Measurement of Internal and External Pressure of Transplanted Kidney: An Underestimated Method of Diagnosis for Renal Grafts

K. Dziewanowski[a], R. Drozd[a], E. Krzystolik[a], A. Krzystolik[a], and B. Machaliński[b,*]

[a]Center of Nephrology and Renal Transplantation, Regional Hospital, Szczecin, Poland; and [b]Department of General Pathology, Pomeranian Medical University, Szczecin, Poland

ABSTRACT

Hardness, or tensity (tonus), of transplanted kidney can change in the course of various pathologic conditions. Manual examination (with palpation), which is most frequently used to evaluate this transplanted organ, is not objective. First attempts of objective evaluation were described in the medical literature in the 1980s. They consisted of evaluation of intrarenal pressure by puncturing the kidney, connecting an intravenous drip line, and measuring the pressure in centimeters of water column. Examination of a group of subjects revealed significant differences in mean measurements, especially in patients with acute rejection process compared with the control group. However, use of this method was not continued, owing to its invasiveness. Our own diagnostic method, described here, is measurement of external kidney pressure (tonus). Two types of devices (tonometers) are described, as well as a project of a future tonometer functioning on the basis of electronically measured differences in values of forces used above the graft and above the symmetric part of the abdomen causing identical deflection of abdominal wall. Thirty-two patients (including control group) were examined with the use of this method. Statistically significant differences were revealed between patients with acute graft rejection and chronic graft nephropathy compared with the control group. The method described here can be a valuable supplement to other currently used noninvasive means of renal graft evaluation, including ultrasonography, Doppler, and elastographic examinations.

TRANSPLANTED kidney has a certain tensity (tonus), which is most often measured by means of palpation, which is usually not objective. This tensity is subject to change in a number of clinical situations, especially in the course of acute or chronic graft rejection, acute tubular necrosis (ATN), inflammatory reactions, etc.

First attempts of evaluation of intrarenal pressure were done by Wagner et al, who performed measurements with the use of a thin catheter located constantly during the surgery underneath the transplanted kidney capsule. They demonstrated that in an efficiently functioning organ the subcapsular pressure is usually <15 cm H_2O, in ATN it is in the range of 15–40 cm H_2O, and in the course of acute graft rejection it exceeds 40 cm H_2O [1].

Salaman and Griffin simplified the measurement technique by using a fine aspiration needle connected to a manometer. In patients with good and stable kidney function they demonstrated mean intrarenal pressure equal to 27 ± 9.8 mm Hg (~37 cm H_2O), whereas in patients with acute graft rejection these values were higher and averaged 51.3 mm Hg (~70 cm H_2O) [2].

MATERIALS AND METHODS

Similar measurements were performed in our center at the end of the 1980s; we used lumbar puncture needles that, after puncturing the kidney, were connected to an intravenous drip line with 0.9 NaCl. The level of stabilized normal saline solution, after correction for the depth of the injected needle, would correspond to the value of intrarenal pressure.

The first simple device measuring external kidney pressure was developed and patented in 1998 (patent no 2239687/88). Its action relied on the basis of deflection of a dynamometric spring placed in

*Address correspondence to Bogusław Machaliński, MD, PhD, DSc, Department of General Pathology, Pomeranian Medical University, Powstancow Wlkp 72, 70-111 Szczecin, Poland. E-mail: machalin@pum.edu.pl

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Fig 1. External view of the 1st device for measuring external pressure in transplanted kidney.

an appropriate casing (drafts of the device and measuring method are shown in Figs 1 and 2 [3,4]).

One end of the spring with pressure tip is based during the measurement on the appropriate point of the abdominal wall above the transplanted kidney. The other end of the spring is pressed with appropriate pressure as measured by spring deflection gauge. Depending on hardness and density of the underlying structures, including the kidney graft, different force needs to be used to achieve the same displacement (1.5–2 cm) of the abdominal wall. The magnitude of this force is an indirect indicator of existing "tonus" of the transplanted kidney.

Another model of the device was developed in cooperation with the Radex company (engineer Piotr Radion). We named it a renal tonometer and based it on a steering microprocessor and electric converters with feasibility to connect to a computer. The scheme of the device, its design, and measurement method are presented in Figs 3–5.

RESULTS

Altogether we performed 53 measurements in 40 patients (in some patients measurements were repeated according to the condition of the graft). In good and stable kidney function the intrarenal pressure in our patients was at the average 26.5 (range, 14.0–45.5) cm H_2O; in acute rejection, 63.5 (35–90) cm H_2O; in ATN, 34.0 (30–42) cm H_2O; and in chronic graft nephropathy, 21.3 (14–42) cm H_2O [5].

We have been using this model for many years. Measurements performed with this device are completely safe, pose no harm to the patient, and can be repeated an unlimited number of times. Simplicity of the examination and its bedside feasibility are additional advantages. In our measurements we pressed the abdominal wall with a force of 1.5–3.6 kg. We usually performed 3 measurements and calculated an average of them. During the examination we assured that the patient lie freely on a stable base and that the tonometer is placed perpendicular to the abdominal wall. Initially, measurements were repeated in the same patient and possible clinical conclusions were drawn from the magnitude of the force necessary to achieve a certain assumed deflection of the abdominal wall. So, for example, if the force necessary to achieve the same deflection was increased by $\geq$20%–30%, it would raise suspicion about the condition of the graft (possible rejection, pararenal hematoma, urine leak, venous thrombosis, etc). This examination was, of course, complementary to other routine methods used in such cases (ultrasound, Doppler examination, tomography, possible renal biopsy). Our method enabled us to follow and monitor the process of acute graft rejection and its resolution after administered treatment.

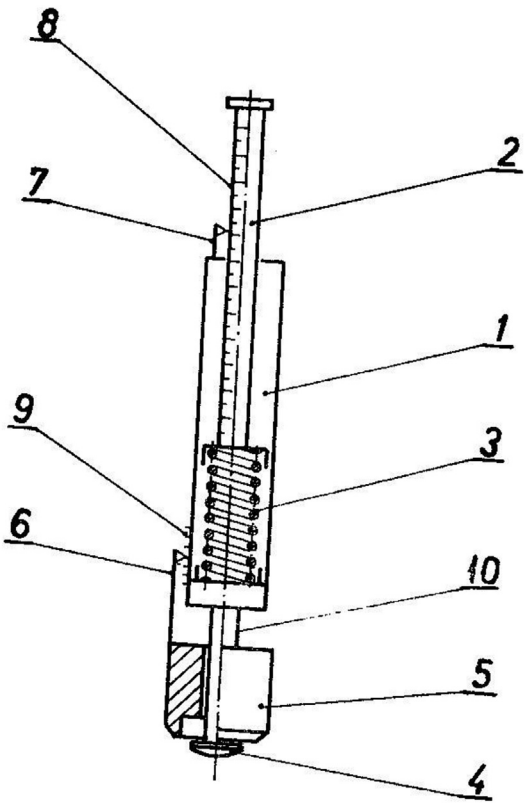

Fig 2. Scheme of the 1st tonometer. 1, 10: Body of the device. 2: Trunk of the tonometer with scale. 3: Spring of the tonometer. 4: Pressure tip. 5: Pressure load. 6: Relative displacement gauge. 7: Spring deflection gauge. 8: Piezoelectric sensor. 9: Electric indicator of pressure force.