As Leonardo da Vinci discovered sarcopenia

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The originality and the modernity of Leonardo's anatomical studies is clearly evident today watching the drawings catalogued in the monumental Corpus of the Royal Collection at Windsor.

During his life Leonardo intended to publish his anatomical work and outlined the project of a treatise of human anatomy that in his mind should begin from the modalities of the conception and of the embryology moving to the illustration of veins, nerves, muscles and bones and finishing with the description of function of the eye and of the ear and with the explanation of the nature of the five senses. This ambitious program (Leonardo wanted to publish 120 chapters!) could not be completed for the death of Leonardo in 1519. His drawings were preserved among his private papers, but they were essentially lost to the world for four centuries.

The anatomy had developed very slowly until the time of Leonardo. One of the causes was that the dissection of the human body was adversed by the ecclesiastic authorities due to an incorrect interpretation of the 1300 bulla of the Pope Boniface VIII (*De sepulturis*). This bulla was acted for people dead during the Crusades and proclaimed excommunication for anyone who should follow the practice of boiling the cadavers in order to preserve the bones, to transport them easily and to bury them at home. It is well-known the legal trial that in 1319 was brought against the students and their teacher Alberto who had exhumed a cadaver buried in the cemetery of San Barnaba in Bologna with the purpose of teaching both anatomy and surgical techniques. The dissection of cadavers was officially recognized by the Florentine Studium only in 1387, by the University of Bologna in 1405 and by University of Padua in 1429. At that time very few were the manuscripts dealing with anatomy. The treatise most diffuse was the anatomy of Mondino de' Luzzi that Leonardo knew. Mondino strictly followed the teaching of Galen and described several organs with macroscopic errors recognized by Leonardo. In 1300-400 human dissections were very few due to the scarce disponibility of cadavers (practically only people sentenced to death) and represented exceptional events taking place publicly and following a classic ritual. The teacher (*lector*) read from the chair (*ex*

cathedra) official texts, while his assistant (*sector*) dissected the viscera. Finally, the parts removed were shown to bystanders from another server (*ostentor*) (1).

Leonardo began his anatomical studies on the animals (cows and oxen) probably for the study of the equestrian monument of Ludovico Sforza. The new approach to the anatomical study initiated by Leonardo clearly emerges observing his drawings and reading his note-book. The methodology of dissection is completely renewed. Leonardo practiced personally the dissections with the perfection and ability of an expert surgeon. He knew that it was necessary to document accurately what he discovered dissecting the various strata of the human body. Thanks to his ability as painter and as sculptor, it was easy for him to reproduce in the drawings what he observed. But he also realized that the vision of an organ from different points was necessary in order to reconstruct the correct three-dimensional view. Not only that, to highlight the structure of the limbs he uses the representation with cross cuts that will be part of topographical anatomy in 1800 and is now widely used in the imaging performed in the course of CT and MRI (Figure 1) (2). Leonardo felt also the need of a new lessic for the appropriate description of the parts of the organs which until that time were unnamed.

Probably, the reason that prompted Leonardo to perform the dissections was the same of other artists, especially Florentines, to perform the *notomia*. As Leonardo stated: "in order that the painter may be able to master the correct representation and coordination of the poses and gestures of the nude body, it is most important for him to know the anatomy of the bones, tendons and muscles so that he will recognize which

Figure 1 - Transversal sections of the leg: these particular views are similar to those adopted in CT or MRI imaging. 12627v, Royal Library, Windsor Castle. Pen and china sepia.

nerve or muscle is the instigator of any given movement and make it alone prominent and thick-swollen, and not, as many do who would like to appear great draughtsmen, all the others, so that their nudes are wooden and ungraceful, looking more like a bag full of nuts than a human form, or a bundle of radishes, rather than a muscular, naked body.”.

But soon a new spirit drove Leonardo during his dissections: the curiosity to understand how organs work, how they develop in the fetus and if their damage is cause of death. Almost all the dissections are dated between 1505-10 and even if very few (the most accredited view is that Leonard dissected no more than 10 human cadavers and most of the time he had only part of the cadaver during his studies) they allowed him to achieve a lot of new anatomical and physiological information. The number of observations and the depth of thought are amazing.

The first dissection of Leonardo was the autopsy of an old men in Florence. Leonardo met him at the Hospital of Santa Maria Nuova and collected important information, he passed one hundred years and his only complaint was an extreme weakness. After a few hours of this interview without any sign of any accident he passed away. Leonardo performed immediately the autopsy searching for the causes of *such a sweet death*: the narrowing of the vessels that supply blood to the viscera and the change of the liver that *was dessicated and like congealed bran both in color and substance*.

The figures on the muscular system are among the best drawings of Leonardo. In the folio Windsor, RL 19017, Leonardo drew the muscles of the anterior part of the leg and of the dorsum of the foot (Figure 2).

The importance of this drawing lies not only in the beauty of the design, but also in the notes accompanying it. They relate to different periods as can be seen from the diversity of the stroke of the pen and the ink used. The first notes are those that refer to the drawing of the leg muscles simply referred with letters as the absence of their official designation. In these notes is explained the origin of the various muscles and their role in the movements of the foot. Leonardo refuted not only what was written by Mondino on the insertion of the muscles of the leg, but also the Avicenna's theory regarding the muscle physiology. It was believed that muscle contraction was due to a pneumatic action according to a pseudo-aristotelic interpretation. Interspersed with these notes there are notes of a dissection performed by Leonardo at a different time: “I have stripped the skin from one who owing to an illness was so emaciated that the muscles were consumed and reduced to the state of a thin membrane so that the cords, instead of being transformed into muscle were converted into a wide sheet; and when the bones were clothed by this leather, they possessed little of their natural thickness” (1, 3).

For the first time the autopsy revealed the muscle wasting and links this with a chronic illness and age. Not only that, Leonardo also put muscle atrophy in relation to a reduced thickness of the bone. This situation, today recognized as sarcopenia, is frequently accompanied by a reduced bone mass and microarchitectural deterioration of the bone tissue. Interestingly, in an-

Figure 2 - Leonardo's notes on the folio with his drawing of the muscular and tendinous anatomy of the anterior part of the leg and the foot. 19017, Royal Library, Windsor Castle. Pen, china sepia (three shades) and black pencil.

other dissection Leonardo had observed that the thickness of a given bone is greater if the muscles that are part of the bone are voluminous.

The association of aging, inactivity and chronic diseases with deterioration of the nutritional status, with loss of muscular mass and function and with increased risk of mortality were for the first time recognized. Leonardo becomes, therefore, the discoverer of sarcopenia and of the muscle/bone unit. This should be remembered in any future description of muscle/skeletal interactions.

References

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