The first description of tubular structures within the renal parenchyma is generally attributed to Bellini [cited in ref. 1] who referred to the substance of the kidney as ‘nothing else than an aggregate of an infinite number of vessels (which)... terminate in the cavity of the pelvis’, in his anatomical treatise on the kidney, *Exercitatio anatomiæ de structura et usu renum*, published in 1662 [2]. Little accurate information on the anatomy of the kidney was available prior to Bellini who no doubt felt that he was describing an important observation for the first time. However, hidden and forgotten in the papal archives was a splendid treatise on the kidney written by Bartolommeo Eustachio (1524–1574) which contained considerable detailed information about the kidney that preceded the observations of Bellini by nearly a century and which surpassed the quality of the latter’s illustrations by a wide margin.

Eustachio’s first anatomical treatise entitled ‘Opuscula anatomiæ’ was published in 1564 [3]. It contained his observations on the kidney, ear, venous system, and the teeth. The section on the kidney is illustrated by seven plates. The first three depict the external appearance of the kidneys and their vascular connections to the aorta and inferior vena cava. In them, the suprarenal glands are shown for the first time. The fourth plate shows the entry of the thoracic duct into the venous system as well as what appears to be a simple polycystic kidney and a pelvic kidney. Of greatest interest is plate five, in which a human kidney is bisected sagittally to reveal the renal pyramids with their papillae opening into the pelvicalyceal system. There is also a depiction of a kidney in which the renal parenchyma is absent. The accuracy of this illustration extends to include a precise depiction of the arcuate and interlobular vessels. The sixth and seventh plates show the interior of bisected dog kidneys.

About the time this work was published, Eustachio had completed the drawings for a more extensive work on anatomy, and the plates for these were engraved in 1552. Apart from the text accompanying the plates that appeared in *Opuscula anatomiæ*, there are no descriptions in existence to accompany the additional illustrations which he prepared. They were either lost or never completed. After his death in 1574, Eustachio’s assistant inherited the plates, numbering 47, including the original seven on the kidney. These ultimately found their way to the Vatican Library where they lay in complete anonymity for a century and a half [4]. Eustachio, in effect, had attracted little attention. In 1714, the physician to Pope Clement XI, Giovanni Maria Lancisi (1654–1720), discovered the plates and added his own descriptions to all except those plates for which Eustachio’s commentary was available [4]. He published a text entitled ‘Tabulae anatomicæ’ (Rome, 1714), containing the 47 plates prepared by Eustachio [5].
There is little doubt that if the plates had appeared 150 years earlier, Eustachio would have ranked with the Vesalius as founder of modern anatomy. Da Vinci suffered the same fate; the delay in uncovering his anatomical studies allowed Vesalius to be heralded, perhaps justifiably, as the uncontested founder of anatomy. Nevertheless, Lancisi’s publication [5] brought the work of Eustachio to the attention of the world and the acclaim it received soon led to a second edition which appeared as a major appendix to Jean Jacques Manget’s ‘Theatrum anatomicum’ (Geneva) in 1717. The plates in this edition were slightly reduced, and the figures crowded into only 21 plates. Apparently dissatisfied with this arrangement, Lancisi published a second Roman edition in 1728 using the original plates from which the two figures accompanying this article are reproduced.

The work of Eustachio was to receive further glory in the hands of Bernhard Siegfried Albinus (1687–1770), the finest anatomist of his day. Not only did Albinus produce his own anatomical atlas, but together with Boerhaave he produced an exquisite edition of Vesalius as well as one of Eustachio. The latter, entitled ‘Explicatio tabularum anatomicarum’ (Leiden) [6], was published in 1744 and contained new copper engravings by the Dutch artist Jan Wandelaar. Departing from Eustachio’s innovative method of localizing the details of his drawings by means of coordinates surrounding the figure (fig. 1, 2), Albinus matched each figure with an outline drawing of the same size on which he depicted the details described in the text by means of letters. He added his own commentary to that of Eustachio to make the work a hallmark of anatomical style of the 15th century.

Of all the editions containing Eustachio’s illustrations of the kidney, only the original Opuscula anatomica’ of 1564 [3] contains a detailed description of the kidney. To my knowledge this work has never been translated into English. It is evident that anyone who could dissect the kidney and illustrate the intricate intrarenal distribution of the blood vessels (fig. 1, 2) with the elegance achieved by Eustachio might have made observations of more minute structures despite the fact that the microscope came into general use a century later. With this in mind, I searched the Opuscula anatomica’ of 1564. This work contains 46 chapters on the kidney and is divided into four sections: (1) on the structure; (2) on the function of the kidneys; (3) on the usefulness of the structure of the kidneys, and (4) on the dissection of the kidneys. Relevant sections, translated into English for the first time, follow.

In chapter 43, Eustachio describes how he dissects the kidney (the italics are my additions for explanatory purposes): ‘... Follow the peeled and retracted renal tunic (capsule) with the scalpel. It will lead you to the renal vessels, the urinary vessel (ureter) and the renal nerves, which you have already ligated. These should be held together with the retracted tunic by the other hand.... After the renal substance has been opened and divided as if into two (the kidney is bisected) the tunic is seen to enter the incision.... The renal substance will appear uneven and pitted, not because it may be different in this part (the hilum of the kidney) compared to other parts but because of the divisions of the great vessels in this area. It does not appear as continuous and uniform as that part which is contained in the curved part of the kidneys (cortex). This region (the medulla) is composed of densely packed (and barely visible) outwardly flowing branches of vessels. For this reason I suspect that most anatomists have asserted that the renal substance in cavernous and sponge like.’
After these things have been accurately observed the membrane of the kidney (the insertion of the capsule in the hilar region) is pulled back and forth so as to expose the branches of the vessels, no less dextrously than felicitously. Indeed these branches are spread out like the digits of the goose (foot) and are supported from above and in between by the same type of membrane. They reach the depth of the kidney supported and surrounded by soft, uneven flesh. However, in order that you may see the distribution and the pattern of the (blood) vessels, care of another kind must be employed. First the substance of the curved part of the kidney (cortex) must be incised in different planes, both transverse and oblique. By compressing with the fingers you will immediately see that drops of blood trickle out (indicating that the blood vessels extend to the outermost cortex). ... Carefully scrape the substance (of the kidney) with the dull side of the scalpel (and)... the finer branches of the vessels will become visible. Then with the scalpel inserted into the draining vessels you will be able to observe their wondrous and elegant arrangement. ... Also you will see that those same branches do not terminate in the renal sinus but end not far from the outer boundary of the edge of their humped part (corticomedullary junction) on account of their fitness.

Having considered Eustachio’s ability to observe the fine structure of the kidneys without the aid of a microscope, but presumably with a magnifying lens, we are in a position to follow his concept of renal function based upon his idea of the ultrastructure of the kidney. This is delineated in chapter 37 as follows:

... Although the kidneys appear to have been designated as bodies with vertical lines extending from their centers to their circumferences, lines of this type are nowhere more distinct than in those segments which we have indicated, and represent small glandules resembling the nipples of the breast (papillae) (fig. 1). ... Although many think that they are fibers of the kidney, some think they are branches of the blood vessels which are as fine as hairs. For my part, I think that there are certain furrows and small canals (tubules) in the substance of the kidney

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Fig. 1. Above: A bisected human kidney illustrating the opening of the ureter into the pelvis and the protrusion of the renal papillae into the pelvicalyceal system. Below: The anatomical relationships of the renal arterial and venous systems and the pelvicalyceal system. The looping arcuate arteries and the interlobar arteries are accurately depicted. In describing the specific details in these illustrations Eustachio used a system of coordinates rather than lettering or numbering the figures directly.

Fig. 2. The vascular system of the kidneys including the intrarenal distribution of arteries and veins, the capsular vessels, and the vascular supply of the female genital system. which are carved out for flowing liquids and fluids. It is through these (tubules) that the urine is filtered into the renal cavity (pelvis). The urinary vessel (ureter) is not perforated in any place other than where it receives these glands (i.e., where the renal papillae project into the pelvis)” (fig. 1).

‘For if one wished to contemplate the ingenuity of nature in many of its facets it should not be so amazing that the furrows or small canals, which are distinct within the substance of the kidney, should filter (distil) the urine.’
Eustachio has clearly described the renal collecting tubules which later came to be known as the ducts of Bellini or collecting ducts. He goes on to point out that there are numerous examples in nature in which fluids emerge from solid structures, i.e., fluid passing through egg shells, perspiration emerging from skin, tears from the eyes, phlegm from the chest, blood which passes through the solid liver from the portal vein to the vena cava, milk from the breast, and semen through the supposedly closed vagina. By analogy, he finds no difficulty in accepting that urine passes through the kidney by similar processes.

Eustachio was obviously unable to appreciate the process of urine formation as we understand it now. He spoke of the expulsive property of the kidney and the attractive property of the bladder. He was somewhat dissatisfied with Galen’s failure to emphasize the attractive function of the bladder. Galen was clearly more insightful in this regard and probably based his supposition that urine is propelled into the bladder by a positive force from the kidneys, on experiments in which he ligated the ureters and observed distention of the ureter proximal to the ligature. Eustachio, however, marvelled at how ‘the urine penetrates from the ureters into the bladder by some wondrous artifice of nature’.

In any case, Eustachio’s clear description of the existence of tubules within the renal parenchyma has hitherto been unrecognized. This omission should be corrected.

Acknowledgements

Figures 1 and 2 were obtained from the 1728 edition of Lancisïs ‘Tabulae anatomicae Bartolomaei Eustachii’ in the collection of Leon G. Fine. Figure 1 was printed from the original engraving which appeared in 1564. Translation from the Latin was made by Dr. John Bernhardt III, Department of History, University of California at Los Angeles, and modified by the author.

References

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