Marty Roberts; The Man Who Brought Sorbent Dialysis to Life

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Marty Roberts, PhD passed away on June 14, 2022. He had just celebrated his 102nd birthday on May 8 with friends, family and many of the countless collaborators that have lined his scientific career. Authors of this article participated in his Birthday Celebration by video (https://vimeo.com/746663546), Dr. Ash thanking Marty for "making me feel so young." By video Marty also received minutes-long applause from the entire audience of the European Home Dialysis congress in Cologne, after his crucial role for sorbent development had been highlighted in the opening lecture by the Dr. Wieringa.

Marty's long career was dedicated to making dialysis simpler, safer and more suited to the home environment. Over many decades, he contributed to almost every type of dialysis therapy that we use today. Anytime we implement hemodialysis or peritoneal dialysis, especially sorbent-based dialysis, we should think of Marty.

Marty received a bachelor of science in chemistry at the College of City of New York in 1942, and was working for a beer consulting firm, assaying beer and devising ways to eliminate the air content when bottling. Strangely, Marty did not[1] even like beer at the time. He later said "I didn't want to be assaying beer for the rest of my life, so I decided I would take a master's at night while I was still working." He received a Master's degree in Organic Chemistry from Brooklyn College in 1947 and a PhD in Biochemistry from the University of Southern California in 1951. Looking for application of his skills in the medical area, Marty met Dr. Morton Maxwell, who was leading the effort to develop peritoneal dialysis therapy. Dr. Maxwell at the time was making his own catheters and dialysis solutions in a laboratory. His catheter was a nylon catheter, and he inserted the nylon catheter using a large trocar. Marty designed a catheter with an obturator inside which had a three-sided tip, which eventually became the "Trocath" catheter.[2] In Marty's words, "the advantage there was that the hole made by the obturator was smaller than the catheter, so the catheter stretched the skin and it was automatically sealed."[1] This catheter was routinely used for acute peritoneal dialysis access and is still being used today.

To develop commercial peritoneal dialysis (PD) solutions was a major challenge. Marty said "some solutions precipitated when you sterilized them. Some solutions turned brown when you sterilized them. So the job was to correct the formulation so that they were clear and colorless."[1] Working first with Dr. Maxwell and then with Don Baxter of Kendall-McGaw, Marty changed the pH and chemical components so the PD fluid remained clear, colorless and stable in spite of heat sterilization. Marty also worked out formulations for nutrition supplementation such as Calorigen and then solutions for patients with acidosis and alkalosis.

Marty moved on to become Medical Director and Manager of the Seattle Artificial Kidney Supply Company, a division of Sweden Freezer. There he worked on the newly developed proportioning dialysis machines from 1966 to 1971. In his words "Scribner and Blagg were the people who were telling me … how to build the machines and what they needed. And one of the things they needed was a blood tubing set that would be commercially available. And Sweden Freezer had a Japanese division in Tokyo. They contacted Japan Medical Supply and arranged for me to visit the Japan Medical Supply and show them how to make blood tubing sets."[1] He later reminisced "I still have an ice cream machine that I use whenever I have a party... it still works."[1]

Perhaps Marty's greatest accomplishment was in guiding the development of the world's first dialysis machine with sorbent regeneration of dialysate, the Redy machine. The aerospace company Marquardt was looking for new applications of ion exchange resin technology after World War II. An engineer in the company got a grant from the government to remove sodium from agricultural wastewater, thus regenerating it. His cousin developed kidney failure, and he thought "Why throw all that dialysate down the drain, why don't we regenerate that dialysate?"[1] In Marty's words "So Marquardt got a grant from the NIH, and through Morton Maxwell, and through Arthur Gordon, who actually were the persons who got the grant because the company itself could not get a grant, and Maxwell and Gordon were both nephrologists, so they headed the group and they hired a chemist by the name of Larry Marantz. It was Larry Marantz who developed the sorbent system and that started in 1968 and continued under Marquardt and then in 1971 they decided that they were going to go on the market and they changed the name from Marquardt to CCI Unknown what CCI stands for. Life Systems."[1] The machine was designed for use by a patient at home. One knob was the main control knob, so it was very easy for a person to learn how to use the machine (Figure 1). The sorbent column contained four layers of mostly inorganic compounds: activated charcoal, a cation exchanger, and anion exchanger, and a layer of urease passively bound to silica. Only 6 L of tap water was needed to perform the entire dialysis. Numerous clinical and *in vitro* studies showed that this simple collection of sorbents effectively removed all uremic toxins, which permeate the dialysis membrane.

Since no company marketing hemodialysis systems was interested in sorbent dialysis, Marty ended up setting up a marketing group to support the machine through CCI Life Systems. The Redy machine in updated versions was produced until 1994, and column production continued until 2007. Over 2

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Figure 1. The URS SorbSystem (Redy) Dialysis Machine, with Sorb Column (middle, top) and 6 L dialysate reservoir (ca 1979).[3]

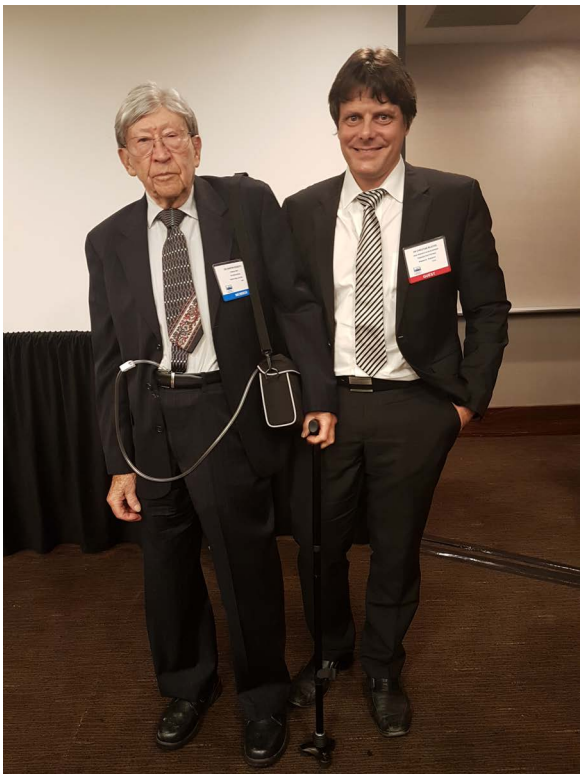

Figure 2. Automated Wearable Artificial Kidney (AWAK) demonstrated by Marty Roberts and Christian Blùchel in 2017. (11)

million dialysis treatments were safely performed using the Sorb columns, in homes, intensive care units (ICUs), cruise ships, and military hospitals.[4] CCI was purchased by Organon Teknika and that company was later purchased by Gambro. The company then became privately owned Sorb Technology which in 2000 merged with Renal Solutions (a spin-off of HemoCleanse Technology). Marty remained an active consultant with these various companies. Today, the basic design of the Sorb column is the basis for dialysate regeneration within at least four projects aimed at developing a highly portable or wearable hemodialysis system.

Marty's interest in dialysate regeneration also focused on development of regeneration of peritoneal dialysate. With Dr. Michael Blumenkrantz and others, the first publications on this application were in 1979.[5,6] The regeneration of peritoneal dialysate presented a number of further challenges compared to regeneration of hemodialysate. The cartridges had to be sterile. Peritoneal dialysate contains significant amounts of proteins and some cellular material, which could clog the columns of sorbent granules. Protein also would compete with urease for nonspecific binding sites on the aluminum oxide granules and also with the endotoxins that were present in the crude urease preparation. Early clinical tests indicated that some patients did develop sterile peritonitis after some hours of treatment, probably due to urease or endotoxin leaching from the column and entering the peritoneum. The team solved this problem by changing to a purified urease solution, which was injected into the column immediately before use. Overall, the tests demonstrated feasibility of sorbent regeneration of peritoneal dialysate, and one patient was maintained on the sorbent regeneration for 2 months.[7] Already in 1979, Blumenkrantz and Roberts envisioned a wearable system with continuous regeneration of peritoneal dialysate.

From 1987 Marty retained a position as Dialysis Consultant & Research Investigator at the VA Greater Los Angeles Healthcare System in Sepulveda, CA. There he collaborated with nephrologist Dr. David B. N. Lee to develop the concept of an Automated Wearable Artificial Kidney (AWAK) based on peritoneal dialysate regeneration. They published several reviews of the potential of such sorbent-based PD systems from 1999 to 2008. In one Editorial, they stated "that Continuous Ambulatory Peritoneal Dialysis is a successful wearable artificial kidney, but is not automated." They pointed out the advantages of a continuous regeneration of PD fluid at 2 L per hour, which would produce a Kt/V 3 times better than the Kidney Disease Outcomes Quality Initiative guidelines. This type of flow rate could be obtained by cycling 250 ml out and back through the single-lumen Tenckhoff catheter every 7.5 minutes, with about a liter remaining in the abdomen as residual (as in tidal flow dialysis). They outlined the whole idea further "Since the dialysate would be regenerated, there would be no need for additional dialysate, which would result in a waterless, bloodless AWAK. Further, the protein in the dialysate coming from the patient, which contains protein-bound toxins, could be regenerated and clean returned to the patient. For the first time, this would remove proteinbound toxins by dialysis. This is the approach we are taking toward the development of an AWAK."[7] One year later, Marty helped to form the start-up company AWAK in Singapore and was installed as Chief Scientist in the organization (as a consultant). In the next 2 years, they published more descriptions of the benefits and potentials of PD regeneration[8,9].

AWAK received considerable funding over the years. A sorbent column was developed specifically for PD regeneration with help and direction by Christian Blùchel, PhD, in Singapore (Figure 2). This column was a new design in which all components (urease, charcoal, cation exchanger, and anion exchanger) were mixed together in the column rather than residing in separate layers.[10] In 2019 AWAK received Breakthrough Device designation of its AWAK Peritoneal Dialysis by Food and Drug Administration, due to its unique sorbent technology. Clinical trial results followed and were reported in 2019 at ICN.[11] Chemical changes in the dialysate and toxin clearances were exactly as predicted during the treatments. There were no major adverse events, although some patients did develop mild abdominal pain during the procedure. There were also some problems with clogging of the sorbent column in human trials, which was not observed in

Figure 3. Marty Roberts (second from left) with Past Presidents of *ASAIO*, photograph by Fokko Wieringa, 2013. From left to right, Eli Friedman, Chris Blagg, Stephen Ash, and Steve Phillips.

animal trials. The success of the AWAK clinical trial confirmed that sorbent regeneration of peritoneal dialysate is effective, if not yet perfected. That is a major step forward towards making the world's first PD machine with a complete sorbent system. Some simple improvements may alleviate the problems seen in the clinical trial and AWAK could soon become a highly practical wearable artificial kidney (WAK).

As important as Marty's contributions were to science and medicine, it was his personality, generosity and concern for all who met him, that many remember most. He was a dedicated family man, a generous and good friend to many, and a role model who was always quick to offer advice and assistance especially to young investigators and scientists in the field of dialysis therapy. In 1975 Dr. Ash established the "Hemodialysis Laboratory" in the Bioengineering Center of Purdue University. This was just after he completed Fellowship in Nephrology and spent 3 months working with Dr. Kolff on his WAK. A major focus of the laboratory was on sorbent regeneration of dialysate. To learn more about how the Redy column worked, Dr. Ash contacted Marty by telephone. The questions asked were answered quickly and completely. At the end of the conversation, Marty was asked if he would be willing to give a presentation in person to the research team on sorbent dialysis. Surprisingly, he said "Yes" and shortly thereafter traveled to West Lafayette to spend a day and gave a lecture filled with detailed information on the sorbent chemical functions and limitations and also the whole history of dialysis therapy and sorbent applications.

Marty's dedication to *ASAIO* was steadfast, from the years when renal therapy science was a major part of the program, and through some years when the program was much smaller. He and his lovely and lively wife Ada regularly attended the annual meetings of *ASAIO*. Marty carefully chronicled the entire 52nd Annual Conference in 2006.[12] He was a friend and confidant of many of the Presidents of the society (Figure 3). Dr. Wieringa fondly remembers meeting Marty during the renal session of *ASAIO* 2013, where he said "young man, during this session you asked some excellent questions, but I don't know you. That's an unusual combination, what is your mission here?" When Dr. Wieringa described he was sent by the Dutch Kidney Foundation's NeoKidney Initiative to scout a sorbent for dialysate regeneration, Marty immediately suggested to contact AWAK and promised to arrange a Telco. Already the next week, we had a kickoff. Later AWAK decided to fully dedicate efforts to PD only, and Dr. Blüchel then split-off Dialyss as a new independent company and created a column for hemodialysate regeneration. We will miss Marty, but it is a comfort to know that at his last birthday, he witnessed a huge ovation for his persistent work on sorbents for PD and HD!

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