very evident (Figure 6e);

Remind students that the pulmonary veins, four in number, open into the upper part of the posterior surface of the left atrium, two on either side of its middle line: they are not provided with valves.

- The area corresponding to the oval fossa (Figure 6f).

On completion of the practical activity on the organ, students carry out the removal of a fragment immediately immersing it in 10% formalin to avoid post-mortem degradation processes and finally students are invited to close the heart and store it in a 70% alcohol solution.

Discussion

The knowledge of anatomy is crucial for a first-year undergraduate medical student for the proper learning of the clinical subjects in the further part of the medical course. The learning process could be particularly hard especially if not associated to practical activity on cadavers. Several solutions have been tried to help students to face the study of anatomy, such as near peer-led anatomy teaching[13] or resident doctors discussion classes supplementary to the traditional course[14].

In anatomy laboratories, first-year students undergo cognitive-motor reactions when facing cadavers and death, probably for the immediacy and the novelty of the experience for which they must be emotionally prepared. However, several authors believe that such emotions add value to human dissection, providing moral transformation and thus promoting the development of professional competence and helping the future doctor to control emotions, that could be an important determinant for their future attitudes and behaviour towards patients[15].

In fact dissection is extremely useful in a variety of ways: it aids understanding of the three-dimensional organization of the human body, implies a tactile appreciation of the body, introduces the concept and demonstration of anatomical variability, develops practical skills[3], promotes teamwork[16], introduces students to the physician-patient relationship[14], reinforces familiarization with the human body[17], and establishes the concepts of humane care and understanding of the phenomena of death and of dying[18].

Moreover, the source of human bodies is becoming a problem, because there are few donations, especially in Italy, and for that reason we used formalin-fixed cadavers for training undergraduate students. They are less useful because the technique of fixation causes: tissue rigidity, loss of tissue texture, limited preservation of surgical planes and spaces and difficulty in identifying small structures such as vessels and nerves[8]. Moreover, formalin has immediate and long term adverse effects and various measures must be taken to eliminate or minimize the danger to staff and students in gross anatomy laboratories[19]. To solve these two problems, donation and formalin, but in the meantime without abandoning the study of dissection, we used fresh pig hearts, easily obtained from a local butcher, where the structures are quite evident and moreover it is accepted for convention that the pig heart is similar to the human heart[20]. In medical training, animal were used in several fields, it is common for surgery residents to practice in simulated emergency and trauma care setting on pig model[21], a recent study reported also the validation of a live animal model for training in endoscopic hemostasis[22] and the learning of cardiovascular physiology[23] and surgery[24] avails itself of porcine model since the high similarity, although they are not the same[20].

Furthermore, in a study was demonstrated that computer-based programs could enhance cadaver dissection in teaching cardiac anatomy to first-year medical students but should not replace dissection[25]. A new interesting three-dimensional printing system (3D printing or rapid prototyping) has been recently developed. Rapid prototyping involves the reconstruction of a 3D physical and graspable model basing on a 3D computer model[26]. It overcome the two-dimensional radiologic imaging, and it is useful also for surgeons, besides students, to appreciate the anatomic relationships between structures and really existing lesions on an anatomically tailored model.

Although new technologies[27] and computer based lessons in the anatomy laboratory are attempted to fill the gap due to the lack of cadavers, learning anatomy cannot be separated from practical activity, with scale models or animal organs[28], in fact active manipulation of organs promotes retention of knowledge[29]. To be comprehensive, anatomical study on the heart, for first-year students of the degree course in medicine and surgery, should include a series of at least three two-hour lessons, later followed by exercise in the theoretical-practical dissection room.

Conclusion

In conclusion we can confirm that this methodological study is useful for improving and better understanding the study of the heart anatomy. Our old data[12] confirmed the usefulness of practical activity compared with traditional anatomical teaching methods and emphasize the utility of practical activity in learning anatomy; considering the limitations of the use of cadavers[25,30,31]. Although the results were positive, the practical activity on animal organs could not replace the traditional methods for teaching anatomy, but it is a very useful adjunct to reinforce the traditional approach to study anatomy using only the textbooks.

Acknowledgments

The study was funded by FIR 2014-2016, Department of Biomedical Sciences and Biotechnologies, University of Catania.

References

1.Chapman SJ, Hakeem AR, Marangoni G, Prasad KR. Anatomy in medical education: Perceptions of undergraduate medical students. Ann Anat. 2013; 195: 409-14.
2.EwonuBari EB, Watson JT, Amaza DS, Madueke NM, Donatus AA, Effiong OE. Problems and prospects of acquistion of human cadaver for medical education in Nigeria. J Pak Med Assoc. 2012; 62: 1134-6.
3.McLachlan JC, Bligh J, Bradley P, Searle J. Teaching anatomy without cadavers. Med Educ. 2004; 38: 418-24.
4.McLachlan JC, Patten D. Anatomy teaching: ghosts of the past, present and future. Med Educ. 2006; 40: 243-53.
5.Drake RL, McBride JM, Lachman N, Pawlina W. Medical education in the anatomical sciences: the winds of change continue to blow. Anat Sci Educ. 2009; 2: 253-9.
6.Macchi V, Munari PF, Brizzi E, Parenti A, De Caro R. Workshop in clinical anatomy for residents in gynecology and obstetrics. Clin Anat. 2003; 16: 440-7.
7.Macchi V, Porzionato A, Stecco C, Parenti A, De Caro R. Clinical neuroanatomy module 5 years' experience at the School of Medicine of Padova. Surg Radiol Anat. 2007; 29: 261-7.
8.Macchi V, Porzionato A, Stecco C, Tiengo C, Parenti A, Cestrone A, De Caro R. Body parts removed during surgery: a useful training source. Anat Sci Educ. 2011; 4: 151-6.
9.Codd AM, Choudhury B. Virtual reality anatomy: is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy? Anat Sci Educ. 2011; 4: 119-25.
10.Macchi V, Munari PF, Ninfo V, Parenti A, De Caro R. A short course of dissection for second-year medical students at the School of Medicine of Padova. Surg Radiol Anat. 2003; 25: 132-8.
11.Alexander CJ, Crescini WM, Juskewitch JE, Lachman N, Pawlina W. Assessing the integration of audience response system technology in teaching of anatomical sciences. Anat Sci Educ. 2009; 2: 160-6.
12.Musumeci G, Loreto C, Mazzone V, Szychlinska MA, Castrogiovanni P, Castorina S. Practical training on porcine hearts enhances students' knowledge of human cardiac anatomy. Ann Anat. 2014; 196:92-9.
13.Ologunde R, Asif H, Nawab K, Craven C, Shah P, Osei-Kuffour D, Koh D, Yao A, Rabiu R, Chawla A, Ahn J, Gibbs V, Asif U, Chamali B, Ceri Davies D. Near peer-led anatomy teaching in undergraduate medical education. Int J Surg. 2013; 11: 691-2.
14. Kumar Ghosh S. Resident doctors: keystone of anatomy teaching. Clin Teach. 2014; 11: 461-2.
15.Arráez-Aybar LA, Bueno-López JL, Moxham BJ. Anatomists' views on human body dissection and donation: An international survey. Ann Anat. 2014 Jul 4. pii:S0940-9602(14)00130-7. doi: 10.1016/j.aanat.2014.06.004. [Epub ahead of print]
16.Pawlina W, Lachman N. Dissection in learning and teaching gross anatomy: rebuttal to McLachlan. Anat Rec B New Anat. 2004; 281: 9-11.
17.Lempp HK. Perceptions of dissection by students in one medical school: beyond learning about anatomy. A qualitative study. Med Educ. 2005; 39: 318-25.
18.Canby CA, Bush TA. Humanities in Gross Anatomy Project: a novel humanistic learning tool at Des Moines University. Anat Sci Educ. 2010; 3: 94-6.
19.Raja DS, Sultana B. Potential health hazards for students exposed to formaldehyde in the gross anatomy laboratory. J Environ Health. 2012; 74: 36-40.
20.Crick SJ, Sheppard MN, Ho SY, Gebstein L, Anderson RH. Anatomy of the pig heart: comparisons with normal human cardiac structure. J Anat. 1998; 193: 105-19.
21.Gaarder C, Naess PA, Buanes T, Pillgram-Larsen J. Advanced surgical trauma care training with a live porcine model. Injury. 2005; 36: 718-24.
22.Camus M, Marteau P, Pocard M, Bal Dit Sollier C, Lavergne-Slove A, Thibault A, Lecleire S, Vienne A, Coffin B, Drouet L, Dray X. Validation of a live animal model for training in endoscopic hemostasis of upper gastrointestinal bleeding ulcers. Endoscopy. 2013; 45: 451-7.
23.Gupta S, Westfall TC, Lechner AJ, Knuepfer MM. Teaching principles of cardiovascular function in a medical student laboratory. Adv Physiol Educ. 2005; 29: 118-27.
24.Fann JI, Sullivan ME, Skeff KM, Stratos GA, Walker JD, Grossi EA, Verrier ED, Hicks GL Jr, Feins RH. Teaching behaviors in the cardiac surgery simulation environment. J Thorac Cardiovasc Surg. 2013; 145: 45-53.
25.Robinson AG, Metten S, Guiton G, Berek J. Using fresh tissue dissection to teach human anatomy in the clinical years. Acad Med. 2004; 79: 711-6.
26.Vaccarezza M, Papa V. 3D printing: a valuable resource in human anatomy education. Anat Sci Int. 2014 Oct 7. [Epub ahead of print]
27.Traser CJ, Hoffman LA, Seifert MF, Wilson AB. Investigating the use of quick response codes in the gross

Competing interests: None declared. Conflict of interests: None declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

anatomy laboratory. Anat Sci Educ. 2014; doi:10.1002/ase.1499. [Epub ahead of print]
28.Azer SA, Eizenberg N. Do we need dissection in an integrated problem-based learning medical course? Perceptions of first- and second-year students. Surg Radiol Anat. 2007; 29: 173-80.
29.Stanford W, Erkonen WE, Cassell MD, Moran BD, Easley G, Carris RL, Albanese MA. Evaluation of a computer-based program for teaching cardiac anatomy. Invest Radiol. 1994; 29: 248-52.
30. Böckers A, Baader C, Fassnacht UK, Ochsner W, Böckers TM. Reduction of mental distress in the dissection course by introducing the body donor experience through anatomical demonstrations of organ systems. Anat Sci Educ. 2012; 5: 321-9.
31.Larkin TA, McAndrew DJ. Factors influencing students' decisions to participate in a short "dissection experience" within a systemic anatomy course. Anat Sci Educ. 2013; 6: 225-31.

Competing interests: None declared. Conflict of interests: None declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.