The history of hemodialysis goes back to the beginning of the 1920s. but on the other hand, more than 60 years have elapsed since the first effective application of hemodialysis used as a method of renal replacement therapy in human. Abel, Rowentree, and Turner, American scientists from the Johns Hopkins University School of Medicine in Baltimore, were the pioneers in the field of hemodialysis therapy. They published in the period between 1913-1914 the results of experimental works carried out on animals with the use of extracorporeal dialysis (1, 2, 3, 4). The device, which they constructed and was actually the prototype of the hemodialyzer, consisted of a big container filled with a solution of sodium chloride. A system of tubes made of collodion, which were connected through glass cannulas with an artery and a vein of a dog, was immerged in this container. The flow of blood was assured by the difference of pressures generated by the work of the heart. Blood clotting was prevented by the use of hirudin, which was obtained from the superior part of the alimentary tract of leeches. In a process called by the authors „vividiffusion”, it was possible with the use of this device to eliminate substances, which were intentionally given to the animals prior to the procedure, from their circulation (5).

The first hemodialysis in a human being was carried out by the German doctor Georg Hass who lived and worked in Giessen near Frankfurt on the Main. His interest in dialysis began in 1914 when he started working at the University in Giessen. Almost at the same time Hass began his experiences, in which he used a device and methods similar to those applied by John J. Abel and his collaborators. However, the majority of the animals which Hass used as the subject matter of his experiments died after a couple of hours. Their death was probably connected with the toxic action of hirudin. These failures, as well as the military actions of the First World War taking place at that time, constituted the reason for the renunciation of further works on dialyses.

Georg Hass came back to the problem of hemodialysis in 1923, when thanks to the work of Heinrich Necheles on preparations of hirudin, which were purified well enough so that they appeared not to show the toxicity obse-
revised earlier, and these preparations were adapted for administration to human beings. At the end of 1924, Hass carried out the first successful dialysis in a human. This procedure lasted 15 minutes and there were no complications. The inflow of blood into the device was assured by a glass cannula placed in the radial artery, and the outflow of the blood to the patient took place by means of the insertion of a needle into one of the veins in the area of the elbow. The tubes with which the dialyzer was constructed were made of collodion. As the method was improved, the duration of the procedure became longer, and a pump, which forced the blood circulation, was installed between the device and the artery providing the blood. In 1927, in order to prevent blood clotting during hemodialysis, Hass used for the first time heparin, which replaced the still imperfect preparations of hirudin. Up until 1929, Hass executed eleven hemodialysis procedures, and thereafter, due to not entirely known reasons, he renounced further works connected with this subject. Georg Hass died in 1971, and before his death he saw the flourishing of the method which he pioneered (2, 3, 6, 7).

The turning point in the further development of hemodialysis was without any doubt due to the use of cellophane, i.e. the use of a film made of modified cellulose. Cellophane, invented at the turn of the 19th and 20th centuries and used earlier mainly as a packaging material in the food industry, met the requirements set for a dialysing membrane in a much better way than the collodion which had been used so far. William Thalhimer, who dealt with experimental hemodialysis in animals, was the first to use a tube made of cellophane for the construction of a dialyzer in 1938. In the conclusions resulting from his works, he included suggestions of the possibility of using a similar construction for the needs of dialysis in humans (3, 4, 8).

The world recognized unanimously 1943 as a landmark in the history of renal replacement therapy. At that time Willem Johan Kolff, a young physician born in 1911 who was working in a municipal hospital in a small town...
Kampen in the central part of The Netherlands, pioneered the treatment of patients suffering from uraemia with the hemodialysis method while using a device of his own design with a rotational drum. The manufacturer of the first four devices was Henk Berk, managing director of the Kampen Enamel Works, who is mentioned as co-author in the pioneering article of Kolff published in 1944 in Acta Medica Scandinavica (4). The semi-permeable membrane was composed of a wall of the cellophane tube with a length of 30 m and with a diameter of 25 mm, which created a dialysing surface of approximately 2 m². This tube was reeled on an aluminium drum with a diameter of 40 cm and a length of 90 cm, whose long axis was placed horizontally. This drum was immersed to up to approximately 1/3 of its size in an enamelled tub containing 70-100 litres of dialysing liquid with a temperature 37°-39°C, and it rotated while being driven by an electric engine with a speed of 30-60 rotations per minute.

The rotation of the drum forced a continuous movement of blood inside the cellophane tube, and due to the gravitational force, this blood flew to the segments of the tube located at the lowest level and was immerged in the liquid. The dialysis could be carried out in a continuous way or in a fractional way, which consisted of removal of successive parts of blood with a volume of approximately 500 ml and re-infusion into the circulation after the dialysis. The clotting of blood was prevented with the use of heparin, which was administered in a dose of 400 mg into the device. An identical dose of 400 mg of heparin was received by the patient in the form of an intravenous bolus at the moment of the beginning of the procedure, and subsequently further doses of 100 mg were administered every 30 minutes during the duration of the dialysis.

The first hemodialysis with the use of this method was performed on March 17, 1943 for a 29 year-old female suffering from the end stage renal disease with a level of urea of 164 mg%. During a 43 day period, 12 hemodialysis procedures were executed for this patient, and due to hemorrhagic complications, almost 15 litres of blood were transfused. The treatment had to be stopped due to the exhaustion of the possibilities for accessing the veins and arteries of the patient, who died on the 6th day after the last procedure. The next attempts of hemodialysis in 15 consecutive patients failed and all they died. Only the seventeenth patient treated by Kolff and his team was saved. This patient was a 67 year-old woman with renal failure which occurred in the course of intoxication with sulphonamides used for the treatment of the cholecystitis. Thanks to hemodialyses, this patient survived the acute phase of the illness, and then her kidneys began to function efficiently enough so that on September 11, 1945 the dialyses were ended for this patient (4, 7, 9).

The artificial kidney of Kolff and his pioneering method gained certain popularity; it was applied in various centres all around the world, and it was modified and improved several times. At this point it is worth mentioning the achievements of the team lead by Jean Hamburger from the Necker Hospital in Paris whose outcome consisted of a dialyzer called the Necker artificial kidney (1, 2). Willem Kolff left The Netherlands in 1950 and moved to the
United States where he continued to work in the Cleveland Clinic Foundation on the problems of hemodialysis. In 1955, in cooperation with Bruno Watschinger, an Austrian nephrologist, he constructed a new model of the artificial kidney, later called the twin-coil kidney. The essence of this construction consisted of the flow of blood and of dialysing liquid in opposite directions, which was generated by the work of a pump and a dialyser, i.e. a duct having the form of a coil, through which blood was flowing, which became a removable part (2, 10).

Independently of Kolff, Nils Alwall was working on an artificial kidney at the University in Lund in Sweden. In 1947 he presented a device which he had been using for two years in order to carry out hemodialyses, initially in animals and subsequently in human beings (3). In a couple of essential points, the solutions constructed by Alwall created differences between his artificial kidney and the device of Kolff. The drum, on which a dialysing tube, also made of cellophane, was reeled, was placed vertically and did not rotate. The work of a system of pumps on one hand forced both the blood flow and the movement of the dialysing liquid in opposite directions and on the other hand allowed the obtainment of negative pressures in a hermetically closed compartment of the liquid that made possible the occurrence of ultrafiltration. This resulted in a significant increase in the efficiency of the device. The dialysing tube could be almost three times shorter, and its length was 11 metres compared to 30 metres in Kolff’s device. The basic part of this device was considerably smaller, because the volume of the space for the liquid which stayed in contact with the dialyser amounted to approximately 25 litres, although it had to be connected with a separate container intended for the storage of the dialysing liquid. Alwall used devices of various sizes. The figures mentioned above describe the type intended for use in human beings. In the case of experiences in rabbits, the dialyser had a tube with a length of 120 centimetres and a liquid volume of 3 litres. For bigger dogs, the dimensions were respectively 4-5 metres and 11 litres of liquid.

One has to stress that although Willem Kolff, thanks to the works on the artificial kidney, entered into the history of medicine forever and he is correctly considered to be the father of hemodialysis therapy, it is the artificial kidney with the design constructed by Nils Alwall which has been commonly and generally used. After the lapse of 15 years, more than 2000 such devices were in use in various dialysing centres all around the world, including Poland (11).

One of the most important defects of the first models of the artificial kidney consisted of the necessity of their initial filling with a big volume of blood amounting to even more than 2000 ml. Therefore, the efforts of numerous researchers and designers were aimed at the modification of this parameter. Significant progress was made by Leonard Skeggs and by Jack Leonards, who in 1948 worked out a sheet dialyzer, and by a Norwegian, These Kiil, who in 1960 presented a device in which a dialyzer was constructed with sheets of cuprofan – a new generation of cellophane. A volume of approximately 300 ml of the patient’s blood was enough to fill it (2, 11, 12). The era of the capillary type designs began in the mid 1960’s and continues until the present day. The dialyzers of the modern devices are constructed with several dozens of thousands of capillaries. Their wall’s thickness was initially 20-30 µm and presently is 8-10 µm and sometimes even 5 µm. Their length is more than a dozen centimetres. They are made of derivatives of cellulose or their material is entirely synthetic. They use the method of countercurrent flow of blood and of the dialysing liquid. A volume of approximately 200 ml of blood, located at a given time outside of the circulatory system of the patient, is sufficient for the correct function of the dialyzer. The modification of the structure and of the properties of the material used for the construction of the walls of a capillary, in other words the modification of the permeability parameters of the dialysing membrane, as well as the modifications in the composition of the dialysing liquid and the regulation of the speed of its flow, allow the obtainment of different dialysing clearances and accurate control of the ultrafiltration process. Such possibilities allowed the development and the introduction of new and more efficient techniques of hemodialysis (11, 14).

In Poland, the era of renal replacement therapy started in 1958 at the moment of the importation of the first hemodialyzer having Alwall’s design. It was given to the 2nd Chair of Internal Diseases of the Medical University in Poznań, which was managed at that time by
Prof. Jan Roguski. The first hemodialysis in Poland was carried out on November 8, 1958 by Kazimierz Bączyk and Andrzej Steffen. Two further dialysis centres were opened in the Medical University in Warsaw and in Cracow, in 1959 and in 1962, respectively (1, 2, 11).

An integral part of hemodialyzotherapy and a prerequisite for its existence consists of the presence of sufficient vascular access, which ensures good drawing of blood from the patient and its return to the circulation after dialysis. At this moment, it is worth reminding that Willem Kolff was forced to end the treatment of his first patient due to the loss of vascular access and of the possibility of drawing blood into the dialyzer (4, 9). This shows the importance of a problem existing until the present day for the hemodialysis process, namely the issue of the vascular access.

The first dialyses were carried out with the use of single punctures or cannulation of vessels with glass tubes made each time for the needs of only one procedure. Hass, Kolff, and Alwall used this procedure, but the vascular access still continued to be the weakest element of this continuously improved method. In 1949 Alwal made an attempt at connecting the glass cannulas placed in the vein and the artery with a rubber tube, but the experiment failed to succeed (7). The Americans Quinton, Dillard, and Scribner from the University of Washington in Seattle (15) were successful in the development of this concept. In 1960 they described a technique for obtaining vascular access, which consisted of the creation of an external arteriovenous fistula with the use of cannulas inserted in the radial artery and in the cephalic vein in the area of the wrist which were connected on the outside with a Teflon duct. In the following years, Teflon was replaced with silicone. An important inconvenience consisted of the risk of the occurrence of infections, thrombi, and haemorrhages in the case of an uncontrolled disconnection of the catheters.

This method was used for the first time on March 9, 1960, and one has to consider this event as the beginning of long-term hemodialyzotherapy (7). Professor Belding Scribner died in June 2003, and as the author of this method he became an important part of the history of medicine together with his first patient, 39-year-old Clyde Shields, who thanks to a programme of long-term hemodialyses lived eleven years after the beginning of this treatment (7).

In October 1961 Shaldon, Chiandussi, and Higgs published a study in which they described a method of obtaining vascular access for dialysis which consisted of the transcutaneous insertion of two catheters of their own design (17) into the femoral artery and vein according to Seldinger's technique. The study included 10 patients with acute renal failure, who underwent 15 hemodialysis procedures in total. This publication initiated the works on temporary vascular access for the needs of dialysis by means of the cannulation of central veins with a double-lumen catheter.

1966 brought the legendary paper from the Veterans Administration Hospital in New York, in which Brescia, Cimino, Appel, and Hurwich (18) described a new technique of obtaining permanent vascular access, which consisted of the creation of an internal arteriovenous fistula in the forearm. Kenneth Appel was the surgeon who created a fistula using this method for the first time. In the area of the wrist, he ana-

Fig. 5. External fistula for dialyses invented by Scribner. According to Scribner (16)
stomosed the radial artery and the cephalic vein with a continuous 7-0 silk suture, using side to side technique and maintaining the patency of both vessels on the distal segment from the place of anastomosis. This event became the milestone in the process of improvement of the vascular access for hemodialysis. Although the technique proposed at that time was subject to numerous modifications, up to the present day the radial-cephalic fistula is considered to be the method of choice in the creation of the primary vascular access.

At the beginning of the 1970s, new possibilities for the needs of the creation of vascular access were opened by the introduction of vascular prostheses. In 1972 in Philadelphia, Joel L. Chinitz applied a biological transplant from the bovine carotid artery for the needs of dialyzootherapy (7). In the same year in New York, Irving Dunn presented the results of his experiences made initially on animals and subsequently the results of operations in humans with the use of Dacron prostheses (7). In the mid 1970s vascular prostheses made of polytetrafluoroethylene (PTFE) were introduced. This event initiated the epoch of prostheses in the tactic for the creation of vascular access for dialysis. In 1976 Baker Jr. presented the results of the implanting of PTFE prostheses in 72 dialysed patients (7). Numerous other works of many authors confirmed the benefits, although at the same time they indicated problems which resulted from such a tactic for the creation of vascular accesses.

In summary, one has to affirm that the success of Kolff realised 60 years ago was possible because it was related to a patient with acute renal failure and because the remission of the disease took place before the possibilities of the patient’s treatment were exhausted. The progress made in the tactic for the creation of vascular access for dialysis resulted in the present situation in which in any case the possibility of obtaining the access is not an obstacle to the application of hemodialysis.

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Received: 2.02.2007 r.
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