Scanning and Transmission Electron Microscopy of Cysts in the Renal Cortex of the Macaque Monkey*

Masayuki MIYOSHI, Koichi OGAWA, Kimiko SHINGU and Noriyuki OMAGARI

Department of Anatomy (Prof. M. MIYOSHI), Fukuoka University School of Medicine, Fukuoka, Japan

Received October 21, 1983

Summary. Renal cysts in the cortex of the monkey kidney were observed by scanning and transmission electron microscopy, in an attempt to determine the three-dimensional structures of the epithelial cells in these cysts.

The cysts were composed of a thin wall which limited a large spherical space containing a jelly-like substance and some wandering cells. Rudimentary tufts of glomerular capillaries and/or a mound-like swelling were present on the inner surface of the cyst wall, and the inner surface of the cysts was lined with an epithelium with pedicels. The epithelial cells were podocytes, whose surface structure was similar to that on the glomerular capillary in the normal renal corpuscle. The terminal foot processes were characteristically interdigitated not only on the glomerular capillaries, but also on the mound-like swelling and concave surface of the parietal portion of the cyst.

A discrete, smooth-surfaced area was found on the side opposite to the glomerulus or swelling. This area was covered by squamous epithelial cells. At the peripheral zone of the smooth-surfaced area, elongated epithelial cells were demonstrated.

Our findings indicate that the podocyte layer of the cyst corresponds to the internal leaflet of Bowman’s capsule, and the squamous cell layer to the external leaflet. The mound-like swelling covered by podocytes is considered to represent a stage of possible evagination of the tufts of glomerular capillaries.

There was no evidence of an opening of the urinary tubule in the cyst wall.

Small cysts without a continuity with the collecting ducts are frequent in the peripheral cortex of normally functioning mammalian kidneys (MÖLLENDORFF, 1930; DU Bois, 1969). In human kidneys, there are often many enlarged cysts, and polycystic kidney or renal dysplasia sometimes occurs (OSATHANONDH and POTTER, 1964; BAXTER, 1965, KISSANNE, 1975).

The cysts of the polycystic kidney are classified into four types with regard to their different origins (OSATHANONDH and POTTER, 1964; DU Bois, 1969; BERNSTEIN, 1973). The glomerular cysts are histologically identified by the presence of tufts of glomerular capillaries (VLACHOS and TSAKRKLIDIS, 1967; TAKY and FILMER, 1976). Furthermore, PARDO-MINDAN, PABLO and VAzQuEz’s (1978) electron microscope examination of the cysts in a case of renal dysplasia in man revealed the presence of an epithelium with pedicels on a part of the inner surface lining the cysts.

*Supported by a research grant in aid (No. 56480081) from the Ministry of Education, Japan 1983
The present study was undertaken to delineate the three-dimensional structure of podocytes on the cyst wall. The findings are discussed in comparison to the structures of epithelial cells in the normal or developing Bowman's capsule.

MATERIALS AND METHODS

Kidneys were obtained from adult monkeys, *Macaca fascicularis*, weighing 3-4 kg. With the monkeys under pentobarbital anesthesia, the kidneys were perfused with 2.5% glutaraldehyde in 0.1 M phosphate buffer solution (pH 7.4) via the abdominal aorta.

For scanning electron microscopy, fixed kidneys were cut with razor blades and the cysts were exposed. The kidney tissue was trimmed into blocks about 5 × 5 × 3 mm, immersed in 2% tannic acid for 2 hrs and then postfixed in 1.33% osmium tetroxide in the same buffer solution mentioned above. The postfixed specimens were dehydrated in a series of graded acetone, dried by a CO₂ critical point method (Tanaka, 1972), and coated with gold in an ion coater. Observation was performed in a Hitachi S-450 type scanning electron microscope.

For transmission electron microscopy, small tissue pieces containing cysts were excised from glutaraldehyde-fixed kidneys. The tissue specimens were post-fixed with

---

*Fig. 1. A cut surface of the monkey renal cortex beneath the capsule (C). The large, cup-like depression is a cut-open cyst (Cy), conspicuous among the many Bowman’s capsules (B) with or without glomerular capillaries (G). V blood vessel. ×180*
a buffered 1.33% osmium tetroxide (pH 7.4), dehydrated in a series of graded alcohol and embedded in epoxy resin. Thin sections of the resin-embedded specimens were stained with uranium and lead. Observations were carried out in a Hitachi H-500 type transmission electron microscope.

**OBSERVATIONS**

On cut-surfaces of the renal cortex, cup-like hollows adjoined the fibrous capsule (Fig. 1). They were cut-open renal cysts with generally circular openings. Their diameter was about 350 μm, but varied by sectionings. These balloon-shaped cysts usually contained a jelly-like substance before being dried.

After removal of the content, the inner surface of the cysts was relatively flat, but rudimentary tufts of glomerular capillaries or a mound-like swelling with one or two capillary loops were located in part of the inner surface (Fig. 2-4). Observation of complementary cut-surfaces of the same cyst (Fig. 3, 4) revealed tufts of the glomerular capillaries or mound-like swelling to be localized on one portion of the cyst wall.

Fig. 2. A cut-open surface of a cyst. a. Two parts are distinct on the cyst wall: the glomerular part and the parietal around the former. A tuft of glomerular capillaries (G) is situated at a pole opposite to a smooth surfaced area (S) in the parietal part. Many wandering cells (W) with a bristled surface are scattered on a layer of podocytes (P). T urinary tubule. ×400. b. A closer view of the glomerular capillaries. Their outer surface shows a laced profile with arrangement of foot processes derived from thick cytoplasmic processes and perikarya (P) of podocytes. ×2,400
Most of the cyst inner surface, including the outer surface of the glomerular capillaries and mound-like swelling, was covered with an epithelium with pedicels (Fig. 2-5). The epithelial cells were podocytes characterized by polygonal perikarya, several thick cytoplasmic processes extending radially and terminal foot processes of uniform size. The surface structure of the podocytes was essentially similar to that of the cells on the glomerular capillary in normal renal corpuscles in the monkey (Andrews, 1975).

At typical portions of the cyst wall, perikarya of podocytes were evenly arranged (Fig. 6a). Cytoplasmic processes extended radially from the perikarya, showing a uniform thickness of about 5 µm. In contrast, the processes with terminal pedicels were concentrically arranged around the perikarya (Fig. 6a). Very thin processes sometimes extended over many cells to distant areas (Fig. 6b). Furthermore, anastomoses among processes of one and the same cell were sometimes evident. Foot processes were formed not only on the glomerular capillaries (Fig. 2b), but also on the concave parietal layer of the cyst at the area of the podocytes. Transmission electron microscope observation showed slits between neighboring foot processes (Fig. 8c) as seen in normal glomerular capillaries. Cell attachment structures frequently seen between neighboring processes were represented by a close apposition of plasma membranes (about 150 Å
Renal Cyst in the Monkey

in distance) and by a thickening of the latter (Fig. 8c). The attachment structure was similar to that noted in developing glomeruli (Aoki, 1967; Miyoshi, Fujita and Tokunaga, 1971).

In the parietal layer of the cyst, there was a smooth-surfaced area about 40 μm in diameter, discrete from the surrounding rough-surfaced area of the epithelium with pedicels (Fig. 2, 4, 7). This smooth-surfaced area was usually located at the pole opposite to the glomerulus or mound-like swelling mentioned above. This area was lined with squamous epithelium. The cytoplasm of the squamous epithelial cells in the transmission electron micrograph (Fig. 8b) was electron lucent with poorly developed cell organelles, and a feltwork of cytoplasmic filaments was observed in the basal cytoplasm, as noted in the parietal layer cells of Bowman’s capsule (Pease, 1968; Webber and Wong 1973; Bargmann, 1978). Junctional structures were also well developed between the neighboring cells (Fig. 8b).

Slender, fusiformed cells were frequently seen in a peripheral zone of the smooth-surfaced area (Fig. 7). These cells were similar in structure and position to those seen

Fig. 4. A complementary cut-surface of the same one cyst in Fig. 3. A mound-like swelling protrudes into the cyst lumen and is associated with two streaks of glomerular capillaries (GC). The whole inner surface of the cyst is covered with podocytic epithelium. The asterisk denotes a cut-end of a glomerular capillary and tallies with the asterisk showing another cut-end in Fig. 3. G glomerulus. ×390
along the boundary between the parietal layer and the visceral layer of Bowman's capsule in the lamprey (Youson and McMillan, 1970, Miyoshi, 1978).

On the epithelial surface of the cyst were disseminated spherical cells, revealing bristled surfaces with finger-like or round-headed processes (Fig. 2, 9). The nature of the cells was not clear, but they might be wandering cells.

DISCUSSION

The cysts examined in the monkey kidney in the present study are considered to be glomerular in origin, because of the presence of glomerular capillaries and podocytes as seen in human glomerular cysts (Taxy and Filmer, 1976; Paro-Mindan, Pablo and Vazquez, 1978).

Fig. 5. A transitional area from a mound-like swelling (MS) to a parietal part (CS) of the cyst. Podocytes (P) in both areas are essentially similar in their surface structure. The free surface of the cells shows some tiny processes and single cilia (arrows). ×2,000

Fig. 6. Podocytes on the parietal part of the cyst. a. Perikarya (P) of the podocytes are evenly arranged. Their processes extend concentrically around the perikarya. Anastomoses (arrows) are also evident between processes from the same podocyte. ×1,300. b. Podocytes (P) in an uneven or irregular arrangement. Cytoplasmic processes extend over many cells to distant areas. ×2,000
Fig. 6. Legend on the opposite page.
PARDO-MINDAN, PABLO and VAZQUEZ (1978) found podocytes not only on the glomerular capillaries, but also on part of the inner surface of the glomerular cysts. They proposed that the existence of these podocytes on the inner surface is due to the evagination of the capillary tufts when the glomeruli become functional and the ultrafiltrate in the cyst causes a hyperpressure in the cyst.

This hypothesis is supported by the occurrence of the mound-like swellings noted in the present study. At the developmental stage of the glomerulus, the glomerogenic tissue forms a massive protrusion in the primordial vesicle of the nephron (Du Bois, 1969) and cylindrical epithelial cells covering the protrusion differentiate into podocytes with the development of the glomerular capillaries (Suzuki, 1959; Miyoshi, Fujita and Tokunaga, 1971). In this sense, the swellings which were seen to be covered with podocytic epithelium and associated with a few of the capillary tufts may represent a stage of evagination of the massive protrusion.

A squamous cell area was expected to appear on the glomerular cyst wall (Pardo-Mindan, Pablo and Vazquez, 1978). However, to our knowledge, there is no available evidence on the structure.

Fine structural examination of cysts in humans and other species has revealed: 1) cylindrical epithelium associated with numerous polypoid structures in the collecting duct cysts (Evans, Gardner and Bernstein, 1979; Coleman, 1980); 2) cylindrical epip-
Renal Cyst in the Monkey

267

thelial cells with well developed cell organelles, microvilli, and interdigitated lateral processes in the proximal tubule cyst (CUPPAGE et al., 1980, PREMINGER et al., 1982); and 3) high cuboidal or cylindrical cells with basal infoldings and dilated intercellular spaces in the distal tubule cyst (CUPPAGE et al., 1980). These structures differ considerably from those of the squamous cells noted in the present study. The squamous cell area may represent the outer leaflet or parietal layer of the normal Bowman’s capsule. However, we found no evidence of an opening of the urinary tubule.

Fig. 8. Transmission electron micrographs of the cyst wall. a. Podocyte (P) on the inner wall issues various-sized processes and sets on the basal lamina, to which a capillary with fenestrated endothelial cells is juxtaposed. T tubule cell. ×3,500. b. Squamous epithelial cells (Sq) of the smooth-surfaced area. Junctional structures (large arrow) and a feltwork (thin arrows) of cytoplasmic filaments in the basal cytoplasm are conspicuous. ×6,500. c. Foot processes are irregular in their size and cut profile. There are close appositions of membranes of neighboring processes and membrane thickening at the sites (arrows). E endothelial cells, R red blood cell. ×11,000
Fig. 9. A wandering cell on podocytes (P). The surface is bristled with numerous finger-like or round-headed processes. $\times 1,700$

REFERENCES

Andrews, P. M.: Scanning electron microscopy of human and rhesus monkey kidney. Lab. Invest. 32: 610–618 (1975).

Aoki, A.: Temporary cell junctions in the developing human renal glomerulus. Devel. Biol. 15: 156–164 (1967).

Bargmann, W.: Niere und ableitende Harnwege. In: Möllendorffs Handbuch der mikroskopischen Anatomie des Menschen. VII/5. Springer Verlag, Berlin-Heidelberg-New York, 1978 (p. 34–204).

Baxter, T. J.: Polycystic kidney of infants and children: morphology, distribution and relation of the cysts. Nephron 2: 19–31 (1965).

Bernstein, J.: The classification of renal cysts. Nephron 11: 91–100 (1973).

Coleman, M.: Multilocular renal cyst. Case report, ultrastructure and review of the literature. Virchows Arch. A Pathol. Anat. Histol. 387: 207–219 (1980).

Cuppage, F. E., R. A. Huseman, A. Chapman and J. J. Grantham: Ultrastructure and function of cysts from human adult polycystic kidneys. Kidney Int. 17: 372–381 (1980).

Du Bois, A. M.: The embryonic kidney. In: (ed. by) C. Rouiller and A. F. Muller: The kidney. 1. Academic Press, New York-London, 1969 (p. 1–59).

Evan, A. P., K. D. Gardner, Jr. and J. Bernstein: Polypoid and papillary epithelial hyperplasia: A potential cause of ductal obstruction in adult polycystic disease. Kidney Int. 16: 743–750 (1979).

Kissanne, J. M.: Congenital malformations. In: (ed. by) J. M. Kissanne: Pathology of the kidney. 2nd ed. Little Brown, Boston, 1975 (p. 69–119).

Miyoshi, M.: Scanning electron microscopy of the renal corpuscle of the mesonephros in the lamprey, Entosphenus japonicus Martens. Cell Tiss. Res. 187: 105–113 (1978).
Miyoshi, M., T. Fujita and J. Tokunaga: The differentiation of renal podocytes. A combined scanning and transmission electron microscope study in rats. Arch. histol. jap. 33: 161–178 (1971).

Möllendoff, W. v.: Der Exkretionsapparat. In: Möllendorff's Handbuch der mikroskopischen Anatomie des Menschen. VII/1. Springer Verlag, Berlin, 1930 (p. 1–328).

Osathanondh, V. and E. L. Potter: Pathogenesis of polycystic kidneys. Arch. Pathol. 77: 459–512 (1964).

Pardo-Mindan, F. J., C. L. Pablo and J. J. Vazquez: Morphogenesis of glomerular cysts in renal dysplasia. Nephron 21: 155–160 (1978).

Pease, D. C.: Myoepithelial characteristics of capsular and tubular cells of the kidney cortex. J. Cell Biol.: 103a (1968).

Preminger, G. M., W. E. Koch, F. A. Fried, E. McFarland, E. D. Murphy and J. Mandell: Murine congenital polycystic kidney disease: A model for studying development of cystic disease. J. Urol. 127: 556–560 (1982).

Suzuki, Y.: An electron microscopy of the renal differentiation. II. Glomerulus. Keio J. Med. 8: 128–154 (1959).

Tanaka, K.: A simple type of critical point drying method. J. Electron Microsc. 21: 153–154 (1972).

Taxy, J. B. and R. B. Filmer: Glomerulocystic kidney. Report of a case. Arch. Pathol. 100: 186–188 (1976).

Vlachos, J. and V. Tsakraklidis: Glomerular cysts. An unusual variety of “polycystic kidneys”: Report of two cases. Amer. J. Dis. Child. 114: 379–384 (1967).

Webber, W. and W. T. Wong: The function of the basal filaments in the parietal layer of Bowman’s capsule. Can. J. Physiol. Pharmacol. 51: 53–60 (1973).

Youson, J. H. and D. B. McMillan: The opisthonephric kidney of the sea lamprey of the Great Lakes, Petromyzon marius, L. I. The renal corpuscle. Amer. J. Anat. 127: 207–232 (1970).