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# The vascular structure of the urethra: a historical overview

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**Abstract.** Penile structure and function aroused interest since ancient times, when the erectile activity was mainly attributed to an accumulation of air by Greek and Roman physicians. In the Renaissance period Leonardo da Vinci was one of the first to recognize the right functional importance of the presence of blood in penile tissues. Since then, although with different techniques and interpretations, the morphological studies reported the description of blood vessels differently arranged in complicated networks. The discovery of blood circulation by William Harvey in his famous *Exercitatio anatomica de motu cordis* (1628) and the demonstration of capillaries by Marcello Malpighi stimulated a deeper research. In particular, the presence of a non vascular spongy tissue (cavernous bodies) with cellular texture (cellular theory) was postulated and interpreted as consisting of a loose and elastic spongy tissue arranged in several cells into which, during erection, blood is poured from the arteries, and from which it is afterwards removed by veins. In the beginning of the 19th century, when both vascular and cellular texture theories concerning the penile anatomy were still coexisting, a particular attention was paid to the urethral structure. Thanks to improved injection techniques, Paolo Mascagni and Alessandro Moreschi provided accurate works on this subject, demonstrating the vascular nature of the cavernous bodies. Finally, in 1899 Victor Vecki von Gyurkovechky confirmed the vascular theory, histologically demonstrated by the presence of endothelium.

**Keywords**: cavernous body of the penis, corpus spongiosum, urethra, cellular theory.

The dynamics of penile erection evoked an anatomical and physiological interest since ancient times. In Greek and Roman medicine, represented by the great figures of Hippocrates and Galen, respectively, an accumulation of air (*pneuma*) was believed responsible for such a phenomenon (Driel, 2015). Significantly, the mythological Priapus just embodied this particular condition, with oversized genitals and permanent erection, giving rise to the medical term priapism.

Although influenced by the previous tradition, in the Renaissance period Leonardo da Vinci (1452-1519) was one of the first anatomists to recognize the presence of blood instead of air in the penile tissues during erection and a similar conclusion was achieved also by the anatomist Costanzo Varolio (1543-1575) (Driel, 2015).

The first anatomical description of erectile tissues can be found in the book V, chapter XIV (*De virilis membri, penisque structura*; On the male organ and the structure of the penis) of the famous *De Humani corporis fabrica* published in 1543 by the father of modern anatomy, Andreas Vesalius (1514-1564) (Fig. 1), who also illustrated male genitals. In his masterpiece Vesalius denied the nature of cavernous bodies of the penis in terms of blood vessels, nerves, tendons, bones or ligaments, but he recognized the presence of venous (dark) blood, describing several *fasciculi* of arteries and veins closely interwoven, within an investing sheath (Vesalius, 2007, p. 163):

> *The Creator constructed the penis from two bodies that resemble nothing else in the human frame (with the possible exception of the nipple). These two bodies can become erect, grow longer, and swell considerably when they are filled with spirit; and when the spirit disperses they contract, collapse, become flaccid, and shorten. They are not veins or arteries or nerves, for they take origin from bones. They are not tendons, for they are not enervations of muscles, they cannot (as they can in dogs and weasels) be regarded as bones or cartilages, for when they are slack and relaxed they can easily be bent and folded like a ligament. But you cannot call them ligaments either, for they definitely have sensation, show clear holes or cavities within them, are rather fleshy and soft in the middle and, quite unlike ligaments, are filled with dark blood.*

The Italian physician and anatomist Giovanni Filippo Ingrassia (1510-1580), student of Vesalius, in his work *De tumoribus praeter naturam*, published in 1552, clearly stated that *corpora cavernosa* are an aggregate of blood vessels (Levi, 1835).

The development of injection techniques and the creation of anatomical models contributed significantly to anatomical discoveries and were very effective in convincing that an accumulation of blood, rather than its mere presence, was important during erection. When Regnier de Graaf (1641-1673) injected the hypogastric artery with water, he observed an engorgement of penile blood vessels, as well. Similar results were obtained by Frederik Ruysch (1638-1731), who also performed injection techniques, realizing wax-like casts of penis (Driel, 2015).

After the discovery of the blood circulation described by William Harvey (1578-1657) in the famous *Exercitatio anatomica de motu cordis et sanguinis in animalibus* (Harvey, 1628), and the microscopic identification of capillaries by Marcello Malpighi (1628-1694) in the *De pulmonibus observationes anatomicae* (Malpighi, 1661), it became clear the continuity between arteries and veins. In particular, in its *Dissertatio epistolica varii argumenti de cornuum vegetatione, utero, viviparorum ovis, plantis &c*, Malpighi (1687, p. 211) considered the structure of the penis as composed of diverticula or appendices of veins. In 1703 the surgeon and anatomist William Cowper (1666-1709) admitted the large communication between arteries and veins in the spleen and penis, as reported in *An answer to Dr Wright's Letter, concerning the Cure of an Aposthumation of the Lungs*, published in *Philosophical Transactions* (Cowper, 1703).


**Figure 1.** Plaster bust of Andreas Vesalius. Museum of Human Anatomy "Filippo Civinini", University of Pisa.

However, in the late 18th century this vascular disposition was not recognized in all organs. In some particular tissues, such as spleen and genitals, the anatomical continuity between arterial and venous system still had to be clearly demonstrated.

One of the first anatomists who showed a vascular structure on the surface of the cavernous body of the urethra was Lorenz Heister (1683-1758). In the footsteps of his master Ruysch, he examined this part more closely, so that in the fifth table of his *Compendium anatomicum*, published in Nuremberg in 1741, he included two figures, illustrating both dorsal and ventral sides of the penis, clearly and accurately demonstrating blood vessels of the surface of the glans behind the mercury injection pushing for the dorsal vein. With this method, not only the perfusion of the surface of the glans, but also of the whole corpus cavernosum of the urethra was easily obtained. Surprisingly, Heister did not note the real anatomical nature of the urethra and the whole glans (Levi, 1835).

This uncertainty favored alternative hypotheses. For instance, in the case of erectile tissues of genitals, the presence of a non vascular spongy tissue with cellular texture (cellular theory) was postulated. In detail, in spite of advanced injection techniques, the nature of the cavernous tissue of the glans and around the male urethra still had to be structurally elucidated. In *Elementa physiologiae corporis humani*, published in 1765, Albrecht von Haller (1708-1777) described *corpora cavernosa penis* as *ex tenacissima cellulosa stipata natura facti*. Furthermore, he found the spongy tissue of urethra distinct form that of the two cavernous body of penis, but he observed a communication between arteries and veins (Haller, 1765). Similarly, Guichard Joseph Duverney (1648-1730), Herman Boerhaave (1668-1738), and Marie François Xavier Bichat (1771-1802) also interpreted the cavernous bodies of the penis and urethra as consisting of a loose and elastic spongy tissue arranged in several cells into which, during erection, blood is poured from the arteries, and from which it is afterwards removed by veins (Todd, 1839).

On the contrary, the famous surgeon John Hunter (1728-1793), who also dealt with the concept of angiogenesis (Lenzi et al., 2016; Natale et al., 2017), in *Observations on certain parts of the animal oeconomy* observed that cavernous bodies were not spongy or cellular, but consisting of a plexus of veins (Hunter, 1792, p. 43):

> *In the perfect male the penis is large; the corpora cavernosa* being capable of dilatation. The corpus spongiosum is very vascular†; that part of the canal which is called the bulb is considerably enlarged, forming a cavity; and the musculi acceleratores urinae, as they are termed, are strong and healthy.*
>
> *The notes are very illuminating:*
> ** The cells of the corpora cavernosa are muscular, although no such appearance is to be observed in men: for the penis in erection is not at all times equally distended. The penis in a cold day is not so large in erection as in a warm one; which, probably, arises from a kind of spasm that could not act upon it if it were not muscular.*
> *† It may not be improper to observe, that the corpus spongiosum urethrae, and glans penis, are not spongy or cellular, but made up of a plexus of veins. This structure is discernable in the human subject; but much more distinctly seen in many animals, as the horse, &c.*

Accordingly, other authors, including Georges Cuvier (1769-1832), Friedrich Tiedemann (1781-1861), Bartolomeo Panizza (1785-1867), and Ernst Heinrich Weber (1795-1878), also recognized the vascular nature of the cavernous tissue in man and other animals (Todd, 1839). In particular, Pierre Augustin Béclard (1785-1825) provided the following definition of the erectile tissue in his *Élémens d'anatomie générale, ou Description de tous les genres d'organes qui composent le corps humain*, published posthumously in 1828 (Béclard, 1828, p. 172):

> *Le tissu érectile, caverneux ou spongieux, consiste en des terminaisons de vaisseaux sanguins, en des racines de veines surtout, qui, au heu d'avoir la ténuité capillaire, ont plus d'ampleur, sont très-extensibles, et réunies à beaucoup de filets nerveux.*

The earliest and most commonly used anatomical technique was to obtain the turbulence of the cavernous bodies of the penis and urethra by pushing the waxy material for a random hole in the cavernous body of the urethra in the bulb region, or in the root of the cavernous bodies of the penis. In fact, examining the anatomical preparations included in the *Index Rerum Musei Anatomici Ticinensis,* published in 1804 by Antonio Scarpa (1752-1832), the preparations number 129, 134, 311 and, in particular, the number 130 realized by Giacomo Rezia (1745-1825), obtained with the procedure just described, clearly demonstrated the superficial vascular network of the cavernous body of the urethra (Levi, 1835).

In the beginning of the 19th century, when both vascular and cellular texture theories concerning the penile anatomy were still coexisting, a particular attention was paid to the urethral structure. Two figures contributed to the understanding of the vascular nature of the urethra. In the *Elogio del celebre anatomico Paolo Mascagni*, Farnese (1816) attributed to his mentor Mascagni (1755-1815) the demonstration in 1809 of the continuity between arteries and veins and the description of venous plexuses, this term replacing the previous and mislead-


**Figure 2.** Plate VII, taken from *Tavole figurate di alcune parti organiche del corpo umano, degli animali e dei vegetabili, esposte nel Prodromo della grande anatomia di Paolo Mascagni* by Francesco Antommarchi (1819b). Library of Medicine and Pharmacy, University of Pisa.

ing name of spongy body attributed to the inner part of penis. In 1817 Alessandro Moreschi (1771-1826) also published two important works on the same subject (Moreschi, 1817a; 1817b) and a dispute also arose. A detailed description of the dynamics of this scientific controversy has been recently published (Armocida and Natale, 2019). The *Prodromo della grande anatomia*, a posthumous work by Mascagni edited in 1819, included a plate dedicated to the structure of the urethra (Fig. 2) and a comprehensive view of this scientific story (Antommarchi, 1819a; 1819b). Then, Mascagni developed a technique to inject urethral blood vessels, but Moreschi was the first to publish an accurate work on this subject.

In *Medico-Chirurgical Transactions* the demonstrator of anatomy John Shaw (1792-1827) published *On the structure of the membranous part of the urethra*, where he stated that Italian anatomists did not extend their observations to the membranous part of the urethra (Shaw, 1819). For this reason, he considered himself the first to demonstrate the vascular structure of this tract of the urethra, as also affirmed in *A manual for the Student of Anatomy* (Shaw, 1825, p. 76):

> *There is, likewise, a set of vessels immediately below the membrane, which, when empty, are very similar in appearance to muscular fibres. I have discovered that these vessels form an internal spongy body, which passes down to the membranous part of the urethra, and forms even a small bulb there.*

In *Additions to the general anatomy of Xavier Bichat*, when dealing with erectile texture, Béclard (1823, p. 118) stated that its vascular nature was recognized by several anatomists, including the Italian ones:

> *In our time Mess. Cuvier, Ribes and others in France, Mascagni, Paul Farnese and Moreschi in Italy, and Tieddmann in Germany have perfectly demonstrated this fact, both in man and various other animals.*

Some years later, the anatomist and physiologist Johannes Peter Müller (1801-1858) anticipated in his *Handbuch der Physiologie des Menschen für Vorlesungen* (Müller, 1833) a very detailed study with eight magnificent illustrations on the vascular arrangement of erectile tissues, published in 1835 in the second number of *Archiv für Anatomie, Physiologie und wissenschaftliche Medicin*, directed by himself: *Entdeckung der bei der Erection des männlichen Gliedes wirksamen Arterien bei dem Menschen und den Thieren* (Müller, 1835a). The study included the description of the deep artery of penis and, besides nutrient ramified arteries, a second set of tendril-like branches, named *arteriae helicinae*, demonstrated with an injection technique. An English translation of Müller's work summary appeared in different journals (Müller, 1835b,c,d; 1836). A Müller's lecture dealing with the innervation of erectile tissues was also published (Müller, 1837): *Über die organischen Nerven der erectilen männlichen Geschlechtsorgane*. The famous French physiologist Flourens (1835) also dedicated a short work to the history of vascular structure of the penis, where he praised Müller's findings.

In the second edition of his *Elements*, Craigie (1851) included also Müller's observations and proposed a hemodynamic role for the vascular structure of erectile tissues:

> *It seems not doubtful that the accumulation of blood in these helicine arteries is the physiological cause of the phenomena of erection. [...] In the tissue now described it is manifest that the physiologist ought to place the phenomena of the process distinguished by the name of vital turgescence (turgor vitalis) by Hebenstreit, Reil, Ackermann, and Schlosser. Though these authors suppose vital turgescence in different degrees in almost all the textures of the animal body, their most distinct examples are taken from those parts which consist of erectile vessels.*

Finally, Victor Vecki von Gyurkovechky (1857-1938) in his *Pathologie und Therapie der Männlichen Impotenz* reported the vascular nature of the cavernous spaces, as histologically demonstrated by the presence of endothelium (Vecki, 1899, English edition, p. 51): *These small hollow interspaces of the three corpora are coated with endothelium resembling that of the veins, and are consequently venous spaces.*

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