

## Reflections on rehabilitation engineering history: Are there lessons to be learned?

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### INTRODUCTION

This author's perspective is possibly unique among the other contributors to this volume because he witnessed the early evolution of rehabilitation engineering in Canada and the United States, first working as a young clinical rehabilitation engineer and later as an academic researcher in both countries. This contribution focuses largely on the Canadian contribution, with emphasis on the political backdrop that created the impetus and funding for program development and the productive partnerships that lead to significant early outcomes. Of course, as with the evolution of any field, key people with vision stepped forward to provide the leadership. These individuals should not be forgotten. Their commitment and contribution to the formation of the field was paramount—and possibly not without equal to this day. Recognition of the early pioneers is not intended to be all-inclusive; it is limited by the personal experiences of the author and largely from the Canadian perspective.

In order to provide the reader with a time frame and career activities that largely influenced the following perspectives, a brief review of this author's education and work experiences follows.

- Education: Mechanical Engineering, 1965, University of Manitoba, PhD, University of Strathclyde, 1989.
- 1963–68: Research Engineer, Prosthetic and Orthotic Research and Development Unit (PORDU), Manitoba Rehabilitation Center, Winnipeg, Manitoba,

Canada. (Development of lower-limb modular prosthesis and mobility devices for thalidomide children.)

- 1969: Research Associate, Biomedical Research Unit, University of New Brunswick, Fredericton, New Brunswick. (Upper-limb myoelectric prosthetics.)
- 1970–74: Director, Rehabilitation Engineering Program, Shriners Hospital, Winnipeg Unit, Canada. (Development of seating and mobility devices for children and development and provision of prosthetics and orthotics and RE client services.)
- 1974–90: Director, Rehabilitation Engineering Center, University of Tennessee, Memphis. (Development of seating, mobility, prosthetic and orthotic technologies for children, provision of prosthetics and orthotics and RE services.)
- 1990–92: Founding President, ARCOR, Winnipeg, Canada. (Nonprofit, government-funded organization for the purpose of developing and marketing technology for the elderly.)
- 1992–96: Director, Center for Assistive Technology, University of Pittsburgh. (Development and management of assistive technology service center.)
- 1992–01: Associate Professor, Codirector, RERC on Wheeled Mobility, University of Pittsburgh. (Academic research, teaching and administration of RERC on wheeled mobility.)

Reflection on the past can also provide knowledge and insights that can guide us in the present. Of particular interest to this author are the political and social environments,

partnerships (people, professional specialties, agencies, and programs) that fostered the exceptional enthusiasm and productivity of the early days of what we now term rehabilitation engineering.

### **THE PROSTHETICS AND ORTHOTICS HEYDAY: 1945–60**

In the United States and Canada, returning veterans with amputations created the political and social will to *do something* to compensate veterans for their tremendous personal sacrifice. Artificial limb technology in Canada was still rudimentary and in need of drastic improvement. Colin McLaurin, an Air Force veteran and aeronautical engineer, initiated a research program in 1949 in the basement of Sunnybrook Veteran's Hospital, Toronto. He was joined by James Foort, a chemical engineer, and Fred Hampton, a highly talented prosthetist. They worked in a clinical environment in which they were exposed to the daily routine of amputation surgery and rehabilitation management. This small team produced the Canadian Symes and Canadian Hip Disarticulation prostheses, as well as the early application of the plastic lamination process to prostheses fabrication. Both prostheses were rather radical departures from the then conventional practice and found widespread acceptance.

Canadian governments are not noted for sustaining productive programs. The work of this pioneer Sunnybrook team was recognized by their colleagues in the United States, and they were enticed south. In 1957 McLaurin and Hampton joined Dr. Clinton Compere, a renowned orthopedic surgeon, at Northwestern University. The Prosthetics Research Program was initiated at Northwestern and located in the Rehabilitation Institute of Chicago. Under the leadership of Compere and McLaurin, significant developments in both upper and lower extremity prosthetics soon resulted. Many of the principles of manual upper extremity prosthetic control were established at this time, in addition to new concepts in prosthetic knee design and swing control for the transfemoral amputee. This research program also functioned as part of a clinical amputation management program. In 1966, Dudley Childress, a young electrical engineer, was attracted to the program, which he directs to this day. (Dudley's reflections on this era can be found in his lead-off piece for this volume.)

Jim Foort joined the program at the University of California, Berkeley. The team was lead by Dr. Verne

Inman, a world leader in orthopedic surgery research and amputation management. Charles Radcliffe, professor of Mechanical Engineering, led the engineering team. Foort lead the development of the Berkeley brim-fitting system used for many years for the "quad" suction socket fitting of transfemoral amputees—a radical departure from traditional manual socket fabrication practices. The team also developed many of the biomechanical principles and early fabrication techniques for the patellar tendon bearing (PTB) prosthesis for transtibial amputees. Radcliffe and Eberhart did the first engineering analysis of the biomechanics of prosthetic alignment and socket force transfer throughout the amputee gait cycle. These fundamental principles are still taught to prosthetists and therapists to this day.

The polio epidemic in the early 1950s created a second wave of political and social will to do something for the afflicted. Engineers and orthotists were integrated into clinical teams in notable locations such as Rancho Los Amigos Hospital in Downey, CA and Baylor University in Houston. These programs again produced technical innovations for persons with reduced limb and upper body function due to neuromuscular disease and resulting dysfunction. At Rancho, Dr. Vern Nickel, a dynamic orthopedic surgeon, lead the team of James Allen, Dr. Vert Mooney, and treatment therapists that produced the early powered upper extremity orthosis, termed the "Rancho Golden Arm," as well as many other simpler orthotic innovations. These early trials also demonstrated the limits of people's gadget tolerance to encumbering technology. This was important knowledge; widespread acceptance would require more elegant solutions such as that promised by functional electrical stimulation. These and other early engineering achievements at Rancho laid the foundation for the initiation of the first Rehabilitation Engineering Center (REC) on functional electrical stimulation at Rancho in 1971, directed by James Reswick.

Although polio treatment programs evolved throughout Canada, there was little focus on innovation toward technology-based solutions.

### **THE U.S. POLITICAL WILL**

In 1945 the Surgeon General of the Army asked the National Academy of Sciences (NAS) to initiate a research and development program with the mandate to improve prostheses by applying technology from other

fields. NAS established the Committee on Prosthetic Devices, a group of prominent surgeons, prosthetists and engineers, to direct what came to be known as the Artificial Limb Program. The committee's name was later changed to the Committee on Prosthetics Research and Development (CPRD). In 1948 Congress passed Public Law 729 authorizing appropriations of \$1 million annually to the Veterans Administration (VA) for a research and development (R&D) program in the field of prostheses, orthopedic appliances, and sensory aids. Additional funds were provided in 1954 with passage of the Vocational Rehabilitation Act (Public Law 565), which authorized the Department of Health, Education and Welfare (DHEW) to support research and training that would lead to improvements in rehabilitation practices. In later years, some of the latter funds were used to support projects of the Artificial Limb Program. (Note: Jim Reswick's contribution provides further details on this early period.)

These government actions resulted in a remarkable period of collaboration between the VA, DHEW and CPRD, as their respective leaders shared a comradeship and common vision that extended to all countries as sources of innovation and clinical expertise. They involved innovators from Canada and Europe with U.S. colleagues in conferences and seminars on topics such as amputation surgery and prosthetic socket design, upper and lower extremity orthotics, and in later years, on wheelchair technology, adapted vehicles for drivers with disabilities and devices for the sensory impaired. These forums also identified common research needs, fostered organized clinical evaluations, stimulated industry involvement, and disseminated results of these activities through training workshops, technical reports, and publications. Not only were the Canadian leaders funded to participate, but also young insecure engineers, such as myself and others, were encouraged and mentored. The enthusiasm and synergy that resulted from these multidisciplinary forums were truly outstanding.

### **THE CANADIAN CONTRIBUTIONS: 1960–75**

Two more international events furthered the development of rehabilitation engineering. Early in the 1960s, it was discovered that thalidomide, a sedative taken by pregnant women for nausea, was causing severe congenital limb deficiencies in children. Governments in Canada and Western Europe, where the problem was most acute,

established research centers to develop prostheses for these children. The second tragic event was the Vietnam War. As a result of this conflict, there was again a dramatic increase in the number of U.S. servicemen returning home with amputations and spinal cord injuries. Engineering research and development programs within the VA therefore began to focus increased attention on wheelchairs, orthoses, and environmental control systems in response to their needs.

The government response in Canada was initially to establish three research centers: in Winnipeg at the Manitoba Rehabilitation Hospital; in Toronto at the Ontario Crippled Children Center (OCCC); and in Montreal at Rehabilitation Institute of Montreal (RIM). Later a fourth unit was established at the University of New Brunswick under the direction of Robert Scott, an electrical engineer. The three clinically based programs were lead by prominent local physicians. Engineers were recruited to lead the R&D teams. James Foort was recruited to Winnipeg, Colin McLaurin to Toronto, and Andre Lippay in Montreal. They immediately recruited talented prosthetists, orthotists, and technicians to work with experienced clinical therapists assigned to the respective research and development teams. These three teams functioned as integral adjuncts of the clinical services within their respective centers. Technical staff routinely attended clinics and patient rounds, and assumed responsibility for selective patient problem solving. Semiannual meetings were held in which the results were shared among the four centers.

Since the thalidomide tragedy in North America was limited largely to Canada, the research teams looked to Russia, Germany, Sweden, and England for new technology and clinical partners. This opened the door to myoelectrically controlled upper limb prostheses that were being developed in these countries, namely Russia (Russian hand), England (Bottomley hand), and Sweden (Sven Hand). Germany was also an early leader in the prosthetic management of the severe child amputee (Muenster socket). Partnerships with several of these developments were aggressively pursued by the Canadian research teams, which provided the departure point for their own innovations in the years that followed. It was within this stimulating environment that this author cut his teeth as an engineering student in Winnipeg. His early design efforts were focused on specialized upper and lower extremity prostheses and powered mobility for thalidomide children.

It soon became evident that the technology solutions for thalidomide children had their limitations, due to both the range and extent of the disabilities of most of the children. However, these teams had created a model for productive technology development that they quickly applied to other areas of disability. The OCCC team developed many of the early seating concepts for cerebral palsied children, lower extremity orthotics for spina bifida children, (parapodium), manual and powered wheeled mobility, and prosthetic components for children. Many of these concepts were then produced commercially by Variety Village in Toronto. They also pioneered the plastic vacuum-forming technique now widely used in prosthetics, orthotics, and specialized seating services. They also demonstrated the value of rehabilitation technology services in the classroom. The OCCC, University of New Brunswick, and RIM pioneered in Canada the early application of myoelectrically controlled prosthesis for the below elbow, above elbow and shoulder disarticulation amputees of all ages.

The Winnipeg unit, after meeting the prosthetic and powered mobility needs of the few local thalidomide children, capitalized on Foort's earlier experience in socket and lower extremity prosthesis design. New modular endoskeletal prostheses, both BK and AK, featuring prefabricated sockets and standardized soft polyurethane covers with embedded adjustable aluminum pylons, were fitted to hundreds of elderly patients. The powered alignment concept for the self-aligning of prosthetic components and four knee mechanisms were also demonstrated by the author at that time.

In 1968 the author and his clinical team began a rehabilitation engineering development and service program at the Shriners' Hospital for Crippled Children in Winnipeg. This program provided prosthetic and orthotic services as well as new innovations in specialized seating and mobility for children with cerebral palsy and other congenital disabilities. Stand-up wheelchairs, early computer access, wheelchair-based communication aids, and specialized mobility devices were all applied clinically and improved over time. The author and his colleagues remained closely affiliated with the activities of CPRD and colleagues in the U.S. throughout this period.

## THE INCUBATION OF REHABILITATION ENGINEERING

As indicated, McLaurin, Foort, and their team members became active participants in the activities of CPRD.

They, with colleagues from Montreal and Fredericton, were active participants in the various seminars and clinical evaluations organized by CPRD. Hector Kay of CPRD organized the Association of Children's Prosthetics and Orthotics Clinics (ACPOC) that established minimum qualifications for the clinical team members to provide surgical and technology services for orthopedically disabled children. Again, CPRD provided the cohesion and forums for information exchange between European and North American researchers and clinicians. CPRD staff fostered team training, clinical evaluations, journal publications, and published a periodical called the *Inter Clinic Information Bulletin (ICIB)*.

Colin McLaurin became the Chairman of CPRD in 1969, a position he held until 1975. It was during his tenure that the CPRD convened the meetings involving leading clinicians and engineering researchers during which the concept of rehabilitation engineering was formalized, justified, documented, and politically promoted by Joseph Traub and Anthony Staros within the U.S. government. McLaurin, with his vast clinical and R&D experience in both countries, provided the clearest vision of rehabilitation engineering and did a masterful job of communicating it to others. He emphasized what could be accomplished by engineers working closely with their rehabilitation partners in clinical programs, supported by leading physicians, all focused on real rehabilitation problems.

The first two RECs were funded by DHEW in 1971 at Rancho Los Amigos Medical Center in Downey, CA, and Moss Rehabilitation Hospital in Philadelphia. Three more were added the following year at the Texas Institute for Rehabilitation and Research in Houston, Northwestern University (the Rehabilitation Institute of Chicago), and the Children's Hospital Center in Boston. The REC program was written into law by the Rehabilitation Act of 1973 (Public Law 93-112) that identified rehabilitation engineering as a priority of the R&D programs of the Rehabilitation Services Administration of DHEW. The priorities and requirements for RERC's that are published in the Federal Register today still reflect many of the fundamental concepts formulated in the early 70s.

The Veterans Administration likewise funded engineering centers at VA Medical Centers in Hines, IL, Palo Alto, CA, and Decatur, GA. Just as with those funded by DHEW, these centers were established to support teams of engineers and clinicians to address established technology needs of persons with physical disabilities.

These RE programs in the U.S. have been vastly expanded over the intervening years.

Unfortunately, the CPRD was disbanded by NAS in 1976. The CPRD had a longevity and operational focus that no longer met the criteria of a NAS-sponsored committee. Efforts were made to find another home, but this never materialized as its two main funding partners, DHEW and the VA, of were now focused on the development and support of rehabilitation engineering centers (RECs). The Canadian government terminated funding for the four research centers in the mid-1970s, and the innovative nature of those programs was quickly lost, as the technical leaders and their protégés moved to other programs, many to the US, as did this author in 1973.

Traub and Staros, in an effort to transfer the CRPD model to the new REC program at DHEW, supported a series of annual Interagency Conferences on Rehabilitation Engineering in the mid- to late 1970s. At the 1978 meeting, Staros, Traub, McLaurin, Reswick, and Hobson met to formulate a concept for a multidisciplinary society on rehabilitation engineering that would function independent from government. It was to provide the forum for information sharing and rehabilitation technology development and application that had been so effective within the CPRD model. In 1979, the concept of a new society, along with founding bylaws, was presented to a multidisciplinary forum of about 250 people. The concept was accepted, and the Rehabilitation Engineering Society of North America (RESNA) was born, with Jim Reswick as its founding President. Colin McLaurin was RESNA's second president, and the rest is recorded history [1].

## LESSONS LEARNED: 1945–75

Why was this period in our early history so productive? Are there lessons to be learned? In the mid-40s, there was clearly a coalescence of national need and emotions regarding the returning WWII veterans that translated into a political will and funded programs within leading federal agencies in both Canada and the US. In the U.S., the agencies and their program administrators worked in a true spirit of cooperation. They boldly reached out nationally and internationally for the best clinical and technical minds and brought them together into interdisciplinary settings with very focused agendas. The majority of the engineering and other technical personnel worked side by side with their clinical

colleagues in rehabilitation settings. The results of their collective efforts were widely disseminated in form of detailed technical reports, information bulletins, journal articles and sponsored training programs. Funding was provided to stimulate the availability of preproduction prototypes for use in structured multi-site clinical trials. This author has not witnessed this level of interagency and international collaboration in rehabilitation technology since the demise of CPRD.

This early impetus was again stimulated by the polio epidemic, thalidomide tragedy and the Vietnam War which maintained and then expanded research and development programs, especially in the U.S. Enlightened interagency leadership channeled these opportunities into international programs of collaboration and productive clinical partnerships. The disability movement of the early 70s with its demands for independence, integration and employment opportunities fostered the political environment for development of the rehabilitation engineering program and RESNA. Again, enlightened and dedicated leadership, interagency partnerships and a clearly articulated statement of need and potential benefits to the disabled population won the political battle for inclusion and funding of rehabilitation engineering within the Vocational Rehabilitation Act of 1973 and its subsequent enactments to this day.

In summary, the lessons for success from past appear to point to the primal necessity of a political will based on a recognized national need that will generate and sustain the funding to support clinically based R&D programs. Strong interagency collaboration, led by enlightened administrators capable of seeing and supporting the larger perspective, including international cooperation, seemed essential. Creative engineering program leaders who fostered multidisciplinary teams that were keen to work within clinical environments led to the most productive outcomes. Highly respected physicians, mainly orthopedic surgeons and physiatrists, who were sufficiently committed to assume ultimate responsibility for experimental fittings, and run interference with the hospital administrations, allowed the engineering leaders and their teams to focus on the technology issues. Finally, a funded independent mechanism, like CPRD, that fostered multisite collaboration, structured clinical evaluations, including industry involvement, and educational workshops was an important ingredient to the successful transfer of innovation to the market place and ultimately their wide spread clinical application.

It is recognized that aspects of the CPRD model, that were effectively developed and implemented throughout the 50 and 60s and documented and articulated in the early 70s, would not transfer directly to today's rehabilitation environment. For example, expansion of the programs within the two lead agencies to encompass community based priorities, such as, transportation, tele-rehabilitation, telecommunications and work site performance, means that new and different partnerships are required for success. Also, the clinical and medical practices within rehabilitation services have changed drastically in recent years as a result of reduced resources and the dominance of HMOs. We now have ADA and other successes of the independence movement. We see rehabilitation engineering R&D programs devoid of experienced engineering leadership, and in some cases, very limited engineering involvement at all. We also see programs with a rehabilitation or community-based focus housed within academic environments that have very limited direct involvement with clinical partners, industry or the disabled population they are intended to serve.

However, these trends are not all inevitable, some can be reversed and new directions can be taken.

This somewhat nostalgic reflection on our early past also reveals that the vision for rehabilitation engineering has become clouded. Is it again time to bring the rehabilitation engineering leaders and their new partners together to reformulate, document and rearticulate the new vision for the future? If yes, our history also suggests that any reformulation of the blueprint for the future should be well grounded in the social and political realities of today, and if possible, tomorrow. To be successful, all key partners must be at the table, and the responsible inter-agency leadership must share and support the vision over the long term. Given the present commitment of President Bush to expansion of rehabilitation engineering, the political will may never be stronger.

#### **REFERENCE**

1. Hobson, DA. RESNA: Yesterday, today and tomorrow. 1996 Assist Technol;8(2).