Historical Note
(Section Editor: J. S. Cameron)

Gordon Murray and the artificial kidney in Canada

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Introduction

Few people even amongst nephrologists are aware that Canadian surgeon Gordon Murray (1894–1976) built the first North American artificial kidney, independently of work by Willem Kolff in the Netherlands and Nils Alwall in Sweden at about the same time. Perhaps this is because Kolff is generally recognized as the ‘inventor’ of the artificial kidney in a clinically useful form, whereas Murray’s fame, publicly and professionally, came from his work in cardiovascular surgery. Unquestionably, Murray was a talented surgeon with a fertile, creative, and restless mind. During his 40-year medical career in Toronto, he investigated the clinical application of heparin with Dr Charles Best, modified and performed new vascular and cardiac surgical techniques, and finally experimented with cancer sera and spinal-cord regeneration therapies. These later controversial projects damaged his reputation as a researcher, but it would be a mistake to overlook this man’s contribution to renal therapy, in particular his artificial kidney machines.

Murray came from western Ontario and enrolled in medicine at the University of Toronto in 1914, but the next year went overseas to fight in the trenches of Europe during the Great War. He completed his degree in 1921 and then travelled to England to train as a surgeon. Surgery demanded dexterity, precision, and skill, and it appealed to Murray’s bold nature and interventionist approach to treating patients. In London, Murray secured the position of Resident Medical Officer at the West End Hospital and during the next 3 years shifted into a variety of postings at several of the city’s notable hospitals. He worked at St John’s Clinic in Leicester Square in the Department of Dermatology, as House Surgeon at the Hampstead General Hospital, as House Surgeon and Clinical Assistant at All Saints’ Hospital, as Temporary Registrar at the London Hospital, as Demonstrator of Anatomy at St Mary’s Hospital and the University of London, and House Surgeon at the National Orthopedic Hospital and St Bartholomew’s Hospital. It was invaluable training for Murray, and he gained a breadth of experience treating various conditions and performing a wide range of operations. In 1926, he passed the Fellowship examination of the Royal College of Surgeons at the first attempt, and later that year returned to North America. After a brief sojourn as House Surgeon at the New York Hospital and the Hospital for Ruptured and Crippled Children in the United States, Murray began a 1-year surgical residency at the Toronto General Hospital. In 1928, he accepted a staff appointment in the Department of
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Surgery, set up a private practice in a nearby office, and remained in Toronto for the rest of his career [1]. Murray became interested in renal therapy during the 1940s after seeing several patients die of uraemia [2]. Frustrated by the profession’s ignorance of this disease, he began investigating the kidney with the prospect of mechanically replicating its functions and in the end he built two different artificial kidney machines. His first successful artificial kidney was a coil design built in 1945–46, with the assistance of Edmund Delorme, a young surgeon from the University of Edinburgh, and Newell Thomas, an undergraduate chemistry student at the University of Toronto. In 1952–53, a second-generation flat-plate model was designed and constructed by Murray and scientist Dr Walter Roschlau, originally from Heidelberg. Unfortunately, these artificial kidneys remained relatively crude prototypes, and were never refined or commercially produced for wider distribution.

Reasons for this failure relate to the circumstances in which Murray’s machines were constructed and utilized. For Murray, his artificial kidney—both his original and second-generation machines—was an unfulfilling success since his Toronto colleagues were reluctant to accept it as anything but a last-ditch therapy for comatose uraemic patients. Experimentation was encouraged in the laboratory, not on hospital wards, and the experimental nature of the artificial kidney persisted despite Murray’s efforts to demonstrate otherwise.

Murray’s first artificial kidney machine (1945–46)

As no one had yet designed and used an ‘artificial kidney’ when he began his experiments, Murray encountered several technical difficulties in the building of his first machine: discovering a suitable dialysing membrane, finding the proper dialysing solution or dialysate, and selecting a viable mechanism for circulating blood through the machine. The dialysing membrane that led the blood through the dialysate had to be a semi-permeable membrane to allow the molecules of harmful wastes to pass into the dialysate. After experimenting with various natural and synthetic products and following the work of William Thalhimer in New York [3], Murray found (like Kolff) that the best semi-permeable membrane was a type of Cellophane used for sausage casing in the form of long tubes. He experimented with the size and length of tubing before settling for the satisfactory size of 1/8 in (6.5 mm) diameter, varying in length from 35 to 150 feet (10–50 m). The tubing was coiled vertically around a wire-mesh cylinder and contained in a large bath jar or drum filled with the dialysate. Next, Murray sought a dialysate consistent with the normal substances of the blood. Finally, after a number of false starts, he settled on using Ringer’s solution. To circulate the blood through the machine, Murray decided to work exclusively within the venous system, taking blood from and returning it to a vein, using a novel atraumatic pump system (in contrast to arteriovenous circuiting chosen by other pioneering researchers, notably Kolff and Nils Alwall). A rubber tambour was inflated and deflated by the action of the piston-syringe, acting as the pump, attached to an electric motor. Intake and outlet valves controlled the blood flow. Tinkering away with relative simple materials at hand, Murray completed the building of his prototype machine [4] (Figure 2).

To test his artificial kidney, Murray first ran trials with uraemic animals, treating them for hours, even overnight, with relative success. The real test, however, came with Murray’s first clinical case in December 1946. A 26-year-old female patient lay in a uremic coma at the Toronto General Hospital as a result of an abortion attempt. Her doctors declared her case hopeless, and they called Murray. They were not terribly convinced that the artificial kidney would actually work, but were at a loss as to what else to do for the patient. They agreed to the experimental therapy because the alternative seemed to be certain death. Murray quickly arrived on the ward with his odd-looking machine. It was massive and cumbersome, and took three men to carry it to the bedside. Murray cut into the large femoral vein on the inside of the patient’s left thigh. A long, plastic catheter was inserted into it and connected to the dialyser coils. Then Murray cut into the femoral vein in the right thigh, pushing another catheter up into the vessel until it reached the inferior vena cava. Heparin solution (the other vital component for successful dialysis that Murray had himself helped to develop) was then injected into the patient’s bloodstream and into the machine. When the machine was switched on and its pump started moving, dark red venous blood was carried into the Cellophane
tubing and slowly flowed through the narrow coils in a 15-quart (14 litre) glass jar containing the dialysate, perched on the bedside table. The blood then passed through an air trap that removed any bubbles, and returned to the patient’s circulatory system. A thermostat control had been built into the machine to maintain the patient’s blood temperature outside the body [5].

It was a case of trial and error. Murray was experimenting with the number and length of treatments. The first treatment was discontinued after only 1 h when the patient developed a severe chill. Nevertheless, the patient had been revived from the coma. A second treatment was administered 2 days later when the patient slipped back into unconsciousness. After 8 h of treatment from the artificial kidney, the patient was again revived. A third treatment was necessary 3 days later when the patient relapsed. After 6 h of treatment, she was revived once more. This final session on the artificial kidney constituted the breakthrough. The following day, the patient’s kidneys began to function and residual uraemic toxins and excess liquid were soon washed out of her body. She made a steady recovery and was released from hospital 33 days after being admitted [6].

Despite its initial success, the artificial kidney machine was used in few cases thereafter—over the next several years up to 1949 no more than 11 patients received treatment. There were several reasons for this. Toronto Hospital medical men viewed the artificial kidney machine—rightly—as still experimental, offering only short-term, intermittent treatment to patients suffering from acute renal failure, and they were reluctant to use the machine as anything but a last-ditch therapy. Also there were no full-time laboratory services or technicians available to support dialysis treatments. The treatments therefore monopolized Murray’s and his assistants’ time, and for Murray, the artificial kidney was only a secondary line of investigation. He was a surgeon, and he devoted more and more of his time to the new, exciting field of cardiac surgery. Therefore poor promotion and acceptance of this first artificial kidney was due to a lack of support and interest in renal therapy at the Toronto Hospital, and perhaps Murray’s own restless nature. The artificial kidney was eventually moved to the hospital basement and seldom used after 1949.

**Murray’s second artificial kidney machine (1952–53)**

By the early 1950s, Murray was director of a privately funded laboratory with full-time research staff. Also by this time, a greater number of commercial and home-made artificial kidney machines were being circulated and used in North American and European hospitals. But these machines remained large and clumsy, and reported clinical series continued to deliver mixed results. The initial success of Murray’s first artificial kidney and his new research setting stimulated him to build a second, improved machine. In 1952, Murray initiated work on a second-generation artificial kidney with Dr Walter Roschlau. They intended to offer a more compact and efficient machine to the medical marketplace.

The Murray–Roschlau artificial kidney was an improved model from the original machine with substantial differences (Figure 3). The significant feature of this second-generation machine was its parallel plate design instead of the original vertical coil dialyser, making it much more compact. Roschlau (who appears to have been unaware of similar designs by Skeggs and Leonards [7] and McNeil [8]) had designed a plate-type dialyser with an enlarged surface area and reduced blood-volume requirements. He experimented with flow patterns, volume requirements, dialysing membrane surfaces, and the production of multiples of blood and dialysate chambers, cannibalizing the original artificial kidney machine for its electric motor, mounting boards, glassware, etc. The fluid storage container was designed to be tucked out of sight under the table, showing ‘less’ machine at the bedside. Its operation was simplified and its efficiency improved; it was easier to handle, clean, and less ‘frightening’.

![Fig. 3. The Murray–Roschlau 'second-generation' flat-plate dialyser. This was an advanced flat-plate parallel-flow dialyser with 30 layers of dialysis units each with two membranes and two dialysis compartments, forming a dialyser of 0.6 m² surface area and with a priming volume of only 225 ml. (National Archives of Canada, MG 30 B110 D.W.G. Murray Papers, Volume 41, File 16, Negative No. C143613; supplied by Dr W. Roschlau.).](image-url)
In 1954, 27 experiments, involving 10 dogs, were conducted to test the performance and reliability of their new machine. Shortly thereafter, this second-generation artificial kidney was used in two clinical cases. Roschlau assembled, sterilized, and transported the machine to the Toronto General Hospital and administered the dialysis treatment. The experimental therapy once again brought successful results. No flaws in the design or function of the machine were noted; however these clinical cases were never reported [9].

Before Murray and Roschlau announced the outcome of their work, one of the engineers, Erwin Halstrup, returned to Germany with the designs of the improved artificial kidney, passing it off as his invention. Halstrup, who had recently arrived in Canada, had approached Roschlau, a fellow German immigrant, for a job. At the time, Murray and Roschlau were struggling with the increasing technological complexities of their new machine. Halstrup was hired, and he helped them develop a new pump and change the prototype from plexiglass to metal. Halstrup left Canada soon after the work was done. Shortly thereafter Murray and Roschlau received letters from two German medical schools asking them for their experience with the ‘Halstrup–Baumann artificial kidney’. Roschlau was devastated and Murray outraged! With the help of German businessman Baumann, Halstrup was peddling the machine as his invention, selling the artificial kidney to medical clinics and hospitals in Germany. After that, Murray totally lost interest in the artificial kidney. He had lost control over his own machine, for he had not sought patent protection, and he walked away from any further involvement with it. Both this second-generation artificial kidney and the remaining remnants of the original machine were locked away in Murray’s laboratory, resurfacing only after his death [10].

Murray’s contribution to renal therapy

Murray earned both public and professional accolades for his work in renal therapy. After Murray’s successful clinical case of 1946, newspapers heralded his artificial kidney machine as yet another life-saving treatment by the successful cardiac surgeon. Murray described his mechanical invention and his success at treating acute kidney failure before his medical colleagues at the meeting of the Central Surgical Association in Chicago in February 1947. He spoke on the artificial kidney in London, England as the Alexander Simpson-Smith Lecturer at the Great Ormond Street Children’s Hospital on July 11, 1949—the same week he presented the Moynihan Lecture on ‘Surgery of Congenital Heart Disease’ before the Royal College of Surgeons of London. Doctors, hospitals, and manufacturing companies wrote to Murray, asking him for specifications of his artificial kidney. Physicians and scientists also traveled to Toronto to see Murray’s artificial kidney, including Kolff himself.

This is particularly interesting because Kolff had built the first practical artificial kidney in 1943, more than 2 years before Murray, in occupied Holland. Murray stated that he had not received any information about Kolff’s work until after the war, maintaining that his work in Toronto had been conducted simultaneously and independently. There were design differences in the two machines that suggest Murray was indeed unaware of Kolff’s unit [11]. Most notably, Murray’s cellophane coil was static, positioned vertically in a glass jar, while Kolff’s artificial kidney had its cellophane membrane or tubing wrapped around a rotating horizontal drum, bathed in an open 70–100 litre tank of dialysate. Kolff’s model became the standard which other medical men used to build their machines, and manufacturers based their commercial models. Kolff’s artificial kidney and work in renal therapy were better presented professionally and commercially than were Murray’s [12]. Several Kolff machines had been distributed around Europe and North America during the 1940s. Kolff freely offered sketches, designs, and information for others to build their own machines, as had Murray, but with greater enthusiasm and acceptance. Most notably surgeons Carl Walter, George Thorn, J. P. Merrill, and H. Swan at Peter Bent Brigham Hospital in Boston recognized the potential of the apparatus and improved upon Kolff’s machine during this period. (The Kolff–Brigham kidney was manufactured in quantity and became the standard unit in the United States throughout the 1950s.) Conversely, few people outside Toronto seemed even to be aware of Murray’s machine. The only exceptions were Conrad Lam and Joseph Ponka who experimented with the original Murray artificial kidney machine in Detroit [13], and Brazilian doctor, Tito Ribeiro de Almeida, in Sao Paulo [14,15]. Nevertheless, Murray’s work contributed to the growing interest of researchers and abilities of physicians to treat acute renal disorders, albeit with substantially less impact than Kolff’s machine.

Conclusion

Murray built and used successfully the first artificial kidney machine in North America. Few medical men outside Toronto were aware of its existence, and Murray himself regarded it as only a secondary line of investigation, losing all interest in the artificial kidney when he lost control over the designs of his machine. Moreover, his machine benefited very few patients. For Murray, it had been a bitter experience, frustrated by insufficient research funds and by the reluctance, even disinterest, of his Toronto colleagues in new procedures and technology. What he did not understand was that many doctors were concerned with protecting their patients from ill-conceived experiments, and during the 1940s and early 1950s, most Toronto medical men viewed the artificial kidney as experimental. They were wary of machines, and took a conservative stance towards the new technology being brought into the hospital, unlike many of their
American counterparts. Unfortunately for Murray, patients and even the Toronto General Hospital, his artificial kidney did not bring about a commitment or leading role by Toronto medical men to establish a dialysis treatment programme. It was not until 1958 that a dialysis service was organized by members of the Department of Urology, Medicine and the Division of Laboratories at the Toronto General Hospital, and the first patient was treated in January 1959 [16]. By this time, Murray had left the hospital and had turned his attention to new research projects in unrelated medical fields. Locked in the laboratory, Murray's artificial kidney machines would have to wait for medical historians to recall their contribution to renal therapy in Canada.

Acknowledgements. This article is part of a larger study of the life of Gordon Murray. See Shelley McKellar, The Career of Gordon Murray: Patterns of Change in Mid-Twentieth Century Medicine in Canada [Ph.D. Thesis, University of Toronto, 1999] and forthcoming biography Gordon Murray: Canada's Lone Wolf Surgeon. I thank Dr J. S. Cameron for sharing his work on the history of haemodialysis and for information on the use of Murray artificial kidneys outside of Canada. I also gratefully acknowledge the support of AMS/Hannah Institute for the History of Medicine, Toronto, Canada.

References


