New Treatment, New Hope, New Design

How does one redesign an 18,000 pound, 12 MeV electron linear accelerator that typically requires at least 100 tons of shielding for radiation protection so that it is mobile and can be used in a standard operating room without having to add any radiation shielding? The following article illustrates how one company approached this complicated challenge.

By Donald A. Goer, Ph.D.
Mobetron, from IntraOp Medical, is a mobile electron linear accelerator designed to deliver intraoperative electron radiation therapy (IOERT) during surgery for cancer in a standard operating room (OR). IOERT is the application of electron beam radiation directly to the tumor or tumor bed during surgery. In IOERT, most of the tumor is removed through conventional surgical techniques. Radiation is then directly applied to the area immediately surrounding the tumor, while still exposed during surgery, with the surrounding normal tissue retracted out of the radiation beam. This direct application of radiation to the tumor site increases the effective dose to the tumor.

The Mobetron is a mobile electron linear accelerator designed to deliver intraoperative electron radiation therapy during surgery for cancer.

IOERT has already demonstrated improved local control and, in many cases, increased survival for a number of disease sites. It can be safely used to escalate the dose for advanced disease because normal tissues can be displaced from the path of the radiation beam. IOERT can also be used to replace a portion of the adjuvant external beam radiotherapy (EBRT) by substituting a single dose at the time of surgery. When used as a ‘‘boost dose,’’ IOERT replaces two to three weeks

of conventional fractionated radiotherapy treatments, with the added benefit of avoiding radiation to normal tissues that would otherwise surround the treatment area if EBRT alone were used. Finally, because IOERT is delivered at the time of surgery, when any microscopic residual tumor cells are most vulnerable, any subsequent adjuvant therapy will benefit from the fact that even a modest IOERT dose is likely to result in one or two log-cell kills.

Combating Old Challenges

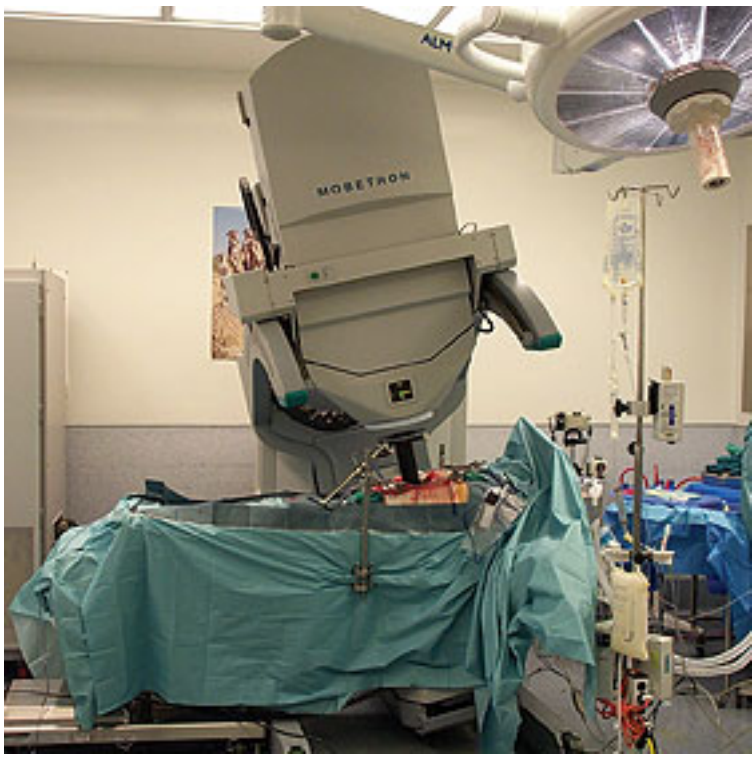
The widespread adoption as a routine adjuvant therapy has been limited by the difficulty of delivering IOERT using conventional electron accelerator technology. Patients either had to be transported from the OR to the radiation department in the middle of a surgical procedure to receive their IOERT, or costly shielded bunkers in the operating theater had to be constructed to house a conventional linear accelerator. The complex logistics of patient transportation and the cost of constructing a shielded bunker in the operating theatre have limited the availability of IOERT. New technologies incorporated into Mobetron allow the medical device to be used in almost any unmodified hospital operating room, thereby facilitating the delivery of IOERT. And, because it is mobile, Mobetron can be used in more than one OR, increasing the flexibility of its utilization in the surgical department.

So, just how does one make an 18,000 pound, 12 MeV electron linear accelerator mobile and eliminate the need for radiation protection? The answer: reduce the weight and eliminate the sources of stray radiation.

In order to decrease the weight, the size of the accelerator needs to be reduced. Conventional electron linear accelerators are S-band linacs designed to operate at a frequency of 3,000 Megahertz. Mobetron uses X-band technology that operates at 9,000 Megahertz. Because the frequency of operation is three times higher, the wavelength of the accelerator structure is three times smaller. Not only is the accelerator structure one-third smaller in diameter, but all the RF components necessary for an electron linear accelerator&#151the magnetron, the wave-guide sections, and the circulator&#151are also one-third smaller in size. The miniaturization of the accelerator structure and its associated RF components allows for a very compact system design. Reducing the size of the accelerator components leads to significant weight reduction in the overall system.

In addition, the compact x-band accelerator structure, because it has a small diameter, can be encased in a lead/steel strongback, with sufficient lead surrounding the accelerator structure to dramatically reduce the accelerator leakage radiation. Thus, Mobetron “leakage” radiation is two to three orders of magnitude lower than the leakage radiation from a conventional S-band accelerator.

The other major sources of stray radiation from conventional electron linear accelerators are the bending magnet that is used for energy selection and control, and the variable collimators that are used to both define the field size as well as help in flattening the treatment beam.



In Mobetron, energy control is achieved without use of the bending magnet, eliminating both weight and a major source of stray radiation. A patented technology also allows energy to be controlled using two small, collinear, accelerator guides. RF power can be injected into either accelerator guide. The first accelerator guide always produces the minimum Mobetron energy of 4 MeV. When operating at 4 MeV, there is no RF power injected into the second accelerator guide, and the second accelerator guide acts as a drift tube. The second guide is capable of adding additional energy to the beam, up to 8 MeV, so that the total energy of the emerging electron beam from the combined guide system is 12 MeV. If greater than 4 MeV is needed, additional RF power is injected into the second guide adding energy to the beam. The phase of the RF power in the second guide is adjusted through the use of phase shifters so that the electrons that enter the second accelerator guide remain coherently accelerated by the microwaves injected into the second guide, resulting in excellent energy control.

In Mobetron, a fixed collimator can be used in place of the variable collimators used in conventional electron accelerators since the largest field needed for most IOERT applications is less than a 10 cm circular field. Suitable flatness is achieved over the energy range of 4 MeV to 12 MeV by use of a thin wall ion chamber, dual scattering foils, and specially designed IOERT applicators that are placed in the surgical cavity for treatment. The applicators are specially designed cylindrical tubes that help flatten the beam. The applicators also protect the surrounding normal tissues by preventing normal tissue from entering the radiation field and containing the radiation to the area inside the tube where the microscopic residual tumor is targeted for treatment.

When IOERT patients receive their treatment, the ambient stray radiation is extremely low, due to the design efforts enumerated previously. However, when the electrons used for treatment are stopped in the patient, the patient acts as a target and produces high energy x-rays. Fortunately, most of these patient-generated x-

rays are in the forward direction, and can thus be intercepted by a beamstopper that is automatically interposed to absorb &#17720&#176 of patient generated scatter.

The elimination of the bending magnet and the miniaturization of the accelerator results in a weight reduction of approximately a factor of eight from that of a conventional S-band accelerator design, even adding in the additional weight of the accelerator guide shielding and the beamstopper. Mobetron can be used in most ORs without any additional shielding. Further, it is motorized to make the transport from one OR to the next easier.

In addition to the technical developments that make it possible to install Mobetron in an unmodified OR, clinical features to enhance IOERT delivery in the OR are included, such as a high dose rate (10 Gy/min), laser aligned, interlocked soft-docking, TV periscopic viewing system; QA system for daily check of energy and output before treatment; and a specially designed surgical table to facilitate use with Mobetron.

Worth the Effort?

Is it really worth the effort to make a mobile IOERT unit for the OR? Just ask any of the 30,000 or more patients who have benefited from IOERT treatment over the years and the more than 2,000 patients who have already received IOERT treatments from Mobetron. For a locally advanced or recurrent disease, studies show that IOERT may be one of the few options available to control the disease and increase survival. Because mobile IOERT units like Mobetron are now available, interest in using IOERT for earlier stage disease, such as breast cancer, is increasing.

IOERT has already demonstrated impressive results for a number of tumors, but has been difficult for most cancer centers to implement with prior technology. Mobetron technology makes IOERT practical for any hospital, and so the use of IOERT can be expected to increase in the coming years.

For additional information on the technologies and products discussed in this article, see Medical Design Technology online at www.mdtmag.com or IntraOp Medical Corp. at www.intraopmedical.com.

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