Debate

Obsolence of telecobalt machine: Is there is a scope for resurrection?

Dr. Nagraj Huilgol

Obsolence is inbuilt in any technology. Isocentrically mounted telecobalt radiation therapy machines, which revolutionized the treatment of cancer also reached its end in last few decades. Morbid fear of nuclear waste and innovations in the technology of the linear accelerator hastened the death of telecobalt machines. However, they are still serving a large population in under developed and developing countries. Commercial availability of compensator based as well as multileaf based intensity modulated radiotherapy has resurrected telecobalt machines from the possible extinction. This is free unedited debate. The views of contributes do not necessarily reflect the views of this journal. A white paper based on this discussion is proposed to be published in future.

Editor In Chief

Marrying the old and the new: The best of both worlds? An opinion piece

Bhudatt Paliwal, Minesh P. Mehta[1]

Telecobalt fitted with multileaf collimators (MLCs) delivering intensity-modulated radiotherapy (IMRT) is being launched in India. Many have wondered how successful this marriage of the “old” and the “new” will really prove to be. There are several differing views on this technology. Many radiation oncologists inherently believe that a telecobalt machine represents inferior technology, but the addition of MLC IMRT should give one reason to pause and reconsider.

Since the discovery of X-rays over 100 years ago, equipment for delivering radiation therapy has gone through many revolutionary advances. It was in the middle of the 20th century that telecobalt units and linear accelerators (LAs) became the prominent delivery tools, and due to the relatively better depth-doses and superior skin-sparing effects when only a few fields are used, LAs carried the day. With the advent of MLCs, initially mostly installed and tested on LAs, IMRT has emerged as a major modality contributing to reduced side effects as well as improved survival. Although few randomized trials have been conducted to categorically establish its superiority in comparison to two-dimensional or three-dimensional approaches, numerous institutional series, and most recently, a very large national cancer database analysis of over 3000 patients with cancers of the head and neck (H and N) strongly suggests that patients who received IMRT not only experienced the anticipated reduction in toxicities, but surprisingly also experienced improved cause-specific survival, even when matched using propensity scoring to correct for bias (http://www.mdanderson.org/newsroom/news-releases/2014/targeted-form-of-radiation.html).

These improvements are related to the advances in conformal therapy techniques implemented on LAs. An MLC fitted cobalt-60 (Co-60) unit has similar potential. However, this technology has never been adequately commercialized to make it readily available. Co-60 units could be enhanced with the application of MLCs and moving field hardware/software to provide dose distributions that would be very comparable to LAs, and the use of multiple fields and beam-entry points significantly obviates the depth-dose and skin-sparing differential. In fact recognizing this very early, the developers of the revolutionary and advanced technique of helical tomotherapy, relied only on a 6 MV beam, much closer in its characteristics than the 10-18 MV beams of modern LAs. On February 7, 2014, ViewRay reported that the world’s first radiotherapy delivery under continuous magnetic resonance imaging (thereby solving the age-old question of intrafraction precision) was performed, using their Co-60 system (http://medicalphysicsweb.org/cws/article/research/56179).

Access this article online	
Website: www.cancerjournal.net	Quick Response Code:

In many countries, Co-60 is now considered obsolete. It is worth recalling that there are no radiobiological differences in the effectiveness of gamma rays delivered by a Co-60 source and photons delivered by megavoltage beams from a LA. Even the depth of penetration differences, a function of beam energy, is not significant when treatment is delivered with multiple (5 to 7) beams. Another common argument against Co-60 has been the blurring of the beam edge or its large penumbra. Several factors need to be considered to understand the overall impact of this on the quality of treatment. These include the radiation oncologist's ability to define target volumes accurately or consistently, usually the largest source of error in treatment delivery; the imaging systems used to delineate target volumes and normal tissues; and patient and organ motion during treatments. Our desire for a tight penumbra is reasonable only if the definitional error from all of the above processes genuinely produces a very well defined target with a very narrow margin, something that is hardly ever achieved in practice. However, in reality, the sharpness of the dose delivered to the patient is strongly dependent on the reproducibility of the patient setup relative to the beam. The net result is that even a small penumbra will be smeared out by the beam placement uncertainty. A perfect example of this is the Gamma Knife system, which is often considered to be a "gold-standard" in the field of stereotactic radiosurgery, and all of its excellent results have consistently been achieved with Co-60! In fact in a perfect example of "imitation is the highest form of flattery," a completely new device, the Gamma Pod, has been developed at the University of Maryland for precise and highly targeted stereotactic radiotherapy of breast cancer, and this too relies on Co-60 (http://www.ncbi.nlm.nih.gov/pubmed/23635251).

An even more important consideration is the "biological penumbra" determined from the tumor or normal tissue type being irradiated. The net effect of this is that even a large geometric penumbra of 1.5 cm, found on a conventional Co-60 machine, could have a "biological penumbra" that is significantly steeper than the physical penumbra. Of course, these biological considerations are much more complex because they depend on the dose level (i.e. in which portion of the dose-response curve) and they could involve partial volume effects for the tumor and normal tissue components. In essence, our usual simple preference for sharp physical penumbras should be based upon the true impact on treatment outcome. It should take into account the reality of nonreproducible patient setups as well as the biological considerations, which greatly accentuate the biological penumbra.

In a recent study, Saenz *et al*., (Journal of Medical Physics, Vol. 39, No. 2, 2014), investigated treatment plan dose homogeneity and conformity of Co-60 from a ViewRay device and compared it with LA plans. In the ViewRay system, three Co-60 sources, each with independent MLCs, allow for IMRT delivery with multiple beams. This study investigated H and N, lung and prostate treatment plans. Images, structure sets, points, and dose from treatment plans created in Pinnacle for patients previously treated with accelerator based IMRT were imported into ViewRay. The same objectives were used to assess plan quality, and all critical structures were treated as similarly as possible. Homogeneity index (HI), conformity index (CI), and volume receiving $<20\%$ of the prescription dose (DRx) were calculated to assess the plans. The 95% confidence intervals were recorded for all measurements. The HI (D5/D95) had a 1-5% inhomogeneity increase for H and N, 3-8% for lung, and 4-16% for prostate. CI revealed a modest conformity increase for lung. The volume receiving 20% of the DRx increased 2-8% for H and N and up to 4% for lung and prostate. Overall, for H and N Co-60 ViewRay treatments, planned with its Monte Carlo treatment planning software, were comparable with 6 MV plans computed with a convolution superposition algorithm on the Pinnacle treatment planning system. These devices have now entered the commercial marketplace in the US, and in the near future, actual patient results will be available.

There is no doubt that Co-60 with improved technology (IMRT and image guided radiotherapy) can be regarded as a very viable and cost-effective option for the treatment of a sizeable fraction of cancer patients. It is our estimate that in this age of individualized medicine and limited financial resources, a large fraction of patients requiring treatment can benefit from a modernized Co-60 therapy system. It provides an important tool to strike a balance between the high-end expensive systems and cost-effective individualized treatments.

Conflict of Interest Statement: MM has historically served as a consultant for Elekta, Phillips, Tomotherapy, Varian, and ViewRay. BP has served as a consultant for Tomotherapy, Varian and ViewRay.

Department of Human Oncology, University of Wisconsin, Madison, Wisconsin, [1]Department of Radiation Oncology, University of Maryland, Maryland, US

Telecobalt units with multi-leaf collimators in India

Dr. G. K. Rath

The burden of cancer in India is increasing. Now, incidence is 11 lakh new cases every year. At any time, we have a prevalence of 30 lakh cancer cases in the country. Majority of the patients present in advanced stages. Hence, about 60% of patients need radiotherapy at some stage of their life. This fact makes the need of radiotherapy in cancer treatment in India very important. As per the latest GLOBOCAN 2012 data, most common malignancy among women are breast, cervix uteri and colo-rectum in that order and among men are lung, oral cavity, stomach and colo-rectum. Common cancers like head and neck and cervical cancer are treated primarily with radiotherapy. The number of patients requiring palliative radiotherapy is also quite large because of the symptomatic late stage of presentation. Needless to say, majority of these radiotherapy treatments do not require sophisticated high-end radiotherapy equipments like linear accelerators (LAs) etc., These patients can be very easily and conveniently managed by simple techniques utilizing machines like a telecobalt unit. At present, India has 231 telecobalt units and 286 LAs at 357 radiotherapy centers. Hence, we need to add more equipments to the country in various cancer centers to catch up with the IAEA norm of 1 radiotherapy machine per million populations, currently, it is 0.41 (Government of India, Department of Atomic Energy [DAE], http://dae.nic.in/?q = node/294). Filling this entire gap with LAs alone, though possible, will require a long time, huge capital as well as manpower requirement. Moreover, there are many remote areas in the country where it may be difficult to run a sophisticated equipment like LA because of constant availability of electricity and lack of trained staff in the peripheral areas of the country like radiation oncologist, medical physicist and technologist. In this context, telecobalt units have its own advantages like low procurement and maintenance cost, minimal power requirements, less downtime, indigenous manufacturing capability, etc., In collaboration with Bhabha Atomic Research Centre (BARC) and the DAE, India has already started manufacturing its own telecobalt unit. 44 Bhabhatron-II cobalt-60 (Co-60) teletherapy machines (named after renowned Indian nuclear scientist, Dr. Homi J. Bhabha) are working in and outside India. The multi-leaf collimator (MLC) designed by BARC has already been installed at the Advanced Centre for Treatment, Research and Education in Cancer, under the Tata Memorial Cente (TMC), Mumbai. This is awaiting regulatory approval from Atomic Energy Regulatory Board before being put to use for patient treatment.

Several technical innovations have further added to the usefulness of Co-60 teletherapy machines. Asymmetric jaws and motorized wedge (The Theratron, Equinox™), ergonomic design of couch (The Theratron, Avanza™) and Multileaf collimation (Gammabeam™) has made intensity modulated radiotherapy (IMRT) and image guided radiotherapy (IGRT) possible. Several dosimetric and planning studies since then have shown feasibility and equivalence of Co-60 based IMRT and IGRT treatments to LA (Fox *et al*., Phys Med Biol 2008 Jun 21;53 (12):3175-88). The radiation safety issue has also been taken care largely with upgraded and improved systems and is no longer an issue of concern. The precision of Co-60 based treatment with MLCs is a tremendous technical advancement.

Recently, IGRT with Co-60 has taken new dimensions with introduction of ViewRay™ (www.viewray.com). This technology blends Co-60 with magnetic resonance online imaging system and allows image-guided and adaptive radiotherapy treatments, which may, in due course of time compete with modern day LAs. This can only be proven by wider application of this technology.

Further technical innovations, up gradation of existing telecobalt units incorporating MLCs and installations of indigenous units might be a solution to the crunching need of radiotherapy facilities in India. Telecobalt facilities are to stay for at least another 50 years in Indian scenario.

Department of Radiotherapy, AIIMS, Ansari Nagar, Delhi, India. E-mail: gkrath@rediffmail.com

Telecobalt intensity modulated radiotherapy

M. S. Vidyasagar, B. Ramya

The advantage of cobalt units is their lower costs, simplicity of design, ease of operation and minimal engineering support. Now many studies have demonstrated the possibility of designing complicated intensity modulated radiotherapy (IMRT) treatment plans comparable to 6 MV photons using cobalt-60 (Co-60) units.[1-3]

Some of the limitations of Co-60 units for IMRT delivery are larger penumbra, lower dose rate, cost of replacement of Co-60 sources and management of decayed sources.

The larger penumbra owing to source size can affect plan quality. Fox *et al*.[2] has showed that a double-focused multileaf collimator (MLC) along with a commercially available 2 cm diameter cobalt source can reduce the penumbra of a Co-60 unit and make it comparable to that of a linac with a MLC. This will enable to design plans with good coverage except where extreme dose gradients are required.

The dose rate of the Co-60 units can be approximately 60% lower than linac. But with the development of higher specific activity Co-60 sources (2 Gy/min source intensity) and tomotherapy type approaches with Co-60, IMRT plans can be delivered with treatment times comparable to linac based IMRT.[1,3] Cadman and Bzdusek[3] has found treatment times for an H and N case planned with segmental IMRT using a 6 MV linac and a Co-60 tomotherapy with 2.0 cm cylindrical source are 11.5 min and 11.4 min respectively. The increase in output of the Co-60 units will reduce the treatment times but at the same time increase in source cost, shielding requirement, transportation regulations, etc., should be taken into consideration. The specific activity of imported pellets is more than 300 Ci/g, whereas that of indigenous pellets obtained from Indian power reactors is 140 Ci/g.[4]

The treatment time will increase as the source decay, and this will lead to need for source replacement after a half-life in spite of 50% of activity still remaining. However, this can be compared with the replacements of magnetrons/klystrons in linacs, along with increased maintenance costs. To some extent management of decayed sources is possible by planning cascade loadings, thereby increasing the dose rate, at the same time the life of the source could be prolonged.[5]

There is no denying that the use of telecobalt units for simple treatments as well as three-dimensional (3D) conformal radiotherapy (CRT) (using Co-60 units with removable add-on MLC or in built MLC) can achieve cost-effective cure and palliation in cancer management in developing countries. Also there could be considerable clinical and economic advantages in modern delivery with Co-60 but the economic advantages over linac based IMRT may become significant when indigenously made higher specific activity Co-60 sources and Co-60 based tomotherapy units becomes available.

Rapid arc, flattening filter free beams and high dose rates achieved with linear accelerators (LAs) are unimaginable. With modern technology and scientific advances, it may be possible to adopt some of the technologies in telecobalt units as well without compromising the quality of treatment. It is not worth adapting newer technologies on cobalt as it will increase the cost of the machine and its maintenance. Any technological advance in telecobalt equipment will increase the cost of equipment that may be as much as LA. If one increases the strength of cobalt source we may need to have stringent protection, and which may again add to the cost. Hence, telecobalt therapy may be used for 3D CRT and simple IMRT treatment by incorporating MLCs.

REFERENCES

1. Adams EJ, Warrington AP. A comparison between cobalt and linear accelerator-based treatment plans for conformal and intensity-modulated radiotherapy. Br J Radiol 2008;81:304-10.
2. Fox C, Romeijn HE, Lynch B, Men C, Aleman DM, Dempsey JF. Comparative analysis of 60Co intensity-modulated radiation therapy. Phys Med Biol 2008;53:3175-88.
3. Cadman P, Bzdusek K. Co-60 tomotherapy: A treatment planning investigation. Med Phys 2011;38:556-64.
4. George JR, Kushwah R, Sastry KV. Teletherapy sources with imported and indigenous Co activity. J Med Phys 2009;34:180-1.
5. Ravichandran R. Has the time come for doing away with Cobalt-60 teletherapy for cancer treatments. J Med Phys 2009;34:63-5.

Department of Radiotherapy and Oncology, Kasturba Medical College, Manipal, Karnataka, India. E-mail: vsagar32@yahoo.com

Cobalt machine with intensity modulated radiotherapy: A real gain?

Dr. Anusheel Munshi, M.D., D.N.B, M.N.A.M.S

Cobalt-60 (Co-60) based radiation therapy (RT) through telecobalt units continues to play a significant role in developing countries, where access to RT is extremely limited. In the context of limited resource setting, these are preferred over linear accelerators (LA) because of various issues including low cost, less down time, low maintenance cost and lower power requirements.[1] Reddy made an analysis and indicated that low energy linacs (6 MV) are preferred to telecobalt machines, the main argument was related to cost of replacement of Co-60 sources and management of decayed sources.[1,2]

Long after the development of multileaf collimator (MLC) in LA, researchers thought of putting the same concept to a cobalt machine. The concept of having MLC's in a cobalt machine could potentially have significant benefits. Even smaller centers with only telecobalts could start practicing three-dimensional (3D) conformal radiotherapy (CRT) using this machine. The clear dosimetric benefits would be precise targeting of the tumor and reduction in volume of normal tissues irradiated and more. This would indeed take precision radiation technology to remote and rural areas.

Cobalt-60 machine is equivalent to a low energy linac of about 4 MV energy, and provides an acceptable megavoltage photon beam for clinical applications. If the 5 mm build-up thickness is preserved by proper planning, skin-sparing would be adequate. Modern cobalt machines have penumbra trimmers, and these cut down excess penumbra thereby reducing dose to critical structures adjacent to tumor volume. Further, no randomized comparisons exist between treatments done by cobalt and a LA demonstrating superiority of the latter.

Indeed, the Bhabha Atomic Research Centre (BARC), Mumbai has developed a telecobalt machine model, the Bhabhatron-II. Bhabhatron-II telecobalt machine that uses block type collimators, which can define either square or rectangular radiation fields. Studies carried out to see various parameters of such a unit have revealed that radiation field sizes are achievable up to 35 $cm^2 \times 35\ cm^2$ with accuracy well within the prescribed tolerance limits.[3] Further, flatness values are in the range of 1.8-3.0%, symmetry in the range of 0.02-0.34% and penumbra varies from 9 to 15.2 mm (large field). Also, the maximum and average radiation leakage through the MLC are acceptable (0.78% and 0.41% of the output for 10 $cm^2 \times 10\ cm^2$ field size). These are well within the tolerance values.

Going a step further would be the question of doing intensity modulated radiotherapy (IMRT) with a cobalt machine. IMRT is a modern technique employing the principle of variation of fluence across the field leading to better conformity to the target and further sparing of normal tissue. Indeed, a dosimetric study explored the use of cobalt beams for conformal and IMRT. Six patients, covering a range of treatment sites, were planned using both X-ray photons (6/10 MV) and Co-60 gamma rays (1.17 and 1.33 MeV). A range of conformal and IMRT techniques were considered, as appropriate. Conformal plans created using cobalt beams for small breast, meningioma and parotid cases were found to compare well with those created using X-ray photons. IMRT plans (LA vs. cobalt: Compensator based) were found to be of comparable quality for meningioma, parotid and thyroid cases on the basis of dose-volume histogram analysis. The authors concluded that it was possible to plan high-quality radical radiotherapy treatments for cobalt units.[4]

However, there could be issues in delivering IMRT with a cobalt source. IMRT is usually delivered with a dose rate of 300-400 cGy/min (MUs per min). The dose rate in the cobalt machine would be close to this when the source is fresh. After 2-3 years, with source decay, the system is likely to give problems and take unduly excess time. Problems would compound if this unit were to be set up in a small center. Smaller centers perpetually suffer from low budget allocation, limited resources and nonavailability of skilled manpower. Given their limited budgetary means, it is doubtful how many of the smaller centers will be able to afford a MLC loaded cobalt machine, capable of doing IMRT. Further, such machines would also require state of the art treatment planning system. Some of the current systems have a price tag close to 120,000 USD or more for their basic model that can only do 3D CRT. Easy access to/availability of a computed tomography (CT) scanner/CT simulator would be a must in such a set up.

Another issue that can be a player is manpower. Even bigger centers in Tier 1 cities often struggle to get trained manpower in radiation oncology. Also, it would make little sense to have MLC and IMRT in a telecobalt machine at a center, which has existing modern linacs. Hence while the potential benefits are many and many cases will potentially benefit, how much can be realized on ground is questionable.

Recent technological innovations have led to the development of Co-60 based tomotherapy.[5]

At the University of Florida in Gainesville, researchers have also proved the feasibility of using magnetic resonance imaging (MRI) to perform treatment planning and visualize tumors during cobalt radiotherapy.[6,7] Unlike X-ray based imaging, used on LAs, MRI excels at visualizing soft tissue. Also unlike X-ray, MRI has no ionizing radiation. And, because cobalt devices use a radioactive source, there are no high-tech electronics for the magnetic field to get spoiled. The same can't be said for LAs, which depend on high-power microwave transmitters (magnetrons and klystrons) to accelerate the particles in the radiation beam. The actual integration of a cobalt therapy unit and MRI came through collaboration with Siemens Healthcare, which is providing the 0.35T scanner and corresponding engineering knowhow.

A study evaluated Co-60 tomotherapy's conformal dose delivery potential by delivering conformal dose plans on a cylindrical homogeneous phantom containing clinical structures similar to those found in a typical head and neck cancer.[8] For experimental validation studies, clinical and nonclinical conformal dose patterns were delivered on circular, homogeneous phantoms containing Gafchromic film. A clinical planning study was also done. Dose calculations were performed with the EGSnrc Monte Carlo program. A Theratronics 780 C Co-60 unit and a 6 MV LAs were modeled with a MIMiC binary MLC. The doses delivered to the homogeneous phantoms agreed with the calculations. This indicated that it was possible to deliver highly conformal doses with the Co-60 unit. Further, the dose distributions for Co-60 tomotherapy clinical plans for both clinical cases were similar to those obtained with 6 MV based tomotherapy and IMRT. The dose area histograms showed that the Co-60 plans achieve the dose objectives for the targets and organs at risk.

Researchers have proposed to combine a MRI scanner with a helical tomotherapy (HT) system to enable daily target imaging for improved conformal radiation dose delivery to a patient. The MR-integrated cobalt tomotherapy unit is dubbed "MiCoTo." HT uses an intensity-modulated fan-beam that revolves around a patient, while the patient slowly advances through the plane of rotation, yielding a helical beam trajectory. Since the use of a LA to produce radiation may be incompatible with the pulsed radiofrequency and the high and pulsed magnetic fields required for MRI, it is proposed that a radioactive Co-60 source be used instead to provide the radiation. An open low field (0.25 T) MRI system has been proposed for the above purpose.[9]

On a preliminary analysis, Co-60 based tomotherapy approach is capable of both highly conformal intensity-modulated dose deliveries and viable image guidance. A counterview could be that addition of more complex beam collimation and megavoltage imaging to cobalt complicates a simple technology. Therefore it is imperative that this concept needs the evidence of dosimetric, logistic and cost benefits to be able to sustain itself in the long run.

ACKNOWLEDGMENTS

I acknowledge the critical inputs by Dr. T. Ganesh, Head Medical Physics, FMRI Gurgaon in the preparation of this manuscript.

REFERENCES

1. Reddy KS. Choice of a Teletherapy Unit: Cobalt-60 Unit vs Linac. 50 years of Cancer Control in India, Government of India Document, Directorate General of Health Services, DGHS; 2008. p. 79-87.
2. Joshi CP, Dhanesar S, Darko J, Kerr A, Vidyasagar PB, Schreiner LJ. Practical and clinical considerations in Cobalt-60 tomotherapy. J Med Phys 2009;34:137-40.
3. Munshi A, Dutta D, Budrukkar A, Jalali R, Sarin R, Gupta S, *et al.* Impact of adjuvant radiation therapy photon energy on quality of life after breast conservation therapy: Linear accelerator versus the cobalt machine. J Cancer Res Ther 2012;8:361-6.
4. Adams EJ, Warrington AP. A comparison between cobalt and linear accelerator-based treatment plans for conformal and intensity-modulated radiotherapy. Br J Radiol 2008;81:304-10.
5. van Dyk J, Battista JJ. Cobalt-60: An old modality, a renewed challenge. Curr Oncol 1996;3:8-17.
6. Dempsey J, Dionne B, Fitzsimmons J, Haghigat A, Li J, Low D, *et al*. WE-E-ValA-06: A real-time MRI guided external beam radiotherapy delivery system. Med Phys 2006;33:2254.
7. Kron T, Eyles D, John SL, Battista J. Magnetic resonance imaging for adaptive cobalt tomotherapy: A proposal. J Med Phys 2006;31:242-54.
8. Dhanesar S, Darko J, Joshi CP, Kerr A, Schreiner LJ. Cobalt-60 tomotherapy: Clinical treatment planning and phantom dose delivery studies. Med Phys 2013;40:081710.
9. Schreiner LJ, Joshi CP, Darko J, Kerr A, Salomons G, Dhanesar S. The role of Cobalt-60 in modern radiation therapy: Dose delivery and image guidance. J Med Phys 2009;34:133-6.

Senior Consultant, Radiation Oncology, Sector 44, Gurgaon - 122 002, Haryana, India

Multileaf collimator on telecobalt machine: Improvement in quality of cancer care in the developing world

Dr. Sapna Nangia, MD

The projected cancer incidence in India for the year 2016 is 1.2 million patients. The shortfall in radiotherapy equipment is approximately 100 and 150 units in the states of Bihar and Uttar Pradesh, respectively. Other states, too, lag behind in providing adequate facilities for treatment to cancer patients, some, such as Kerala, with a shortfall of 18 units, faring better than others.[1]

Experts entrusted with equipping a modern cancer centre face a dilemma. Cost-effective, easy to operate, telecobalt units administer treatments that are obsolete inasmuch that conformality, and therefore, dose escalation and/or sparing of critical organs is not possible. On the other hand, linear accelerators (LAs) are expensive to buy and run and require significant service support, the latter not always accessible outside metropolitan and Tier II cities. LAs have, however, been essential for administering intensity modulated radiotherapy (IMRT) and image guided radiotherapy, thus far.

While the compulsion for using telecobalt machines, at least in the developing world, has so far been economic and practical, the impetus to image the tumour and normal tissues with magnetic resonance imaging (MRI), has led to development of treatment units that combine MRI with telecobalt (ViewRay Inc., Cleveland, USA). A LA cannot be used in this situation in view of the magnetic field generated in an MRI unit. Dosimetric comparisons between ViewRay and LA based IMRT plans have demonstrated a marginal impact on conformality and homogeneity indices (HI), partially improved by increasing the number of beams. The HI was 1-4% worse for head neck cancers, 1-7% for lung cancers and 3-11% for prostate cancers, respectively, improving in all cases by increasing the number of beams to 54. A similar impact was noted in the conformality index.[2]

Dosimetric studies of tomotherapy based IMRT plans, created using a NOMOS (Best nomos, Pittsburgh, USA) MIMiC multileaf collimator (MLC) mounted on a Theratron 780 C unit (Best Theratronix Ltd., Ottawa, Canada) have also been found to be adequate.[3]

The availability of a MLC on the Equinox telecobalt unit will facilitate the delivery of three-dimensional conformal and intensity modulated radiotherapy, impacting the quality of treatment administered using telecobalt units across nearly all sites. The technology of telecobalt was obsolete only in reference the capability of the equipment housing and operating the cobalt-60 source. The emphasis on isocentric accuracy, down to the last millimeter or fraction thereof, while relevant in certain situations, that is, stereotactic radiosurgery or radiotherapy, often overlooks the big unknown of what actually constitutes the clinical target volume. In this context, especially with better understanding of dose-volume constraints, the less sharp dose falloff of telecobalt may not be relevant. Insights into the particular requirements of cobalt based IMRT will develop with time and experience, as has been the case with LA based IMRT. The latter evolved from compensator based, aperture based and static field IMRT to the currently widely used dynamic IMRT and volumetric modulated radiotherapy. Similar energy specific planning requirements are not specific to cobalt based treatments alone and are required for other modalities such as electrons and protons too.

The addition of a MLC will confer versatility on a treatment unit that is relatively inexpensive and easy to operate, albeit with some constraints such as the obese patient and sites requiring a very sharp dose falloff. It is likely to improve access to quality cancer treatment in the developing world. What it will also require is introspection within the community of radiation oncologists working on telecobalt units, regarding skill enhancement with reference to target delineation and plan evaluation, as well as a commitment to allocating the man hours that these treatments require in the planning stage.

REFERENCES

1. Murthy NS, Chaudhry K, Rath GK. Burden of cancer and projections for 2016, Indian scenario: Gaps in the availability of radiotherapy treatment facilities. Asian Pac J Cancer Prev 2008;9:671-7.
2. Saenz DL, Paliwal BR, Bayouth JE. A dose homogeneity and conformity evaluation between ViewRay and pinnacle-based linear accelerator IMRT treatment plans. J Med Phys 2014;39:64-70.
3. Schreiner LJ, Joshi CP, Darko J, Kerr A, Salomons G, Dhanesar S. The role of Cobalt-60 in modern radiation therapy: Dose delivery and image guidance. J Med Phys 2009;34:133-6.

Radiotherapy, Sr. Consultant and Clinical Coordinator, Radiation Oncology, Apollo Cancer Institute

Debate

Dr. Vedang Murthy

Telecobalt is definitely an inferior technology as compared to the modern linear accelerator (LA). There is no doubt about that. However, what is being debated is if this inferior technology has any place in the context of modern radiation oncology in India or needs significant "enhancement" with tools like multileaf collimators (MLCs).

My view is that a robust telecobalt machine is not only necessary, it is essential in the larger context for delivery of basic oncological services in the country. As you will agree, the USP of this machine is its cost, simplicity, durability and relatively easy upkeep. Ironically the advent of an MLC attachment to this basic machine is converting it into something it is not and has not been designed to be. It is bound to affect all the four features I have mentioned above. The very essence of the machine and its utility in a developing country will be lost as it will be no different from a basic LA albeit with poorer physical, geometric and dosimetric characteristics. The gain from such a move on the other hand, would be negligible for a large majority of patients.

We have still not seen the first MLC having been successfully installed on a telecobalt in the country. I am confident this will happen soon and we will have the initial dosimetric and functional data soon. I hope it will be a successful venture for the stakeholders in its development but doubt if a large number of patients will benefit directly. In any case the simple elegance of the machine will be lost.

Advanced Centre for Treatment, Research and Education in Cancer, Kharghar, Mumbai, Maharashtra, India. E-mail: vedangmurthy@gmail.com

Debate

Dr. Vijay Anand Reddy

- Most of the Indian patients are not obese
- Today we hardly use 15 Mev photon in our treatments with high end tech LA
- LA 6 Mv can be reasonably compared to cobalt-60 in terms of dosimetry
- In view of the multiple beam that we use in intensity modulated radiotherapy/image guided radiotherapy (IMRT/IGRT) with isocenter SAD technique skin and S/c dose is quite low
- Based on the above facts, I think Cobalt with IMRT/IGRT technique and if you can add volumetry are it would be acceptable replacement for 6 MV LA.

Also not to forget the:
- Maintenance cost for cobalt machines is quite low
- Cobalt machine cost is low!

Apollo Cancer Hospital, Jubliee Hills, Hyderabad - 500 033, Telangana, India

Is there a case for an advanced telecobalt machine?

Dr. Rajiv Sarin

The first major revolution in modern radiotherapy was ushered simultaneously by the telecobalt machine and the early linacs in the mid-20th century. Both these technologies, one emitting gamma rays and the other X-rays, had a unique combination of megavoltage beam, larger source to skin distance and isocentric mounting. Within a decade of their introduction, these two megavoltage technologies sealed the fate of deep X-ray machines. Once considered rival and contemporary technologies, the linac technology grew in leaps and bounds while telecobalt moved into oblivion in the western world. Now the emerging economies are also witnessing a move away from telecobalts. However, in rest of the developing world, telecobalt continues to be the ubiquitous workhorse and is unlikely to become inconsequential in the near future.

While a modern linac with more versatile features, higher energy and sharper beams has the potential to improve therapeutic ratio, its advantages over telecobalts are not universal. There is no radiotherapy equipment with universal superiority over other technologies in diverse clinical contexts. This would apply as much to Proton Therapy, Cyberknife, Tomotherapy and other newer technologies or drugs as it would apply to telecobalt. The important consideration is whether a technology or equipment can be efficiently used in certain clinical contexts and compliment other available radiation therapy (RT) equipment to maintain or improve the overall clinical efficiency and cost-effectiveness of a center or health care set up. There are several curative and a few palliative clinical contexts where the use of telecobalt would be sub-optimal and should be the second choice if there is access to linac based RT. The converse is also true. In a few curative and many palliative clinical contexts, linac based RT is unlikely to produce any meaningful clinical benefit over skillful use of telecobalt.

To discuss how telecobalts will fare in future and the need to promote and sustain further technological developments on telecobalt it is important to understand what made it redundant in the west. Was it just the minor handicap in terms of beam energy and penumbra or something more than meets the eye. To my understanding, two major factors were responsible – one to do with the industry and other with the public perception. Historically, the manufacturers of telecobalt machines were mainly limited to Canada, France and a few other countries while the linac manufacturer's hub was in USA and some European countries. Sensing the growing public paranoia in the west about radioisotope disposal, the linac manufacturers invested heavily and marketed aggressively their technological developments, while the telecobalt manufacturers were deterred by the uncertainty on return on investment in R and D. General electric stopped manufacturing telecobalt very early in its development as their marketing team predicted there will be no market for it within a decade.[1] Not surprisingly the telecobalt now is a poor cousin of linac and relegated to treat the poor man in the developing world. Quite naturally it has become easy to argue in an academic debate or corporate planning to keep these Beatles era beauties as they are and let them die a natural death. Fortunately, with increasing R and D capability in emerging economies, indigenization of medical devices,[2] realization that telecobalts will not disappear in haste, have some inherent advantages and even the poor man deserves better quality RT, the long pending technological developments in telecobalt technology are happening now.

A low downtime and a very stable beam with energy adequate to treat many anatomical sites are inherent advantages of telecobalt machine. Most advanced features of modern linac based RT are crucially dependent on beam shaping and modulation made possible by the multileaf collimator (MLC). With MLC, dynamic wedges and better electronic controls becoming a reality for telecobalts, we are now poised for major gains in terms of dose conformity and verification on telecobalt. While it may not be able to deliver the best intensity modulated radiotherapy at a desirable dose rate, satisfactory 3D conformal RT may not be too difficult. The legendary Gilbert Fletcher honed finer skills of using telecobalt for curing and palliating diverse cancers in the 60s and his expositions still hold true in several clinical contexts. One could only wish that the spirit of Fletcher comes to life in the modern Radiation Oncologist who can harness the gamma rays emitted from a modern telecobalt machine with MLC to alleviate suffering from cancer. Alas the radiotherapists of the modern world will have to learn from the chemotherapists how to use old drugs along with newer drugs without calling for their ouster.

REFERENCES

1. Robison RF. The race for megavoltage. X-rays versus telegamma. Acta Oncol 1995;34:1055-74.
2. Sarin R. Indian national cancer control programme: Setting sight on shifting targets. J Cancer Res Ther 2005;1:240-8.

Department of Radiation Oncology, Tata Memorial Hospital, Parel, Mumbai, Maharashtra, India. E-mail: drrajivsarin@rediffmail.com

My opinions on the technology

Dr. Ramesh Bilimagga

Telecobalt multileaf intensity modulated radiotherapy: does it compensate for its weakness?

When one makes the above statement the implied meaning is that the teletherapy machine having cobalt as a source has inherent weaknesses. Let us count them one by one.

- Large source size: Consequent to this these machines will receive a wide penumbra effect resulting in unwanted radiation to neighboring structures (organs at risks [OARs])
- Increased skin dose: (a) Due to electrons, (b) due to D maximum at 0.5 cm depth hence higher surface dose
- Lesser percent depth dose (PDD): Hence difficult to treat deep seated tumors
- Source related issues such as procurement, safety and disposal
- Dose rate issues: These machines have a lower dose rate (maximum 250 cGy/min)
- Source decay issues: Hence treatment time is prolonged
- The reluctance of personnel for working in cobalt teletherapy units
- Availability of imaging systems.

Above are the known disadvantages of cobalt teletherapy machines. This is true when comparing basic cobalt machine with the basic linac machine. However, when one adds multileaf collimator (MLC) and imaging devices to cobalt source based machines and enabled it for performing intensity modulated radiotherapy (IMRT), certain of the disadvantages of cobalt may be mitigated.

Let us examine these one by one.

The penumbra effect can be reduced by using double focused built in MLC's from 1.5 cm to 5 mm. This will reduce the unwanted radiation dose to the neighboring structures (OAR).

In a clinical study cited by Fox *et al*.[2] in his article stated.

- A total of 25 clinical patient cases that each contains volumetric computed tomography studies, primary and secondary delineated targets, and contoured structures were studied: Five head and neck, five prostate, five central nervous system, five breast and five lung cases. The data presented demonstrates that excellent plan quality for IMRT using inverse treatment

planning can be achieved with low numbers of equidistant beams, with little gain from extending beam numbers beyond nine beams in terms of target coverage and critical organ sparing. They also demonstrated the feasibility of employing commercial cobalt-60 (Co-60) sources with a divergent MLC for IMRT and show that nearly identical plans can be achieved when compared to 6MV IMRT. Therefore, concluded that the common assumption that the Co-60 penumbra is inferior to linac penumbra for MLC based IMRT is not supported by the literature
- Skin (surface) dose: This cannot be reduced as to Dmax of cobalt continues to be same. Whether it has IMRT capability or not
- PDD won't change even after adding MLC. Hence difficult to treat deep seated tumors
- Source procurement may be not an issue. INDIA is planning for the production of cobalt isotopes from Rajasthan Nuclear Reactors very shortly
- Source disposal also not an issue as we have well established source disposal mechanism by Bhabha Atomic Research Centre.
- Source security continues to be a problem
- Since source decay is also the same as a regular cobalt machine. The IMRT treatment time will be more that too after the first half life of cobalt is over treatment will be unacceptably prolonged
- Because of IMRT capability with this cobalt source machines there may not be any reluctance on the medical professional to work on these machines
- Imaging is now possible, hence this will not a disadvantage.

Finally, taking overall picture the cobalt source based IMRT machines are surely an improved variant of the basic cobalt units. Nevertheless, the issues related to skin dose, treatment of very deep seated lesion continue to prevail. Similarly, because of the dose rate and the source decay factors the treatment time will certainly be more. With these restrictions, we can conclude this newer variant of the machine is one step better than the earlier cobalt based teletherapy machines.

REFERENCES

1. Ayyangar KM, Rani RA, Anil Kumar, AR Reddy Monte Carlo study of MLC fields for cobalt therapy machine. JMP 2014;39:71-84.
2. Fox C, Romeijn HE, Lynch B, Men C, Aleman DM, Dempsey JF. Comparative analysis of 60Co intensity-modulated radiation therapy. Phys Med Biol 2008;53:3175-88.
3. Singh IR, Ravindran BP, Ayyangar KM. Design and development of motorized multileaf collimator for telecobalt unit. Technol Cancer Res Treat 2006;5:597-605.

Department of Radiation Oncology, HCG, #44/45-2, Rajaram Mohan Roy Extension, Off Lalbagh Double Road, Bengaluru, Karnataka, India. E-mail: bilimaga@gmail.com