IJAE
Vol. 124, n. 1: 72-78, 2019
ITALIAN JOURNAL OF ANATOMY AND EMBRYOLOGY

Research Article - Education in Anatomy and Embryology

The anatomical representation of the human body: From epistemological examples deriving from medical history to morphometric imaging performed with the laser scanner technique

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Abstract

The anatomical illustration of the human body is a topic rich in epistemological elements in the course of medical history. Since ancient times concerns about the real correspondence of the scientific and/or artistic representation of human anatomy with the original one arose. First of all, a static two-dimensional representation, the one typical of drawings, was not able to get the depth and complexity of dynamic three-dimensional anatomical morphology. In addition, the epistemic issue that a post-mortem illustration could not somehow correspond to living structures was present even in the past. For a long time the anatomical representation of the human body has been attracting the interest of medical doctors, artists, scholars and philosophers as a fact-finding technique of dissection of corpses preparatory to curative surgical practice in the living body. With regard to that, in the Western world the sixteenth century is often seen as the golden age of normal and macroscopic human anatomy. Major steps in the evolution of the anatomical discipline are the switch from the "normal" to the "pathological" area during the seventeenth century and the transition from the macroscopic to the microscopic level in the eighteenth century; that is true also from an illustrative and iconographic point of view. The tradition of setting up three-dimensional models for the study of the human body dates back to the eighteenth century too. Today's research techniques in the field of anatomical images are so advanced that they allow the full conformity of human representation, the continuous availability of preserved images, the complete multi-dimensionality of the rendering and the complete dynamism of the whole view. In this context, laser scanner could be the ideal tool to create a new Atlas of Human Anatomy composed of models which are rotatable, observable from every perspective, absolutely faithful to reality, analysable as in a real dissection and carefully measurable.

Key words

Anatomy, history of medicine, epistemology, research methods, laser scanner, morphometry.

The anatomical illustration of the human body throughout history of medicine and scientific progress is a fascinating topic rich in epistemological elements.

Since ancient times concerns about the real correspondence of the scientific and/or artistic representation of human anatomy with the original one arose (Carlino, 2000). First of all, a static two-dimensional representation, the one typical of drawings, was not able to get the depth and complexity of dynamic three-dimensional

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http://www.fupress.com/ijae

DOI: 10.13128/IJAE-25246

anatomical morphology. In addition, the epistemic issue that a post-mortem illustration, even if accurate, could not correspond to living structures and to morphological vitality was present even in the past (Conti and Conti, 2010).

For a long time the anatomical representation of the human body has in any case been attracting the interest of philosophers, artists and medical doctors (Conti, 2011).

In the IV century BC the Greek philosopher and logician Aristotle from Stagira (384-322 BC) dealt with the anatomical illustration of female and male structures and, some decades later, Herophilos of Chalcedon (335-280 BC) and Erasistratus of Ceos (305-250 BC), the founders of the medical school of Alexandria (Egypt), performed some of the first autopsies (Cosmacini et al., 1996). These two anatomists began to practice the dissection of animals in a systematic way and they were also pioneers in the anatomical study of the human body (Porter, 1995).

In the II century AD the physician Galen of Pergamon (129-201 AD) dealt with the schematic illustration of the human body in his "De usu partium". Galen was a great expert of the anatomy of various animals, from pigs to monkeys, from dogs to goats, and set a new anatomical descriptive standard which influenced the study of the discipline until Renaissance (French, 1993).

Between the XIII and the XIV centuries, the scholar and precursor of French surgery Henri de Mondeville (1260-1320 AD) developed illustrative plates of advanced anatomical interest and he used to employ these plates as a didactic tool during his lessons. Iconography was essential for the anatomical study, in particular when the direct visualization of human body structures was not formally possible (for religious or legal reasons) or technically feasible (because of the scarce availability of corpses). In this context, the physician and anatomist Mondino de' Liuzzi (1270-1326 AD) used human cadavers for his medical lessons (anatomical lessons) for the first time in Italy and ordered to place the corpses of two women in a University classroom (Feher, 1989). The bodies were placed in horizontal position to be dissected, as it was appropriate in the educational and institutional environment of the University, and no more in vertical position, as pork butchers used to do when they slaughtered pigs (Grmek, 1998).

This change in the position of the body to be dissected (etymologically, to undergo "anatomy" means to undergo "cut", "dissection") represented a major cognitive and procedural innovation during the Middle Ages in the Western world, pioneering the Renaissance anatomical revolution of Andreas Vesalius. Vesalius (1514-1564 AD), a Flemish physician and a very young lector in surgery and anatomy in Padua, determined a paramount change of paradigm in the anatomical field, challenging the work of Galen in a systematic way, also thanks to an innovative methodology of morphological representation (Lippi and Baldini, 2000). "Tabulae Anatomicae Sex" (1538 AD) are among the first scientific illustrations explicitly conceived for University students and they were useful to the critic reconsideration of Galenic writings (Siraisi, 1990). The anatomical plates masterfully drawn by the German painter and engraver Johannes Stephan von Kalkar (1499-1545 AD), which accompanied the text "De Humani Corporis Fabrica" (1543 AD), the most important work of Vesalius, still today represent a milestone in the two-dimensional human anatomical representation, since they referred to positions (although they were static and two-dimensional) inspired to the dynamic posturology of the living body (O'Malley, 1964).

Some historians of medicine consider the XVI century as the golden age of normal and macroscopic human anatomy, interpreted as a fact-finding technique of dissection of corpses preparatory to curative surgical practice in the living body (Pazzini, 1947). Successive steps of the history of the anatomical discipline were the switch from the "normal" (that is the study of human morphology in healthy subjects) to the "pathological" area during the XVII century and the transition from the macroscopic to the microscopic level in the XVIII century, and this was relevant also from an illustrative and iconographic point of view (Richardson, 1987). Even the tradition of setting up three-dimensional models for the study of the human body dates back to the XVIII century and it is fundamental at the anatomical representative level too. With regard to that, the leather-covered puppets prepared by the Scottish physician William Smellie (1697-1763 AD) were essential for the progress of anatomical-clinical education (Porter, 1997). Smellie was a pioneer in the obstetrical-gynaecological field with his fundamental work "Treatise on the Theory and Practice of Midwifery" (1752 AD) (Premuda, 1957).

The Italian ceroplastics deserves to be mentioned in the anatomical eidetic-educational framework (Musajo Somma, 2007). In the century of Enlightenment the morphological representative tradition in medicine was in fact enriched by an original and innovative contribution, coming from Bologna and Florence, specifically anatomical ceroplastics, the art of re-creating whole bodies or single anatomical parts through wax modelling (Orlandini and Paternostro, 2010). Ceroplastics worked as a bridge between the two-dimensional illustration and the three-dimensional representation of the human body, anticipating the scientific imaging of the XX century, thanks to the simultaneous attention both for details and for the subject as a whole.

The photographic representation of anatomy is worthy of note. Since the invention of the technique, photography allowed to fix the image of anatomical preparations with high fidelity to particulars, bypassing the artistic representation by the author, apart from accuracy.

Even if frames can be layered and assembled in sequence, they remain static, so they offer a limited possibility of interaction with the observer.

The advent of information technology and of graphic synthesis techniques has allowed to realize four-dimensional human virtual models. They can be rotated according to the three spatial axes and, thanks to this, they can be observed from every point of view. They allow to visualize the whole body or to emphasize the particular structures we are interested in: it is possible to zoom in on muscles, vessels, nerves, on their topographic relation; it is possible to observe the organs in situ or isolated. It is even allowed to observe cavities, organs or the whole body dissected according to sagittal, frontal or transverse planes. For example, muscles which are characterized by a very complex organization can be visualised singularly or all together and even their dynamic action can be showed thanks to some animations. It is also possible to resect superficial anatomical structures, in order to reach deeper ones and vice versa. The possibility of observing the examined object both intact and dissected from every point of view, according to the rotation perspective, definitely represents a big help. However, the representations obtained through virtual graphic synthesis are very far from reality, apart from the accuracy, since they are schematizations. It is fundamental to emphasize the fact that these reproductions lack real colour and real light.

The gap between the iconographic representation and the existing thing is not eliminable and will always remain. However, today, a particular application of laser technology, the laser scanner, allows to reduce this gap to minimal levels, with a quick and easy acquisition process.

Laser scanners generate a cloud of points of the examined object. Each point is identified through exact coordinates. Besides, the photos of the same object can be layered on the 3D model deriving from cloud. The result is a virtual model that reconstructs the real object, faithfully corresponding for morphology and colours, rotatable, observable from every perspective and measurable (Gelati and Tanga, 2015).

The laser scanner was born as a measuring instrument in industry and it maintains such feature in the anatomical field, allowing to quantify with high precision the area of the organs, the diameters, the volumes, and so on, with an accuracy of ±25μm. The anatomical preparation is literally "immortalized", up to under-millimetre details, where a naked eye is ineffective. The image thus obtained allows to observe and measure the object forever.

The marriage between the ancient dissection techniques and the modern laser scanner technologies allows the realization of a lot of innovative and revolutionary applications. For physicians, non-medical staff and for any researcher in the field of human body studies, Human Anatomy represents a great part of the basis of the whole professional knowledge. At the stage of university education the dissection of a fresh cadaver represents the most effective and preferable approach, however, the use of an atlas cannot be renounced during personal study on anatomical books and treaties.

The process of acquisition of anatomical images conceived by the first of the present authors and protected by patent, takes place through a series of existing instruments: computerized tomography (CT), 3D surface scanner and high resolution cameras; the combination of the images through a process of scale superimposition allows to obtain a three-dimensional object which can be analysed at the same time both on the surface and in depth, according to sagittal, frontal or transverse planes. Moreover the finished product can be processed in order to be observed even in 3D through different types of glasses and visors: anaglyph glasses, polarized glasses, active glasses with shutter, virtual reality visors, augmented reality visors.

Taking a human cranium as a model, let us illustrate in detail the process leading to the obtainment of a complete model.

Computerized Tomography (CT): the CT images allow to observe and to analyse in depth the object under examination, according to the sequential sagittal, frontal, or transversal planes. The scanned images can be processed through specific software, in order to obtain a 3D reconstruction, which offers a global three-dimensional overview of the anatomical structure and it can still be observed according to cross sectional planes at the same time (Figure 1).

Non-contact surface scanning: the non-contact surface scanning of the examined object can be made through different types of scanners, such as laser scanner or structured-light scanner. In our case laser scanner has generated a cloud of points of the examined object. Each point is identified by specific coordinates and starting from this cloud, laser scanner reconstructs a three-dimensional model of the scanned surface, which is characterized by very high quality and definition: the technologies that are available nowadays can reach an accuracy of micron (Figure 2).

High definition photography: the object under examination can be photographed in controlled conditions (particularly referring to the ambient light conditions, through flashes, lights, etc.), in order to obtain high resolution images, absolutely faithful to real colours and real light, with the possibility of zooming in on the smallest anatomical details. Then it is possible to superimpose the high definition photos

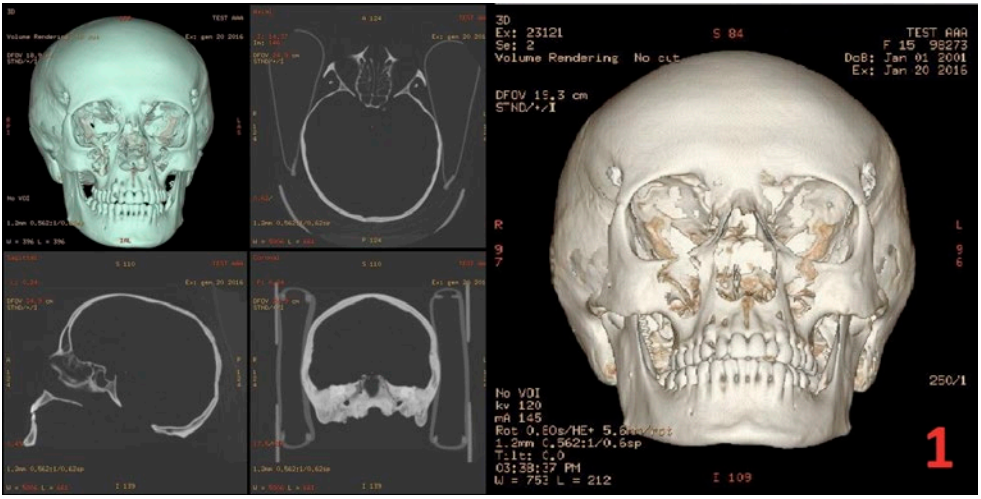

Figure 1. Computerized Tomography (CT) of a human skull.

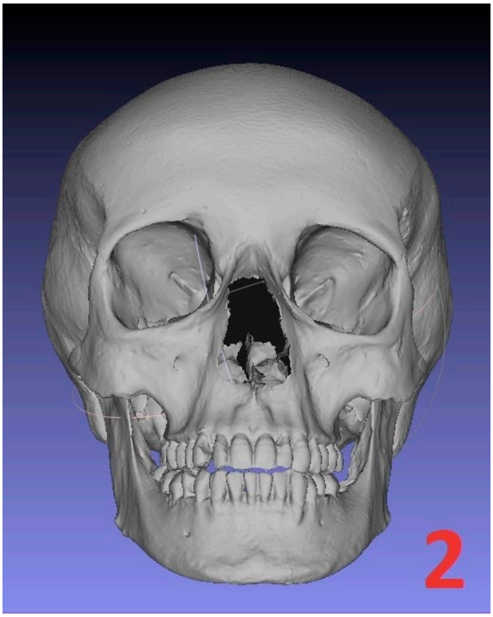

Figure 2. Three-dimensional interactive model of the surface of the same skull as figure 1, derived from the cloud of points, obtained by the laser scanner (see text for the complete explanation).

Figure 3. High definition photography of the same skull as figure 1: the object under examination can be photographed in controlled conditions (particularly referring to the ambient light conditions, through flashes, lights, etc.), in order to obtain high resolution images, absolutely faithful to real colours and real light, with the possibility of zooming in on the smallest anatomical details.

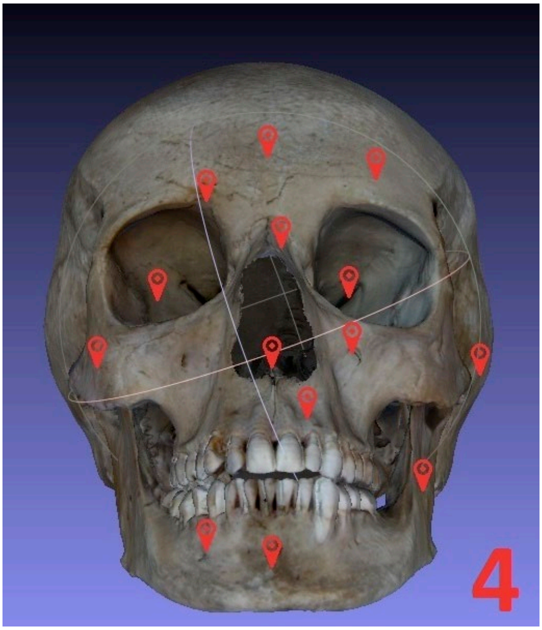

Figure 4. Scale superimposition of the 3D reconstruction from CT images, of the three-dimensional model from the non-contact surface scanning and of the high definition photos of the skull of preceding figures.

to the three-dimensional model of the cranium surface, obtained through laser scanner, in order to give real colour and real light to the model (Figure 3).

A scale superimposition of the 3D reconstruction from CT images, of the three-dimensional model obtained from the non-contact surface scanning and of the high definition photos leads to the complete finished model, which can be analysed both on the surface and in depth. The aforesaid model can work as an Anatomy Atlas if some hyperlinks are added in order to tag the anatomical details (Figure 4).

More models of the same anatomical structure made through the aforesaid procedure in different moments of the dissection, can be overlaid and organized in sequence, in order to obtain a new model (much more interactive and dynamic) which allows the observer to eliminate some structures from the anatomical preparation and/or to add some others, as in a real dissection. It is important to emphasize the possibility of measuring the anatomical model with the highest authenticity and precision (±25 μm in accuracy).

There is a big dimensional/informational gap between the world of 3D laser scanner models and the world of watercolour tables, of photos and of three-dimensional models of virtual graphic synthesis. The digital anatomical preparations obtained with laser scanner techniques can be observed and measured with a resolution which is much higher than human eye's potentialities. As a consequence, the informational content of these figures is beyond the physiological limits of our naked eye: only after enlargement the under-millimetre structures become analysable. This is made possible by the billions of points identified by specific coordinates which make up the models. They can be processed and managed only through powerful computers existing today. In this case the observer has the opportunity of analysing no more a schematization, but a model made through an objective instrumental data acquisition process, not falsifiable, highly corresponding in colours, in light and in morphology, from the macroscopic aspect to the under-millimetre details, which are visible only after enlargement.

Laser scanner could be the ideal tool to create a new Atlas of Human Anatomy composed of multi-dimensional models which are rotatable, observable from every perspective, absolutely faithful to reality, analysable as in a real dissection and carefully measurable.

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