DEVELOPMENT OF RADIATION THERAPY UNITS 1951 TO 1985
(As seen by J.C.F.MacDonald)

The workhorse of radiotherapy prior to 1951 was the 200 - 250 kVp x-ray therapy unit. This was normally used at a source-surface distance (SSD) of 50 cm, because the output was low, and larger distances would result in low skin input doserates, and long treatment times. (S*ome of the larger radiotherapy centres in the USA had experimental 600- 1000 kVp units)* When I joined the Radiotherapy Department at TGH in 1951, the armamentarium consisted of a typical 100 kVp superficial unit, two 200 kVp Picker orthovoltage units and a custom – built (by Picker) 400 kVp unit. This latter was unique, in that a single generator in a loft drove two 400 kVp tubes, each in its own lead-lined drum. From each drum two ports, one vertical and one horizontal, emerged, to which field-defining applicators were fitted to treat at an FSD of 100 cm.. Both tubes were energized at all times, and a shutter at each port controlled the treatment Because each port was at about 45 degrees from the central axis of the x-ray beam, flattening filters were built in to the system. Four patients could be treated at a time, two by a vertical and two with a horizontal beam. Since the doserate at the skin was about 10 R/minute, the treatment times were about a half hour.

In Cliff Ash's private clinic in the Medical Arts Building there was another 400 kVp unit built by Keleket. In this unit the tube was enclosed in a large oil-filled bathtub-shaped enclosure. Between the tube window and the exit port the oil was displaced by an glyptol-coated block of balsa wood.. I was expected to calibrate this unit from time to time. On one occasion, I found the output to be nearly zero when the unit was operating at therapeutic conditions. We found that, sometime since the last calibration, the glyptol coating had broken down and the balsa wood had become permeated with oil. Just how many private patients had been treated (?) in this way will be forever a mystery!

The drawbacks of these kilovoltage units were well- recognized, including low doserates, rapid fall-off of relative dose within the tissue, large scatter penumbra, and differential absorption in different tissues. Severe skin reactions and bone necrosis were not uncommon sequelae of treatment. But these units were all that was available: their use did not produce a great deal of optimism in the outcome of radiation therapy, or encourage the detailed treatment planning and accurate dosimetry of today.

The other beam therapy unit in the Department was a teleradium unit, as designed by Rolf Sievert in Stockholm. Gordon Richards, the pioneer radiologist, had somehow arranged to have this installed in the 1940's in a treatment room whose walls incorporated 2 cm of lead sheathing to a height of 2 meters In use, the unit head contained 4 curies of radium, and treated at head and neck cancers at a source-to-skin distance of 6 cm. Because of the resulting low doserate, treatments lasted up to an hour.

When I arrived at TGH, this unit had fallen into disuse, because the source had to be transferred from the storage safe to the treatment head by hand with a pair of foot-long tongs! Even in those days, this was considered dangerous, but only after the responsible technician developed an abnormal blood picture was it taken out of service! So the instrument maker, Jim Webb, built a remotely-controlled pneumatic transfer device {that I copied from one built in the UK), using an old Electrolux vacuum cleaner as the drive mechanism and a length of flexible 2 inch diameter auto exhaust tubing to transfer the radium source. He and I spent the whole of one night removing the forty 100 milligram radium tubes from the Sievert container and loading them into our transfer bobbin. This device worked pretty well, but occasionally I'd get a call to say that the bobbin was stuck in the transfer tube. The remedy was for me to go into the room and hit the tube with a broom handle, which always dislodged the bobbin.

This unit was used routinely in the treatment of head and neck cases. Eventually, we replaced the radium source with a 10 curie source of Co-60, which was used at TGH until 1957 when the PMH opened. I arranged for the sale of the 4 grams of radium to AECL at a price of $12.50/ milligram, and made an unearned $500 when they forgot the decay and paid for the activity of the radium when it was bought 20 years previously!. (At that time, large activities of radium were used in radium-beryllium sources for well-hole logging).

In those years, the other treatment modality depended upon a large stock of radium tubes and needles for intracavitary and interstitial therapy.. The Department at TGH had more than a gram of radium in this form. It was prepared for insertion by 'radium nurses' working behind a 5 cm lead shield, carried to the OR in lead pots, and inserted by the radiotherapist with no shielding whatever! I had to check each piece annually for radon leakage, which was found occasionally. We also used radon seeds (from a radon plant operated by the Ontario Government) and later gold-198 grains and gold-198 colloid.

I had graduated in 1941 from UBC, spent 5 years as an army artillery officer in Canada and Europe, took an M.Sc. at UBC in 1948, and a Ph.D. in molecular physics from U of T. In June 1951, I was approached to take a post on the staff of the Ontario Cancer Foundation as physicist in the Radiotherapy Department at TGH. I took the offer after explaining that I knew nothing about medical physics (very few people did, as I found out later!). I think that they took me on because, having been in battle, I didn't faint at the sight of some of the patients that presented to the Department. In the days before state-supported health care, many cancer sufferers delayed asking for medical assistance until their disease was far gone I spent a month or so reading the journals and becoming acquainted with the Victoreen dosemeter (the only measuring instrument available at the time), and observing what went on in the Department. Being the only active physicist in Ontario, I was also responsible for therapy machine calibrations, using my trusty Victoreen, in Kingston, London, Hamilton and Windsor as well.

At the time of recruitment by the OCTRF, I was told that I would have to become involved with the "cobalt bomb". There was absolutely nothing in the accessible literature that made any reference to such a device. After hiding my ignorance for a time, I eventually found out that it was a treatment unit based on cobalt-60 being produced at Chalk River, and that there were two Canadian centres, Saskatoon and Ottawa, involved in its development.

The advent of the cobalt unit ushered in a new era in the treatment of cancer by radiation therapy. Many of the disadvantages of orthovoltage therapy were left behind, and the medical physicist became an integral part of the team.

The Saskatoon unit had been designed by a group led by Harold Johns. The beam on/off mechanism was a rotating wheel on the periphery of which was mounted the cobalt source . My experience was with the unit developed in Ottawa by a crown corporation, Eldorado Mining and Refining Ltd. It was to be installed in the London Clinic of the Ontario Cancer Foundation after undergoing calibration and preparation for clinical use at NRC. Unfortunately, Jack Brown, a physicist who had preceded me in Toronto, and who was then the physicist in London, had come down with tuberculosis and was in the London sanitarium for an extended stay. So I was expected to do the clinical physics involved with the London cobalt unit, while holding down the TGH job as well.

This Eldorado unit incorporated a mercury shutter to turn the beam on and off from outside the treatment room and a set of continuously- variable lead diaphragms to adjust the size and shape of the treatment beam . Because of the low source strength, the unit was used at a source-skin distance of 80 cm, with a diaphragm-skin distance of 22 cm. The skin doserate with this first source was about 30 R/minute at 80 cm SSD.

I spent the next three months traveling from Toronto to London by train on Sunday night and returning on Friday night to take up my duties at TGH on Saturday. During the week I made measurements on the Eldorado unit, and used the results in planning patient treatment. Fortunately, Dr Frank Batley (a radiotherapist who had been recruited from Manchester) and Joyce Lawson (a trained radiographer from Glasgow) were there to teach me the ropes, and to bring British expertise to the operation.

(It is worth remarking that, at that time, Canadian radiotherapy was extremely crude by the standards obtaining in England and Sweden, and so radiotherapists and physicists had much to learn from the British and Swedes. Generally, US radiotherapy was no better than Canadian. *The cobalt unit was the catalyst that brought North American radiotherapy into the modern world .)*

Planning for radical treatment was, by modern standards, extremely crude. While the object was the same as it is today, we had no isocentric units, CT scanning, lasers and computers to make the process more rapid and accurate, and to permit calculated, rather than guessed, corrections for inhomogeneity and obliquity.

Because of the limited resources available in the fall of 1951, the treatment of only a relatively few patients could be planned in detail. These were the cases in which a cure was considered possible. At that time, in most of the patients that presented, the disease could only be palliated. In the first year of cobalt therapy in London, treatments were proceeding for up to 16 hours a day, six days a week, with a staff of one radiation oncologist, one part-time physicist and three technologists, only one of whom could be considered to be fully-trained.

Ivan Smith, the Director of the London Clinic was trained in pathology, surgery and radiotherapy, but above all, he was a salesman! He was a personal friend of Roy Errington of Eldorado, who was the spark-plug in the development of the commercial cobalt unit. Between them they set out to spread the word on cobalt-60. Ivan was interviewed extensively by the media: in particular, the popular magazine Coronet (now defunct) publicized it over all of North America. Desperate cancer sufferers and their physicians were calling from all over the US and Canada, and literally pounding down the doors.

One well-known person with cancer was Evita Peron, the powerful wife of Juan Peron, the dictator of Argentina. Upon hearing of this new development in cancer therapy, the Argentine ambassador to Canada was told to acquire one immediately and have it shipped the Argentina to cure the poor of that country! Of course, it would be another year or so before any new sources would be available from Chalk River, even though Eldorado dearly wanted to sell a unit to Argentina.

So, when Eldorado threw a big publicity event with cabinet ministers, etc. in London, the ambassador was invited. The next day, Ivan being out of town, Frank Batley and I were swamped with calls from newspapers all over the world, asking when Evita was to arrive. To this day, many people still believe that she was treated in London. In fact, on a cruise around South America in 1998, I had to correct one of the invited speakers on this point.

By December 1951, my duties in London were finished, and so I visited Saskatoon to see the other cobalt unit, and to be impressed with Harold Johns' group, and the work they were doing with the betatron. there. I then spent 1952 in the UK, first at Manchester and then at the Royal Cancer Hospital in London, with a side trip to Rolf Sievert's lab in Stockholm.

Professor Val Mayneord, who had studied cobalt-60 in Chalk River and proposed its use in teletherapy, was then at the Royal Cancer Hospital. When I arrived, he pumped me about source handling and transfers, because he had gone on record as saying that kilocurie cobalt sources would be too dangerous to handle!

A final anecdote about the Eldorado unit. When we got one in Toronto in 1954, I was concerned about mercury vapour emissions from the shutter system. The local experts made measurements, and considered that the level was negligible and so posed no hazard. Many years later, the acceptable levels having been refined, the mercury vapour emission from this unit was considered to be so hazardous that the units were taken out of use!

In 1957 I moved to London permanently, at the time of the installation of an isocentric Theratron Junior cobalt unit. This was the latest unit produced by Eldorado (by then named AECL(Commercial Products)). Although the source-to-isocentre distance was only 55 cm, it allowed us to initiate isocentric treatment planning for the head and neck patients treated with it. We developed an optical backpointer and an optical skin-isocentre measuring device for this unit – the first of their kind! We also produced an atlas of precalculated isodose distributions, using Hollerith cards in an IBM 650 computer. This atlas was used widely before individualized treatment planning became possible with the advent of PC's.

We also found that we could extend the useful life of a cobalt source by removing it from the 80 cm SSD Eldorado when the output became too low, and installing it in the 55 cm unit for an additional few years.

Later, the Eldorado was replaced with an isocentric Theratron 80. I developed an automatic system for reading out and printing the significant treatment parameters on this unit – a forerunner of the systems used routinely today.

When Sandy Watson came from Saskatoon to London as Director, he insisted that a betatron be acquired. The choice was the Brown Boveri Asklepitron 35, which introduced us to all the benefits of 33 MV photons and 10 to 35 MeV electrons. This was an improvement on the Allis Chalmers betatron in Saskatoon, in that it was designed specifically for radiation treatment, both fixed and isocentric. It also introduced us to the problems of dealing with the European concept of service-from-a-distance. When a donut failed, treatments could be suspended for as long as six weeks!

The London cooperation with AECL(CP) continued with the installation of the first Therac 6 (a Canadian version of the CGR Neptune) in 1975. This was our first experience with a computer-controlled linac.

About this time, the development, for research purposes, of a racetrack microtron by Heinrich Froelich in the Physics Department of UWO caught my attention. With financial support from AECL, Bill McGowan (the head of the physics department) assembled a team to develop a therapeutic version of this accelerator. By 1976, this project had produced a successful continuously-variable energy unit capable of electron energies from 1.5 to 18 MeV, with a beam intensity suitable for therapeutic applications. Two 180 degree bending magnets separated by a three cavity linac section resulted in a very compact accelerator, which was very attractive from a commercial viewpoint.

Unfortunately, AECL(CP) had also been supporting another project at Chalk River, which resulted in a 25 MV linac in which the electrons were first accelerated, turned around with a 180 degree magnet, and received additional acceleration on the return path. While an independent consultant group favoured the microtron, the AECL(CP) tie-in with Chalk River was too strong, the Therac-25 was born, and the commercial racetrack microtron was stillborn! The Swedes picked up on the idea, and now market one.

Within a few years, we replaced the Brown Boveri betatron with one of these Therac 25 units which, after the usual teething problems, became the workhorse of the centre. Unfortunately, a flaw in the operating software produced lethal malfunctions in some of these units, and resulted in AECL(CP) getting out of the therapeutic accelerator business entirely.

So, since practically my entire career was tied up in a usually-fruitful cooperation with this company, it is probably just as well that I retired when I did.

I think that I was lucky to have been part of the medical physics field during those years, because these were the years in which the physicist became a necessary part of the practice of radiation oncology. This synergy of science with medicine has now extended to diagnostic applications of radiation, as well as to ultrasound and MRI. Many of the physicists who entered through the doors of the radiation oncology department became involved in such fields as radiobiology, and still continue to make major contributions to many aspects of medical research and treatment.

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