CHOICE OF A TELETHERAPY UNIT: COBALT 60 UNIT vs LINEAR ACCELERATOR

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Cancer has been present throughout human history. Egyptian and Incan mummies show evidence of the disease. Accurate information regarding the disease and different modalities of treatment have been developed only during the last century. In the later half of twentieth century, it was well recognized that cancer has been the leading cause of death and it affects approximately one in two men and one in three women during their life times. In fact, the global cancer incidence is predicted to double between now and the year 2020 at which time there will be over 200,00,000 new cases diagnosed each year. Majority of these will be in the developing countries. Of these, 12,000,000 deaths will result. WHO estimates that if these trends continue, cancer will be the leading cause of death everywhere except in sub Saharan Africa and most victims will be in the 50-60 year age group.

Treatment strategies for cancers have evolved mainly during the last 50 years. Radiotherapy is one of the major modalities of cancer treatment and every alternate cancer patient will require radiation during the course of treatment. It is also well recognized that over 40% of the course of cancer result directly from the use of radiotherapy. By 2020, 70% of the global need for radiotherapy will be in the currently defined developing world.

History

First application of x-rays for therapeutic purpose was made on Jan.29, 1896 in Chigago by Grubbe for treatment of breast carcinoma. The first case of cure of malignant tumour by radiotherapy alone was reported on a patient with a histologically confirmed squamous cell carcinoma of the nose. In 1899 she received 150 radiations over 9 months, was cured and was alive and well 30 years later. Curative results for some head and neck cancers were reported from Curie

Institute in Paris (Coutard 1932). In mid 1930s, radiotherapy was beginning to be used as an adjuvant to radical mastectomy.

Cobalt 60 Unit:

In 1951, Cobalt 60 teletherapy was first put to clinical use in London, Ontario. It was adopted with tremendous enthusiasm in the treatment of malignant disease.

A typical teletherapy 60 CO source is a cylinder of diameter 2 cm., height 5 cm., and is positioned in the Cobalt Unit with the circular end facing the patient. The fact that the radiation source is not a point source complicates the beam geometry and gives rise to what is known as the geometric penumbra and the transmission penumbra. These penumbras create a region of dose variation at the field edges. Cobalt-60 Gamma radiation typically has energy of about 1.2 MV, D-max being 0.5 cm. and a percentage depth of 55% at 10 cm. Cobalt units with low energy of gamma rays are ideal for treatment of head and neck cancers. This would cover 25% of cancers seen in a large cancer treatment center. Majority of others will be cervical cancers and others like cancers of oesophagus, lung, prostate, etc. where the separation or thickness of parts to be treated will be greater that 20 cm. Even though Cobalt units can be used for above clinical situations they do not give the ideal depth dose and require complicated plans to deliver the effective tumor dose.

Dr. Herman Suit of Harvard Medical School wrote in an editorial that Cobalt units should be modernized with state of the art ancillary devices and then they could be fully acceptable for the treatment of head and neck cancers, cancer of breast and some soft tissue sarcomas of extremities. However Cobalt-60 units over the last several decades have remained static in design and there has been very little change in ancillaries and accessories. The major problem with these units is the decaying source, reduced output resulting in increased treatment times which in turn will effectively reduce the patient output. The source needs to be replaced every 5-7 years and is becoming more and more expensive and is also hard to get. Disposal of spent source is another major problem and this will be compounded if as per estimates our country should have at least 1000 teletherapy units, (1 unit per million if not 2 per million population) we will need at least 200 sources to be replaced every year and a similar number to be sent for waste disposal.

Linear accelerator:

In the first few decades after discovery of x-rays only low energy x-rays were available and they were used predominantly for palliative treatment. From the technology of World War II radars came the ability to produce high energy microwaves. This field advanced with the development of high energy microwave tubes known as Klystronsor Magnetrons which are still at the heart of todays' modern Linear Accelerators. The First medical Linear Accelerator was created and used in England in 1953 followed by USA (at Standford University (Gintzon 1984)[5]. Basically the Linear accelerator (Linac) is a device that uses high frequency electromagnetic waves to accelerate charged particles such as electrons to high energies through a Linear tube. The high energy electron itself can be used for treating superficial tumors or it can be made to strike a target to produce x-rays for treating deep seated tumours. Linear accelerators have made rapid progress in technology, design, ancillaries and utility. In the '60s & '70s Cobalt Unit have largely been replaced by Linear Accelerators in most of the radiation oncology departments in the developed countries. Low, medium and high energy Linacs are now available which can generate not only x-rays but also electrons for treatment. Newer technologies like multi leaf collimators (MLC) fittedto Linac, intensity modulated Radiotherapy Plans (IMRT) have helped to improve accuracy in executing treatment. While the high energy Linacs (with x-ray and variably energy electron generating potential) are expensive, Low energy Linacs (4-6 MV) compare favourably with traditional cobalt units in terms of cost as well as uptime. The characteristics of the Linac beam and out put are superior to Cobalt-60 gamma ray beam.

Comparison

Several arguments have been put forward both for and against Cobalt Units as well as Linear accelerators. These arguments relate to physics, clinical advantages and more importantly, the cost consideration. The following table summarises the data that is available.

Feature	Low Energy	Cobalt Accelerator	Remarks 60Unit
Dose rate	600 MU/Min	Reducing dose starts at 200r/min	In Cobalt units dose will reduce because of decay, and depends on source activity. whereas with Linear Accelerator one has the guarantee of constant dose rate
Energy Source DIA	<2mm	20mm	Penumbra effect is higher in cobalt machines
Source change	None	Every 7 years 30-35 lakhs	Source cost for 12,000 curie source is very much on the increasing trend. Current cost for 12,000 curie source is around Rs. 35, 00,000. since the higher curie sources are not available with BARC one has to import the source along with the machine and at the time of change of source one has to send the decayed source back to the manufacturer, which is very expensive.
D- max	1.5 cm	Only 0.5cm	Linear accelerator with 6 MV, photon, we are able to get D-max 1.5 cm. This is very useful for deep seated tumours. Skin sparting is better with Linac (6 mv).
Perchantage Depth dose at 10cm	67%	55%	Difficult to treat deep seated tumors in Thorax, abdomen or pelvis.
Colimator trasmission	Not exceed o.5%	More than 3%	—
Minimum field size	0.5x0.5 cm	5 x 5 cm	In cobalt one cannot treat field size less than 5x5cm.
Radiation leakage through the head	Nil	Less than 0.2%	—
Penumbra	Less than 5 mm	More than 1 cm	With 2 cm. Cobalt source the Penumbra effect is very high.

Feature	Low Energy	Cobalt Accelerator	Remarks 60Unit
Precision	Dose delivered to any arc is reproducible within 3% or 1MU which ever is greater	—	In Linear accelerator one c an have reproducibility of Dosimetry system and the dose delivered is continuously monitored and recorded
Motorized wedges	Possible	Not possible	-
Variable dose rate	80 to 600 MU/min	Not variable	Dose rate if fixed, decreases with decay of source
Multileaf collimators, stereotactic attachments	Possible	Not possible	Increases accuracy in dose delivery
Asymmetric collimator jaws	Yes, standard features	No	Electronics are cheaper Independenty collimator jaws are very useful for precise and accurate cancer treatment
Parts replacement	Parts costlier	No	The costly maintenance is compensated as source cost is not required for Linacs
Portal vision attachment	Yes, possible (Optinal)	No	Allows to view actual tumour while treatment
Stereoetatic applications	Yes, can be used with additional tools		Provides wider application usage
Civil requirement for the installatin of telepherapy Unit	Marginally costly compared to cobalt unit	—	—
Patient support system	Superior	Inferior, low accuracy	—

Feature	Low Energy	Cobalt Accelerator	Remarks 60Unit
Beam matching with second unit	Possible	Not possible	Beam matching is a very good feature available in Linear accelerator. This will help institutions to buy the 2nd machine with the same beam characteristics of the existing units. Thereby patients can be shifted between different Linear accelerator. More flexibility.
Uptime	95%	95%	WHO recommends built in guarantee/performance clauses for 5-10 years after procurement
Source disposal	Nil	Major problem with cobalt units, and source cost is increasing every year. It is also becoming increasingly difficult to obtain a source	BAARC does not permit disposal for imported source. In the event the source is imported along with the cobalt machine the decayed source has to be transported back to the manufacturers, which is very expensive.
Cost of the machine		Rs. 2.5-3 crores	Rs. 1.90 crores (cost of cobalt source) Since the number of Cobalt units sold worldwide is on a decreasing trend during the last 10 years, the cost of cobalt units is increasing due to high manufacturing cost with less number of units being sold every year.(not mre than 50 units worldwide per year). Whereas Linear accelerators are sold at least 500 units per year worldwide.
AMC with labour		2 lakhs/year	1 lakh/year In ten year span accelerators are slightly expensive.
Spare parts cost for 10 years operation	INR20,00,000	INR 10,00,000	

Feature	Low Energy	Cobalt Accelerator	Remarks 60Unit
Source replacement cost	Nil	INR 35,00,000	The source to be replaced at least once every sever years
Running cost of the machine for 10 years including labour, spare parts and cobalt source	AMC charges .for 10 years = Rs. 20 lakhs, cost of spare parts for 10 yrs = Rs. 20 lakhs, total mainte- nance cost of low energy accelerator = 40 lakhs.	AMC charges for 10 years = Rs. 10 lakhs. Cost of spare parts for 10 yrs = Rs. 10 lakhs. Cost of source replacement = Rs. 35 lakhs. Total maintenance cost for Cobaltmachine = 55 lakhs.	In ten years period we need to spend more money towards maintenance and source replacement. The running cost of linear accelerator over 10 years is less when compared to a cobalt unit. Also Linear accelerator has definite clinical advantages over Cobalt.

At the present time the treatment machine to population ratio ranges from 12 machines per million in US to fewer than 0.3 machines per million in china. In India we have around 290 telepherapy machines spread over 62 cities/towns for a billion population. Around 35 of them are Linear Accelerators and the rest are Cobalt Units. Currently around 30 countries have no access to radiotherapy at all. In 1993 the cancer division of WHO conducted it's first consultation on Radiotherapy and repeated it's consultation to refine the recommendations concerning radiotherapy at London in March 1999. This meeting summarized a statement regarding the results of the second consultation in the UICC News Archives.[6]

The assumptions were that radiotherapy remained an important and cost effective modality in treatment of cancer. The WHO supported the growth of programmers in which the sales of megavoltage equipment, planning systems and simulators is linked to training, education staffing and the use of treatment protocols. They further recommended that service contracts together with peformance guarantees be built into the programmes and these contracts should run from 5 to 10 years. They also considered the question of cobalt

60 vs. Linear Accelerator and considered the need for Linac technology in the developing world. The group recognized that linac technology is associated with advantages over cobalt teletherapy, especially as regard collimation, conformal therapy and the ability to perform intensity modulation. The working group concluded that if capital costs and service were essentially equal, then linac technology would be considered superior to cobalt technology for modern day curative radiotherapy.

Contrary to the popular belief that radiotherapy is expensive, it is salient to note that the cost of one military jet fighter represents the entire costs for radiation therapy for most countries. In fact, together with surgery, radiotherapy currently remains the most cost-effective way of curing cancer.

Conculsion:

Cobalt 60 units provide relatively high energy gamma rays for radiotherapy which are ideally suited for treatment of head and neck cancers and other superficially located tumours like breast cancers and soft tissue sarcomas of extremities. They are not adequate for treatment of deep seated tumours and have the added disadvantage of decreasing output with decay of source and the need for source replacement within 5-7 years. Disposal of decayed source is another major concern. The beam characteristics when compared to 6mv Linacs are inferior and fewer ancillaries are available for cobalt machines as compared to Linacs. High energy Linacs in addition to giving two or three x-ray energies can also generate variable energy electron beam for treatment. While such high energy Linacs are expense, 6 MV Linacs compare favourably in terms of cost with the Cobalt 60 units. Even though the initial cost appears to be high, over a ten year period maintenance costs are less as it does not require change of source. It is stressed that service contracts with performance guarantees for 5-10 years have to be built into the contracts while procuring the equipment.

To summarize Linear accelerators have several advantages:

1. Very high energy beams can be created with a machine that is not very bulky or cumbersome to use.

2. The edges of the beams are much more sharply defined than those of a cobalt machine, allowing additional precision in dose delivery.

3. Electron beams can be created (with high energy linacs) that is of particular value in treating superficial lesions.

4. The dose rate per minute is variable and can be turned up very high allowing the patient to be located at substantial distance from the machine in order to create large fields necessary for total skin or total body irradiation while still maintaining adequate dose rate. With cobalt, the rate is determined by the amount of cobalt source in the machine and cannot be regulated.

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